DATA COLLECTION SURVEY
ON
THE MAINTENANCE OF POWER PLANTS
USING STATE-OF-THE-ART TECHNOLOGY SUCH AS
IOT AND AI
IN
THE REPUBLIC OF THE UNION OF MYANMAR

EXECUTIVE SUMMARY

【ENGLISH】

September 2019

Japan International Cooperation Agency（JICA）

The Kansai Electric Power Co., Inc

Mitsubishi Hitachi Power Systems , Ltd.

Outline of Survey（Summary）

1. Background, Purpose and Schedule of Survey

This section indicates the objective and scope of the survey, target plants, and the actual survey schedule. The outline is as follows.

Table 1 Purpose of Survey and Results

Items	Contents
Purpose	Investigate the current state of O&M of the five thermal power plants (Thilawa, Hlawga, Ahlone, Ywama, and Thaketa) and one hydropower plant (Yeywa), and grasp the issues. The JICA study team will examine and make recommendations on improving power plant maintenance from the viewpoints of operation, facilities and organizational structure, by taking advantage of the latest technologies such as IoT and AI, and examining the possibility of introducing the technologies related to O&M of Japanese SMEs in particular.
Subject Area	Yangon (location of thermal power plant) Naypyitaw (location of headquarters of Electric Power Generation Enterprise of MOEE) Mandalay (location of hydropower plant)
Scope of Survey	Following organization of MOEE - Electric Power Generation Enterprise: EPGE
Schedule	(1) General information on the O&M systems of the power plants (2) Visit to each power plant and investigation of the O&M systems (3) Study of the possibility of applying the latest technologies such as IoT and AI (4) Improvement of O&M and proposal for the possibility of cooperation by JICA

Source: JICA study team

2. Operation, Maintenance, Management System, and Results of Survey of Power Plants

【Outline of general survey】

This chapter indicates the results of a fact-finding survey on the development of the surrounding environment related to the maintenance and operation of power plants in Myanmar. As a result, although the development of laws and regulations for the operation of power plants is currently underway in Myanmar, it has not yet been completed. The usefulness of the laws and regulations could not be confirmed. In terms of acquisition and improvement of employee technical skills, education for the hydroelectric power plant was confirmed. However, education for the thermal power plants was limited. From the above results, it was confirmed that it is necessary to improve the environment surrounding the power plants, as well. Moreover, there were diverse approval processes for budget acquisition related to the operation and maintenance of the power plants, and the difficulty of budget acquisition related to operation and maintenance was confirmed.

3. Operation, Maintenance, Management System, and Results of Survey of Power Plants [Outline of survey for each power plant]

This chapter indicates the results of on-site inspection of maintenance and operation of each power plant. As described in Chapter 2, operation, maintenance and other manuals were not prepared at the power plants, because laws, regulations and the environment surrounding the power plant had not been prepared. For this reason, operation records, inspection records, etc. are handwritten, and there was no system to utilize them. Therefore, the power station personnel cannot grasp, analyze, or utilize conditions of the power station. It was confirmed that there were frequent long-term and unplanned shutdowns of the power stations (Figure 1). The following figure shows that the frequency of unplanned shutdowns is much higher than what happens in Japan, and that the long-term shutdowns occurred at more than 300 MW of the 760 MW of original capacity of the thermal power plants due to inadequate O & M.

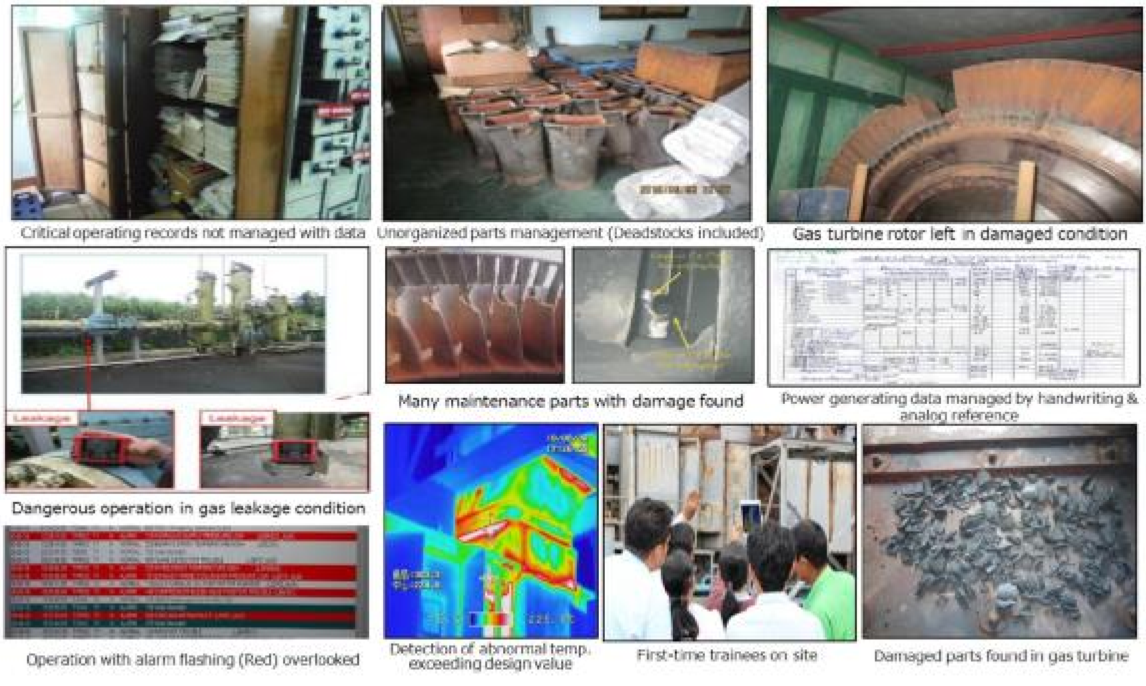

Figure 1 Summary of Site Survey

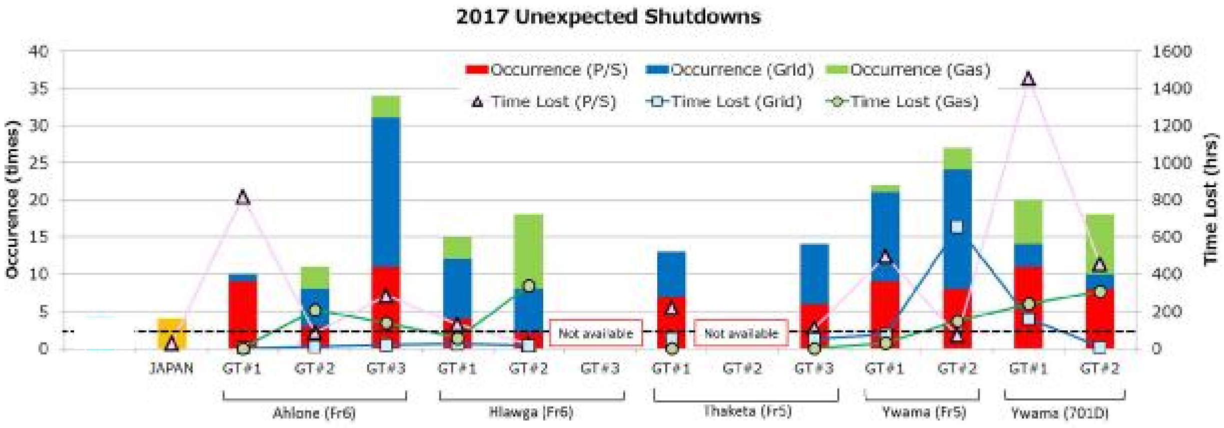

Figure 2 Number of Unexpected Shutdowns Compared to Typical Japanese Power Plant

Plant	Type	Plant Configuration	Original Capacity	Latest Capacity	Δ (Delta)	Main Reason
Yeywa	Hydro Power Plant		790MW	N/A	N/A	✓No Issue
Ywama	Fr5	2GT CHP	37MW	37MW	153MW	✓H-25 1on1 Was Stopped Due to Heavy Damage of Turbine Buckets From 2014. ✓701D Was Stopped Due to Heavy Damage of Compressor Bucket From July 2018.
	H-25	1on1 C/C	33MW	0MW		
	701D	2GT S/C	240MW	120MW		
Thaketa	Fr5	3GT S/C	57MW(GT) 35MW(ST)	38MW(GT) 0MW(ST)	54MW	✓GT#2 Was Stopped From 2015 Due to IGV Damage. ✓ST Was Stopped From 2013 Due to High Vibration.
Hlawga	Fr6	3on1 C/C	100MW(GT) 54MW(ST)	67MW(GT) 36MW(ST)	51MW	✓GT#3 Was Stopped From 2013 Due to GEN Ground Fault Damage.
Ahlone	Fr6	3on1 C/C	100MW(GT) 54MW(ST)	100MW(GT) 0MW	54MW	✓ST Was Stopped From Mar. 2018 Due to HRSG Tube Leakage.
Thilawa	H-25	2GT S/C	50MW	50MW	0MW	✓No Issue
Total (Except Hydro)			760MW	448MW	312MW	

Figure 3 Approx. 300MW Generation Loss Due to Inadequate O&M (As of Oct. 2018)

As a summary of Chapters 2 and 3, the current problems in O & M in Myanmar are summarized. It is considered that it is necessary to promote O & M improvement comprehensively by categorizing problems into intangible, tangible, and digital.

	O & M Category	Results from Fact-Findings	Direction of Improvement	Category
1	Development of Laws, Regulations, and Manuals	✓Rules, regulations, and manuals NOT developed ✓No PDCA control for O & M improvements, leading to frequent recurrence of accidents	Legal developments; manual maintenance Education; systemization	①Soft
2	Management of Personnel Education	✓Systematic educations HARDLY provided (Especially at each power plant)	Education; systemization	①Soft
3	Management of Quality and Safety	✓Very dangerous due to gas leakage occurring everywhere ✓Safety management system such as fire fighting equipment NOT functioning	Legal developments; manual maintenance Education, additional equipment	①Soft ②Hard
4	Management of Parts Procurement	✓Third-party products being introduced without careful consideration ✓Parts purchasing process being extended for a long period and complexed	Long-term maintenance contract Legal developments; manual maintenance	①Soft
5	Management of Documents and Records	✓Key index management such as power generation record and gas quantity being performed in handwriting	Digitization	③Digital
6	Management of Operation and Power Generation	✓A way of copping with an alarm continuously sounding in central control room Not known ✓Very large performance degradation during operational process (Fuel loss) ✓300 MW of existing EPGE thermal power plants NOT in operation due to O & M failure.	Legal developments; manual maintenance Systemization; education Long-term maintenance contract	①Soft ②Hard ③Digital
7	Management of Maintenance Plan	✓Total of 567 unplanned outages/approx. 2 years at 5 thermal power plants of EPEG ✓No regularly provided periodic inspection plan, regular cost, and actual records	Legal developments; manual maintenance Systemization; Long-term maintenance contract	①Soft ②Hard ③Digital
8	Management of Spare Parts	✓Many deadstocks existing and NOT organized ✓Spare parts not available in stocks and reused from other power plants	Legal developments; manual maintenance Systemization; education	①Soft
9	Handling at Accident/Failure	✓QC education NOT provided; causes not proved and appropriate measures not established at occurrence of accident/failure ✓Accident records NOT managed or accumulated	Legal developments; manual maintenance Systemization; digitization; education	①Soft ③Digital
10	Environment Management	✓Environment values not managed; total CO2 emissions and noise emissions unknown ✓Fuel gauge not installed; accurate fuel efficiency unknown anyway	Legal developments; manual maintenance Digitization	①Soft ③Digital
11	Gate Access Control	✓Security measures not sufficient	Systemization	①Soft
12	Equipment Maintenance	✓Equipment NOT sufficiently maintained, leading to many dangerous portions in equipment conditions	Rehabilitation, additional equipment	②Hard

Figure 4 Summary of Fact-Finding Survey of O&M in Myanmar

4. Consideration of IoT/AI Technology Application

This chapter indicates the results of the survey on the usefulness of IoT and AI in the operation and maintenance of the power plants in Myanmar. During the survey period, the usefulness of IoT/AI pilot equipment was verified by installing and testing the IoT/AI pilot equipment from Japan. An outline of the trial operation follows.

【Outline of IoT/AI pilot equipment trial operation】

(1) Installation place : Thilawa power plant (25MW X 2units)

(2) Trial period of IoT/AI equipment : Jan. 2019 to Jun. 2019 (Approx. 4 months)

(3) Function of IoT/AI pilot equipment : GT anomaly prediction detection, KPI visualization, and Operator support

As a result of the trial operation, it was confirmed that the plant personnel actively accessed the IoT/AI equipment to understand the operation status of the plant. (For reference, the following graph shows the number of accesses to IoT/AI devices from March to May, 2019.)

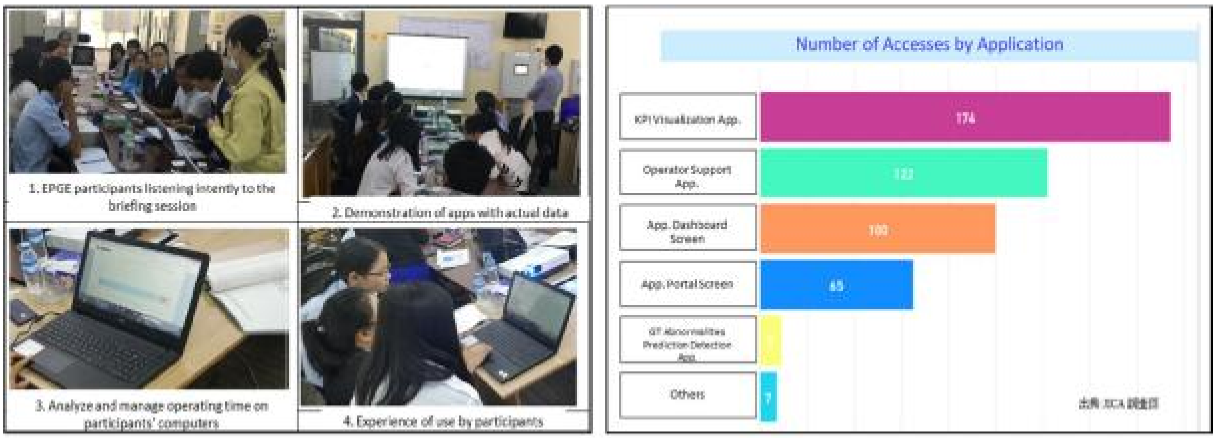

Figure 5 Result of Trial Operation Using IoT/AI Equipment

Interviews were also conducted with the power plant personnel who were actually using the system. From the interviews, we could grasp the monitoring conditions of trend of operation and request, etc. for the IoT/AI equipment. It was confirmed that the IoT/AI equipment would facilitate the operation, maintenance and management of the power plant by deploying the IoT/AI equipment, and a certain degree of usefulness could be confirmed.

5. Issues in Operation, Maintenance and Management and Improvement Methods

Based on the results of on-site inspections described in Chapters 2, 3 and 4, future issues and proposals are indicated in this chapter. According to the results, in order to solve the current problems in operation, maintenance and management, it is necessary to take various measures such as to (1) digitize, (2) develop laws and manuals, (3) educate, (4) systematize, (5) LTSA, (6) rehabilitate, and (7) add facilities. With the aim of enabling EPGE to autonomously improve the operation, maintenance and management of the Myanmar power plants, we propose the formulation of an improvement program utilizing Japanese technology. (The outline is shown in the table below.)

Table 2 Support Program

Support program	Category of improved items
Solution A (Digital O&M Infrastructure Package)	① Digitization
Solution B (Soft O&M Infrastructure Package)	②Develop laws and manuals, ② Education, ④Systematization
Solution C (Hard O&M Infrastructure Package)	⑤LTSA ⑥Rehabilitation ⑦Additional equipment

※For details, please refer to the original report.

6. Utilization of Japanese Technology (Technology Possessed by SMEs)

This chapter indicates Japanese technologies (Technology possessed by SMEs) related to the maintenance and management of power generation facilities, as well as the results of validations of the usefulness thereof to the Myanmar power plants. During the 2nd site survey, we demonstrated (1) electronic form management, (2) an ultrasonic gas detector, and (3) portable device (thermo camera), and confirmed their usefulness. As shown in the results in Chapter 3, the operation and inspection records of the power plant are handwritten and are analog data that cannot be utilized. Therefore, it is considered that recording and sorting by digital equipment is useful.

7. Consideration of Possibility of JICA's Cooperation

This chapter indicates the possibility of JICA's cooperation for realizing the improvement proposals in Chapter 5. When reporting to EPGE, which was done at the time of the survey, it was agreed that the JICA survey team and EPGE would jointly proceed with actions for O & M improvement. The support program shown in the table below should be established. The following table is a draft of the proposed solutions A, B, and C described in Chapter 5, and shows which solution should be applied to each power plant.

<table>
<tr><th colspan="2"></th><th>Ahlone</th><th>Hlawga</th><th>Thaketa</th><th>Ywama</th><th>Thilawa</th><th>EPGE HQ</th><th>Assumed Assistance by JICA</th></tr>
<tr><td colspan="8">Solution A Digital O&M Infrastructure</td><td></td></tr>
<tr><td colspan="2">Digital Solution (including technologies of SMEs)</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>Included in Other Projects</td></tr>
<tr><td colspan="8">Solution B Soft O&M Infrastructure</td><td></td></tr>
<tr><td colspan="2">PDCA O&M Management Support</td><td></td><td></td><td></td><td></td><td></td><td>✓</td><td rowspan="6">Technical Cooperation etc</td></tr>
<tr><td colspan="2">O&M Guideline Preparation Support</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td colspan="2">Asset Optimization Support</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td colspan="2">QMS Manual Preparation Support</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td colspan="2">Operational Support</td><td colspan="5">✓</td><td></td></tr>
<tr><td colspan="2">Training in Japan</td><td colspan="6">✓</td></tr>
<tr><td colspan="8">Solution C Hard O&M Infrastructure</td><td></td></tr>
<tr><td>Short Term</td><td>Overhaul Maintenance Rehabilitation program</td><td>✓</td><td>Already Planned</td><td>Already Planned</td><td>✓</td><td></td><td></td><td rowspan="2">ODA Loan / Private Sector Investment Finance etc</td></tr>
<tr><td>Mid / Long Term</td><td>Rehabilitation Program
LTSA
O&M Service Program etc</td><td>✓</td><td>Already Planned</td><td>Already Planned</td><td>✓</td><td>✓</td><td></td></tr>
</table>

Figure 6 Recommended Solution to Be Implemented for Improvement in O&M

※ For details, please refer to the original report.

More concrete images of the projects for each solution are shown as below. In order to realize those solutions, further detailed study with the cooperation of Myanmar is required.

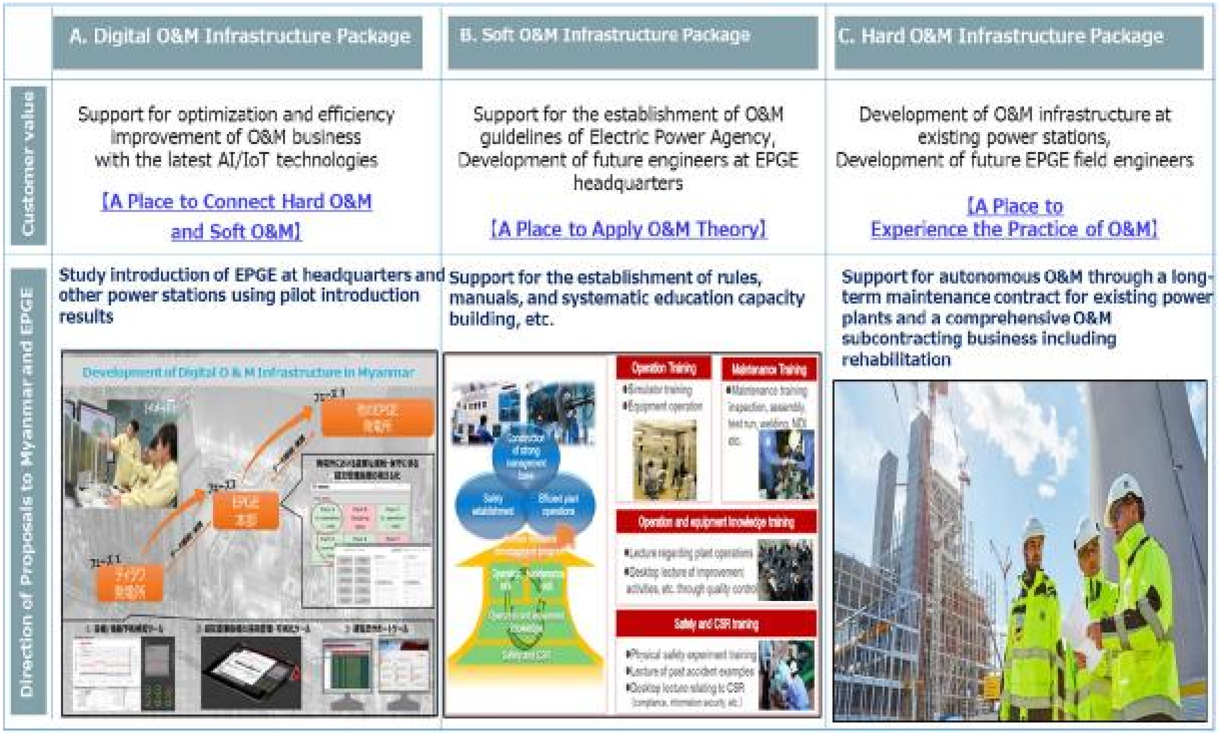

Figure 7 Concrete Image of Each Solution

8. Conclusion and Proposals

The current situation of O & M in Myanmar is that an adequate system of operation, maintenance and management (structure) has not been established. The development of the surrounding environment and human resources has not yet started. As a result, long-term or unplanned shutdowns of power plants have occurred due to insufficient operation performance of power plants, and the operating and maintenance budgets become tight due to early restoration to secure power. This negative cycle of long-term and unplanned shutdowns of power plants occurs . We believe that the O&M improvement proposals in this report by Solution A (Digital O&M Infrastructure package), Solution B (Soft O&M Infrastructure package), and Solution C (Soft O&M Infrastructure package) will be effective.

End of Sheet

【Usability Evaluation】

DATA COLLECTION SURVEY ON THE MAINTENANCE OF POWER PLANTS USING STATE-OF-THE-ART TECHNOLOGY SUCH AS IOT AND AI IN THE REPUBLIC OF THE UNION OF MYANMAR

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September 2019

1.Survey key results for Myanmar O&M

See the attachments for details.

- Visiting the existing thermal power plants owned by EPGE (/Hlawga/Thaketa/Ywama/Thilawa) produced the following info.
- To separate challenges into Hard, Soft, and Digital issue, and then apply a comprehensive O&M improvement program for each issue.

	O & M Category	Results from Fact-Findings	Att.	Direction of Improvement	Category
1	Development of Laws, Regulations, and Manuals	ü Rules, regulations, and manuals NOT developed ü No PDCA control for O & M improvements, leading to frequent recurrence of accidents	-	Legal development; manual maintenance Education; systemization	①Soft
2	Management of Personnel Education	ü Systematic education HARDLY provided (Especially at each power plant)	①	Education; systemization	①Soft
3	Management of Quality and Safety	ü Very dangerous due to gas leakage occurring everywhere ü Safety management system such as fire fighting equipment NOT functioning	②	Legal development; manual maintenance Education, additional equipment	①Soft ②Hard
4	Management of Parts Procurement	ü Third-party products being introduced without careful consideration ü Parts purchasing process being extended for a long period and complex	-	Long-term maintenance contract Legal development; manual maintenance	①Soft
5	Management of Documents and Records	ü Key index management such as power generation record and gas quantity being performed in handwriting	③	Digitization	③Digital
6	Management of Operation and Power Generation	ü Way of copping with an alarm continuously sounding in central control room Not known ü Very large performance degradation during operational process (Fuel loss) ü 300 MW of existing EPGE thermal power plants NOT in operation due to O & M failure.	④	Legal development; manual maintenance Systemization; education Long-term maintenance contract	①Soft ②Hard ③Digital
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8	Management of Spare Parts	ü Much dead stock existing and NOT organized ü Spare parts not available in stock and reused from other power plants	⑥	Legal development; manual maintenance Systemization; education	①Soft
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10	Environment Management	ü Environment values not managed; total CO2 emissions and noise emissions unknown ü Fuel gauge not installed; accurate fuel efficiency unknown anyway	-	Legal development; manual maintenance Digitization	①Soft ③Digital
11	Gate Access Control	ü Security measures not sufficient	⑦	Systemization	①Soft
12	Equipment Maintenance	ü Equipment NOT sufficiently maintained, leading to many dangerous portions in equipment conditions	-	Rehabilitation, additional equipment	②Hard

2. Results of site survey in Myanmar

- Site survey in Myanmar revealed the following. They have promoted O&M in their way because of a lack of knowledge, know-how, and budget in the O&M field, which may lead to the following situation.

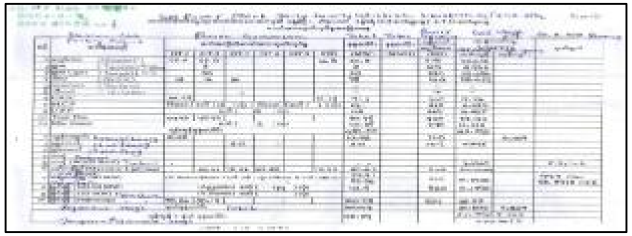
Critical operating records not managed with data

Unorganized parts management (Dead stock included)

Gas turbine rotor left in damaged condition

Dangerous operation in gas leakage condition

Many maintenance parts with damage found



Power generating data managed in handwriting & by analog reference

Operation with alarm flashing (Red) overlooked

Detection of abnormal temp. exceeding design value

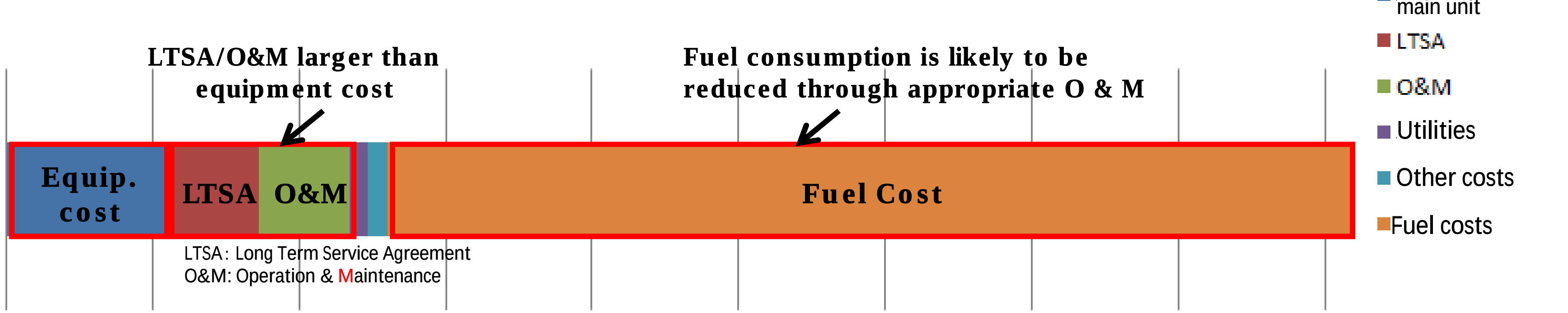
First-time trainees on site

Damaged parts found in gas turbine

3. Importance of O&M field in thermal power sector

- Although the focus of the thermal power generation business tends to be on developing new power plants, O&M offers very large potential for improvement.
- This is why electric power companies around the world are seeking a stable electricity supply by improving O&M.

1. 25-year life-cycle of a power generation plant (Image)



2. Annual effects to EPEG supposing O&M improves by 1% (Image)

Operating rate improved by 1% through O & M:

2,312.8 GWh (Existing MOEE thermal power in Myanmar, 2016-17) × 1%

Effect in reducing electric energy of approx. 23 GWh / year

Power generation efficiency improved by 1% through O & M:

2,312.8 GWh (Existing MOEE thermal power in Myanmar, 2016-17) × Average Efficiency (i.e. 25%→26%) × USD 7.5/mmBTU

Effect in reducing fuel consumption of approx. USD 9 Mil / year

Output loss improved by 1% through O & M:

992 MW <Estimated thermal power generation by EPGE in Myanmar> × 1%

Effect in improving power supply of approx. 10 MW

NOTE: The above figures are just for reference purposes, and need to be verified individually and specifically.

4. Application of AI/IoT technologies to O&M field

- Introduced the pilot equipment utilizing AI/IoT on a trial basis. Confirmed that EPGE frequently used it. (477 web site access／2 months)
- EPGE MD expressed desire to continue use of the digital O&M support tools and expand use to other plants.

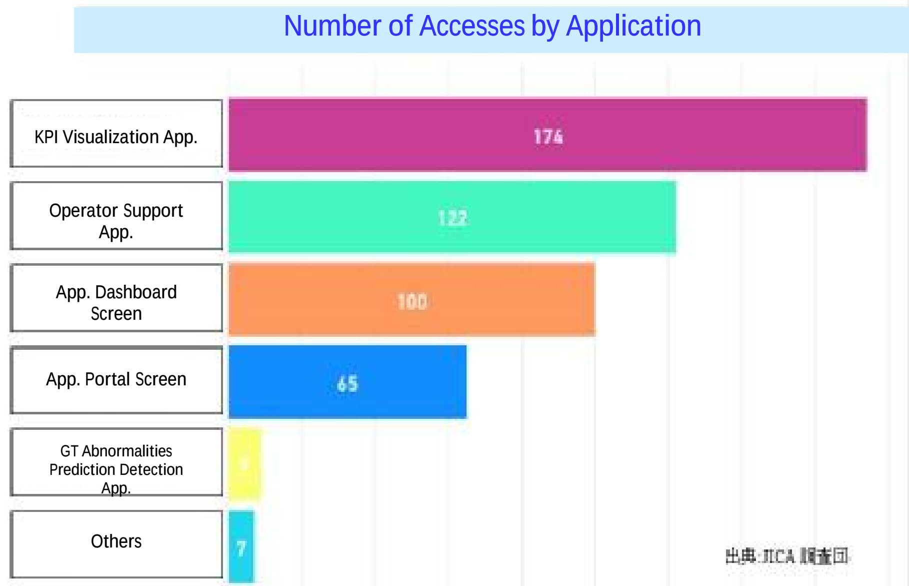
Trial Verification App.	Outline
GT Abnormalities Prediction Detection App.	Detects signs of major trouble leading to power plant trips and contributes to improved operating rates and minimization of unexpected maintenance costs. In addition, by estimating the cause and presenting actions to address the presumed cause, supports prompt response.
KPI Visualization App.	Visualizes main operating parameters and management indicators of plants (Thermal efficiency, output, and unplanned shutdown, etc.). This helps to realize optimal operation and maintenance, and supports the management of EPGE's power generation business.
Operator Support App.	Helps expedite response by timely displaying the relevant information in the operation manual online at the time of alarm transmission. In addition, contributes to information-sharing and technology transfer by recording and storing unit specific information at EPGE.


1. EPGE participants listening intently to the briefing session


2. Demonstration of apps with actual data


3. Analyze and manage operating time on participants' computers


4. Experience of use by participants



5. Future directions

- In the future, O&M improvement proposals should be advanced comprehensively by classifying the proposals into digital, soft, and hard categories.
- In order to ensure stable operation of the power generation facilities in Myanmar, it is important to assist Myanmar in making their way to autonomous implementation based on appropriate O&M.

A. Digital O&M Infrastructure Package

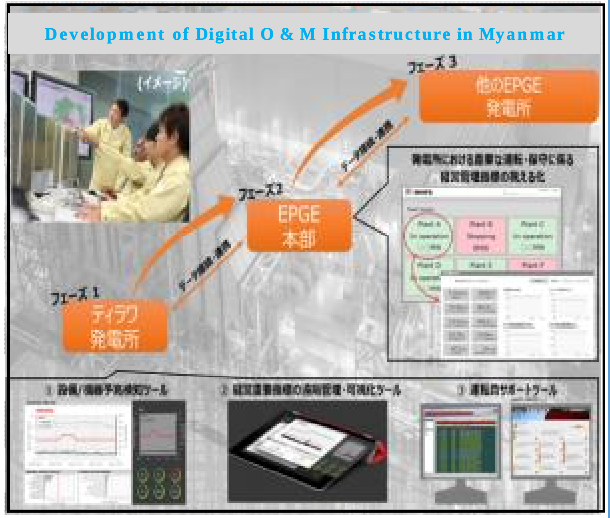
Customer value

Support for optimization and efficiency improvement of O&M business with the latest AI/IoT technologies

【A Place to Connect Hard O&M and Soft O&M】

Direction of Proposals to Myanmar and EPGE

Study introduction at EPGE headquarters and other power stations using pilot introduction results



B. Soft O&M Infrastructure Package

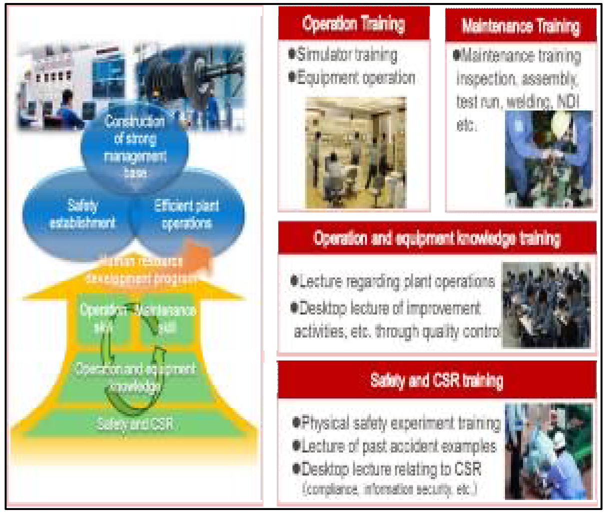
Customer value

Support for the establishment of O&M guidelines of Electric Power Agency, Development of future engineers at EPGE headquarters

【A Place to Apply O&M Theory】

Direction of Proposals to Myanmar and EPGE

Support for the establishment of rules, manuals, and systematic education capacity building, etc.



C. Hard O&M Infrastructure Package

Customer value

Development of O&M infrastructure at existing power stations, Development of future EPGE field engineers

【A Place to Experience the Practice of O&M】

Direction of Proposals to Myanmar and EPGE

Support for autonomous O&M through a long-term maintenance contract for existing power plants and a comprehensive O&M subcontracting business including rehabilitation

Attachment

Less Planned Training

especially for plant members

Impressions (Paticipants:14)

1.	Highly Satisfied	10
2.	Somewhat Satisfied	1
3.	Neutral	3
4.	Somewhat Dissatisfied	0
5.	Highly Dissatisfied	0

② Gas leakage and overheating

Gas leaks and Overheating

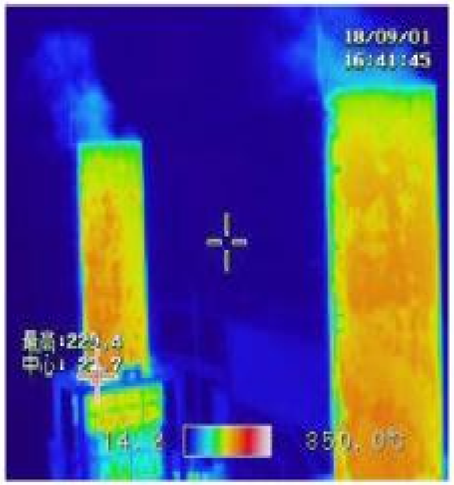
were found at some power Plants. (Dangerous situation)

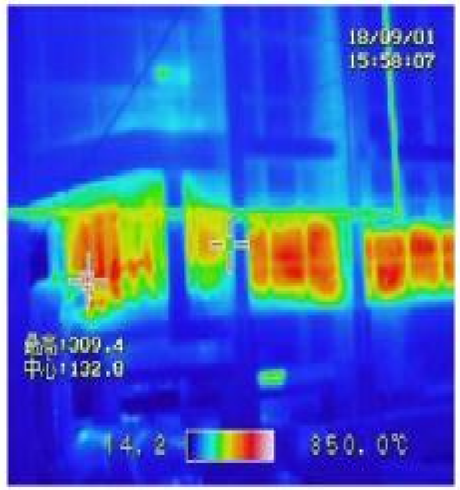
Check valve flange (15%LEL)

Strainer level gauge lower side flange (100%LEL)

Strainer level gauge lower side flange (100%LEL)

Cyclone separator level gauge lower side flange (32%LEL)





③ No digitalization

Almost no data is
digitalized,
but recorded contents are excellent.

Type	Contents
Operation Logbook	It is used for operators to take over between shifts. Shift members, Successors and the Instructions from LDC In the Ywama power station where the generator is hydrogen gas cooling type, the purity of hydrogen gas is described as an important matter.
Maintenance Logbook	The maintenance department describes defect events and repair results. Details on repair content etc. are not described. Even with the same logbook, the criteria for items to be described are different depending on the person in charge. Therefore, there are cases where the details of the defect contents are not described.
Inspection Logbook	Inspection results are recorded. Power output, oil level, oil temperature, presence / absence of oil leak, winding temperature, number of cooling fans in operation, GCB gas pressure, presence / absence of gas leak etc. * Depending on the power plant, there are cases where the logbook is used separately from the operation data recording sheet.

Control status of operation data

Record of power generation

④ 300MW unplanned shutdown

More than

300MW

loss due to inadequate O&M


IGV was missed


Broken pieces in Exh.Duct


Blades were damaged


New materials not used


Comp. Blades were damaged


Casing over heated

Plant	Type	Plant Configuration	Original Capacity	Latest Capacity	Δ (delta)	Main Reason
Ywama	Fr5	2GT CHP	37MW	37MW	153MW	✓H-25 1on1 was stopped due to heavy damages of Turbine buckets from 2014. ✓701D was stopped due to heavy damages of Compressor bucket from July. 2018.
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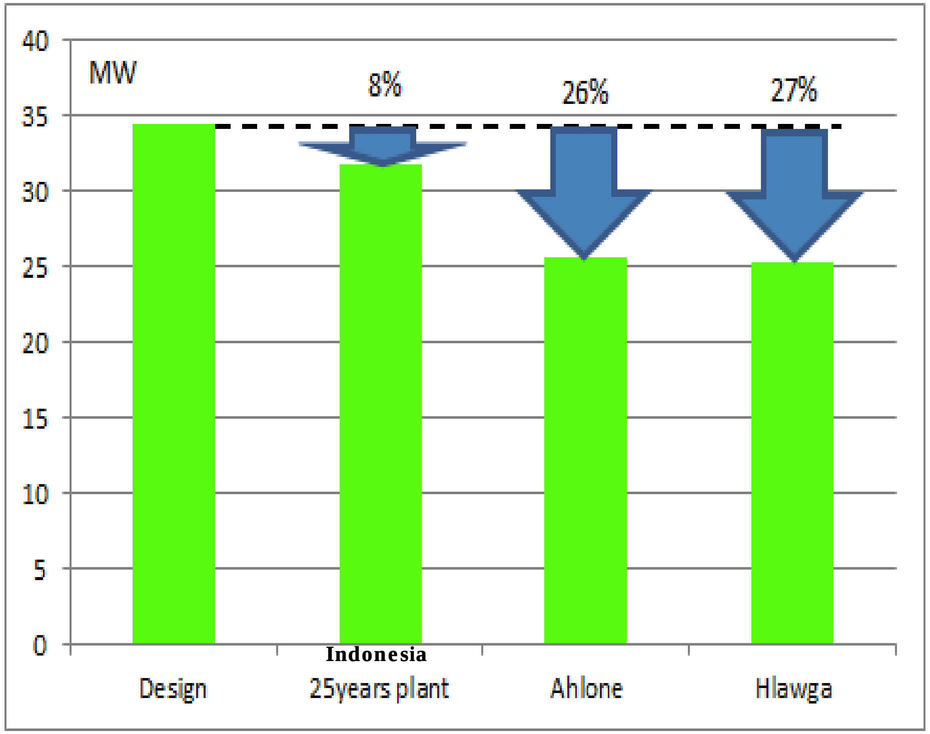
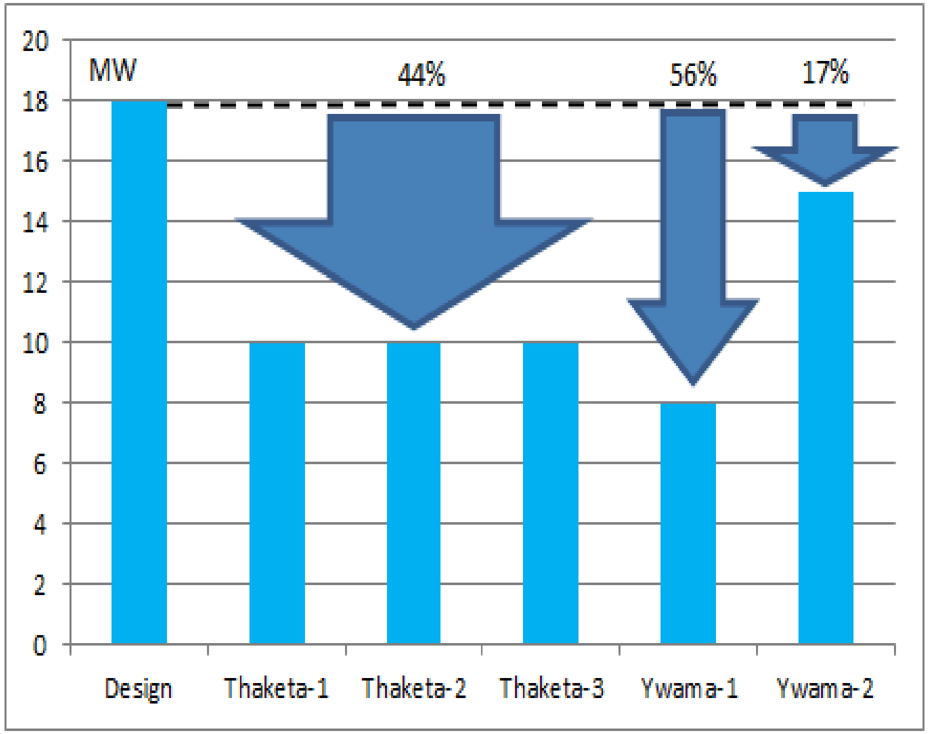
Thilawa	H-25	2GT S/C	50MW	50MW	0MW	✓No issue
Total (Except Hydro)			760MW	448MW	312MW	

As of Oct, 2018

④ Loss of Power Output

Decreased power output is Δ8%~56% from design figure

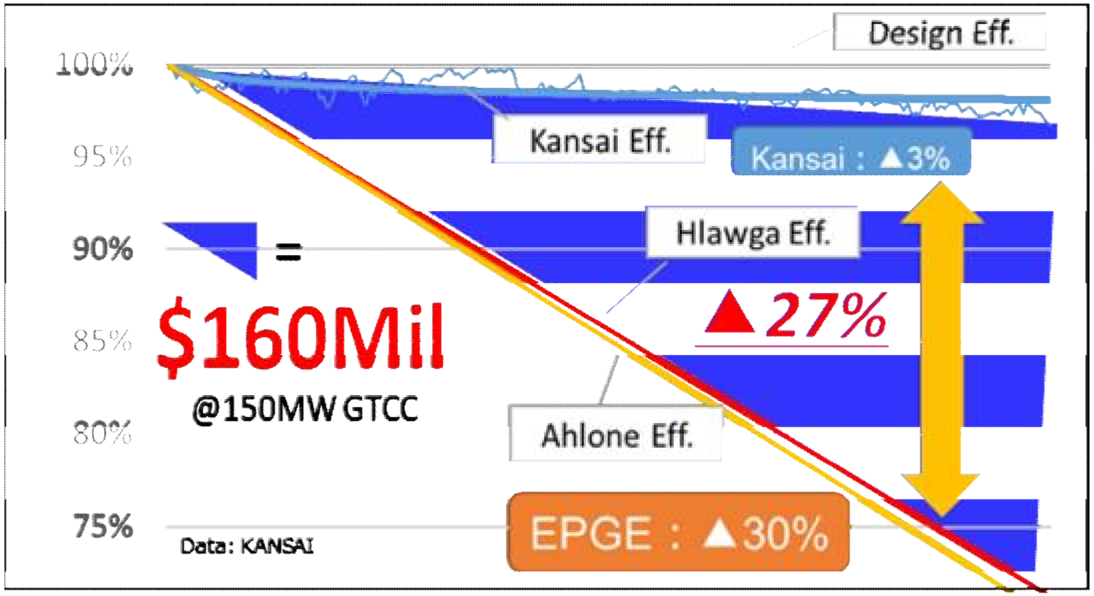




④ Loss in Fuel Consumption

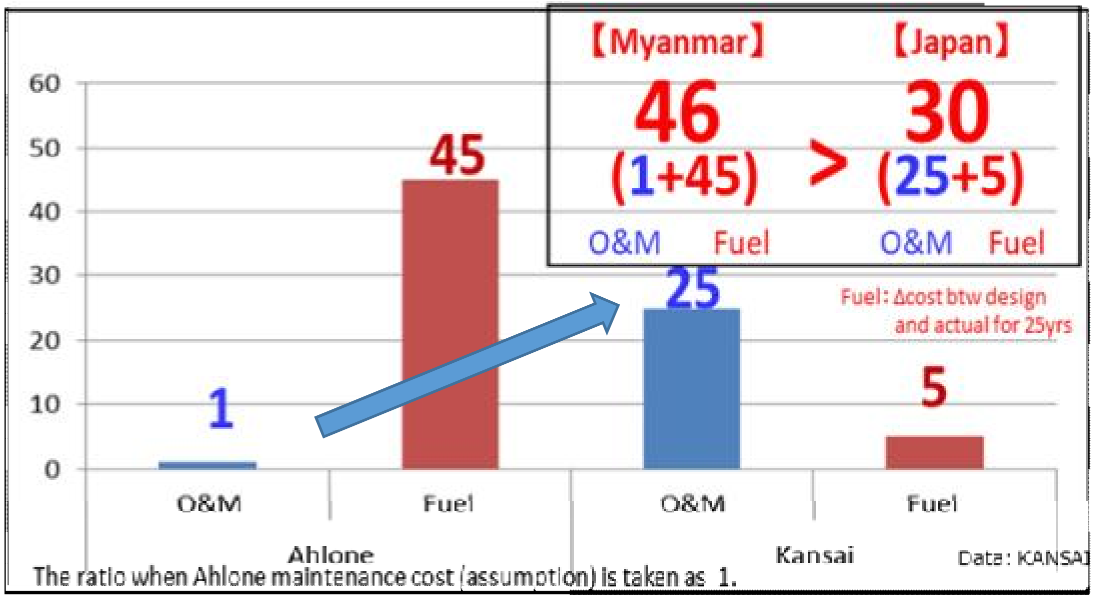
Δ27%

Difference in efficiency degradation compared to Japanese power plants



25times

O&M cost is expensed at Japanese power plants to save on fuel.



④ Ringing alarms in the Control Center

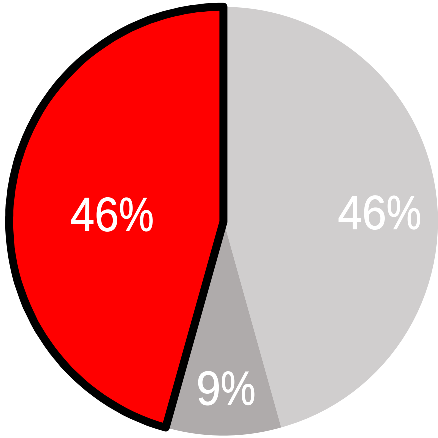
Alarms keep ringing

and it takes time to take countermeasures.

⑤ Unplanned Outages

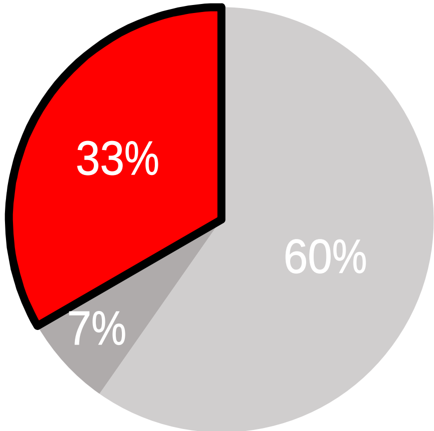
Unplanned outages occurred about 567times over a 2-year period.

: Grid Trouble
: Gas Supply Trouble
: Power Plant Trouble



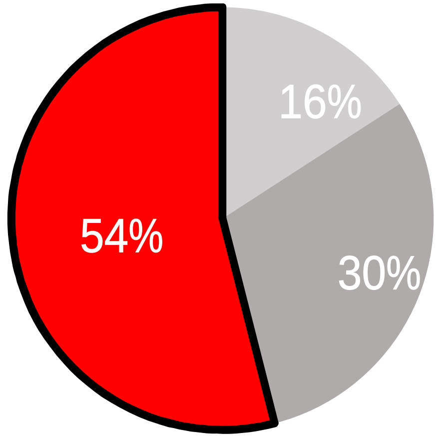
Thaketa operation data

Duration : Apr. 2015~Nov. 2018
Unexpected Stop No. : 92 times/3units
Thaketa P/S (Fr5 X 3)



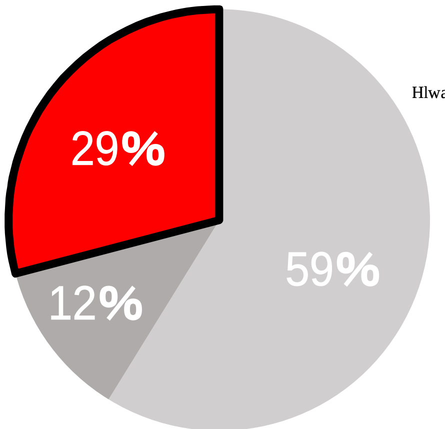
Ywama operation data

Duration : Jan. 2016~Nov. 2018
Unexpected Stop No. : 144 times/2units
Ywama P/S (Fr5 X 2)



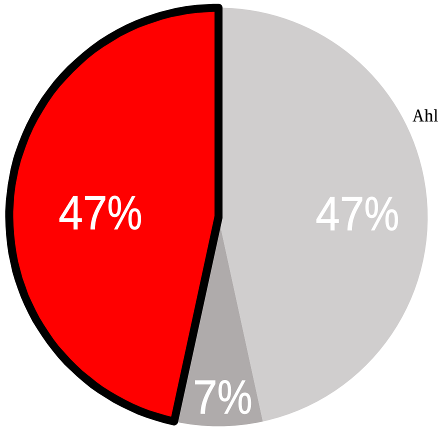
Ywama operation data

Duration : Jan. 2017~Nov. 2018
Unexpected Stop No. : 63 times/2units
Ywama P/S (701D X 2)



Hlwaga operation data

Duration : Jan. 2015~Nov. 2018
Unexpected Stop No. : 165 times/3units
Hlwaga P/S (Fr6 X 3)



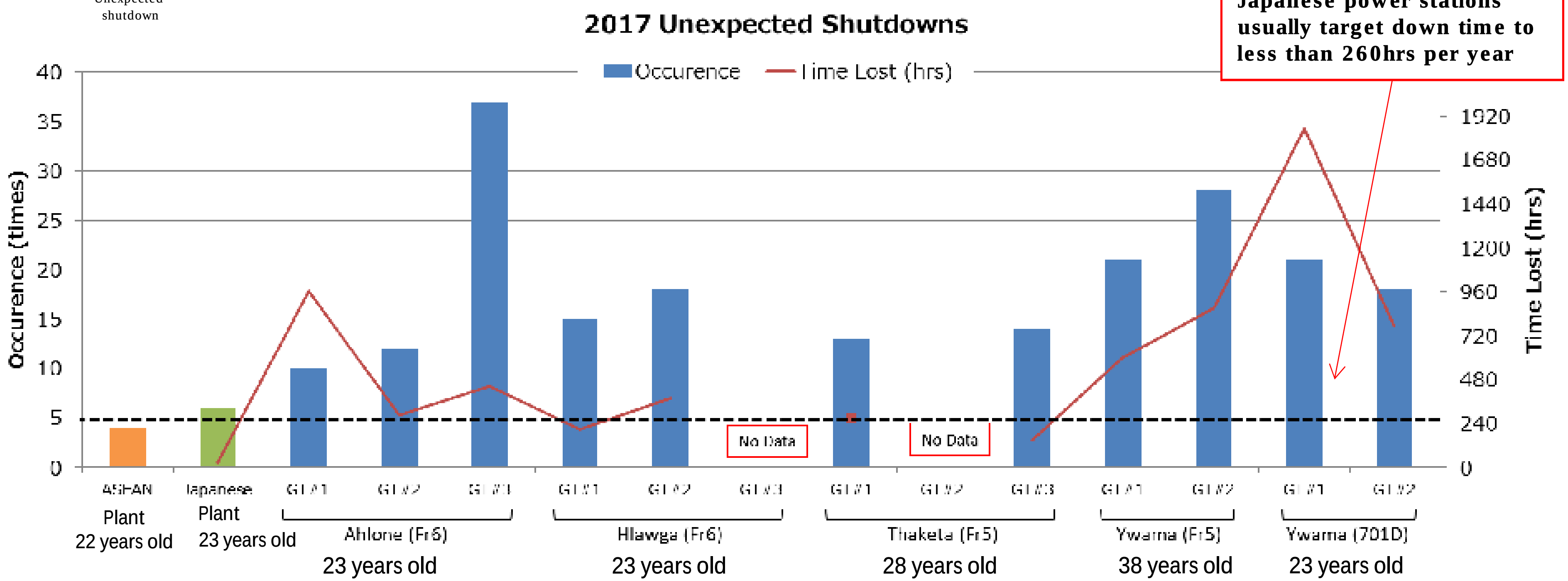
Ahlone operation data

Duration : Jan. 2017~Nov. 2018
Unexpected Stop No. : 103 times/3units
Ahlone P/S (Fr6 X 3)

⑤ Unexpected Shutdowns

Unexpected shutdowns occurred about **2~7times** **more than in ASEAN/Japan.**

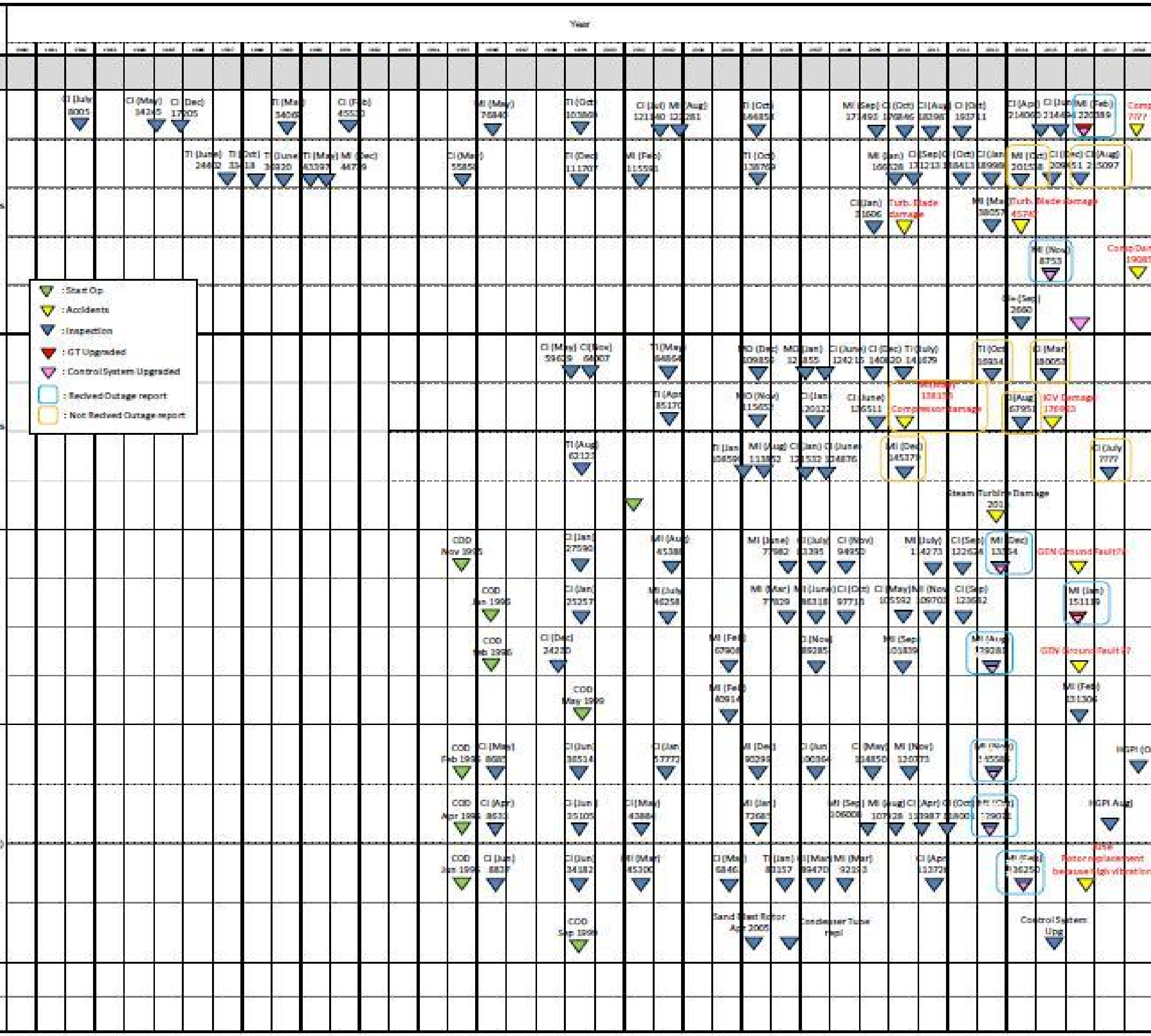
Unexpected shutdown



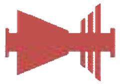
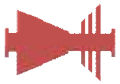
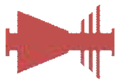
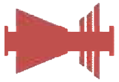
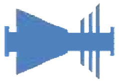
⑤ Less Scheduled Maintenance

Less scheduled maintenance is carried out.

Plant	Frame	Unit #	Original Capacity (MW)	Latest Capacity (MW)	Shortage (MW)	Elec Loss (C/F assumption =60%)	Total Operation Hr (Aug. 2018)
Yeywa	Hydro	-	790	N/A	N/A		
Ywama	Fr5 2GT CHP	1	19	19	138	785GWh (33MW×21,024hrs + 105MW×864hrs)	
		2	19	19			
	H-25 1on1 C/C	1	33	0			
	701D 2GT S/C	1	105	105			
		2	105	0			
Thaketa	Fr5 3on1 C/C	1	19	19	54	936GWh (19MW×10,512hrs + 35MW×21,024hrs)	
		2	19	0			
		3	19	19			
		ST	35	0			
Hlawga	Fr6 3on1 C/C	1	33	33	51	536GWh (51MW× 10,512hrs)	154578
		2	33	33			172422
		3	33	0			148684
		ST	54	36			
Ahlone	Fr6 3on1 C/C	1	33	33	54	117GWh (54MW×2,160hrs)	177698
		2	33	33			160291
		3	33	33			167574
		ST	54	0			
Thilawa	H-25 2GT S/C	1	25	25	0	-	19033
		2	25	25		-	9308



Unusable assets sit in a warehouse.

	GT#1	GT#2	GT#3
Thaketa *Plan to be Upgraded in 2019			
Ywama			

Original

Upgraded

	Thaketa Stock	Ywama Stock	Total Original	Total Upgraded
Combustion Liner	Original	Original	36	0
Transition Piece	Original	Original	52	0
Turbine 1 Nozzle		Original	10	0
Turbine 2 Nozzle			0	0
Turbine 1 Bucket	Original	Original	240	0
Turbine 2 Bucket	Original		90	0
Turbine 1 Shroud Block		Original	36	0
Turbine 2 Shroud Block		Original	30	0

Dead Stock !! No Spare !!

Parts List

Stock List

Security management system

exists, but it is not digitalized.

Security card

Guard office

Key management box

Status of key management

THE REPUBLIC OF THE UNION OF MYANMAR

MINISTRY OF ELECTRICITY AND ENERGY

DATA COLLECTION SURVEY ON THE MAINTENANCE OF POWER PLANTS USING STATE-OF-THE-ART TECHNOLOGY SUCH AS IOT AND AI IN THE REPUBLIC OF THE UNION OF MYANMAR

FINAL REPORT

September 2019

Japan International Cooperation Agency (JICA)

The Kansai Electric Power Co., Inc.

Mitsubishi Hitachi Power Systems, Ltd.

1R
JR
19-069

Data Collection Survey on the Maintenance of Power Plants
Using State-of-the Art Technology such as IoT and AI in the Republic of the Union of Myanmar
Final Report

Table of Contents

Appendixes

List of Figures

List of Tables

Abbreviations

Symbol	Abbreviation
ABB	Asea Brown Boveri
ADB	Asian Development Bank
AE	Assistant Engineer
AI	Artificial Intelligence
ASEAN	Association of Southeast Asian Nations
AVR	Automatic Voltage Regulator
BOP	Balance of Plant
BPT	Blade Path Temperature
CABS	Computer Aided Balancing System
CBM	Condition Based Maintenance
CCGT	Combined Cycle Gas Turbine
CCYW	Sinohydro Corporation Limited
C/C	Control Center
CE	Chief Engineer
CHMC	China National Heavy Machinery Corporation
CHP	Combined Heat and Power
CI	Combustion Inspection
CITIC	China International Trust Investment Corporation
CNEEC	China National Electric Equipment Corporation
COD	Commercial Operation Date
COD	Chemical Oxygen Demand
CRI	Comprehensive Rotor Inspection
CSR	Corporate Social Responsibility
C&I	Control & Instrumentation
DCS	Distributed Control System
DCT	Disc Cavity Temperature
DPTSC	Department of Power Transmission and System Control
EDI	Evans Deakin Engineering
EE	Executive Engineer
EL	Elevation Level
EPC	Engineering, Procurement and Construction
EPGE	Electric Power Generation Enterprise
ESDD	Equivalent Salt Deposit Density

Ex	Exhaust
FT	Fault Tree
FTL	Full Tank Level
GCB	Gas Circuit Breaker
GCC	Generation Control Center
GE	General Electric Company
GEN	Generator
GGE	Golden Green Energy
GIS	Gas Insulated Switchgear
GSMaP	Global Satellite Mapping of Precipitation
GT	Gas Turbine
GtoG	Government to Government
HCF	High Cycle Fatigue
HGPI	Hot Gas Path Inspection
HQ	Head Quarters
HRSG	Heat Recovery Steam Generator
ICT	Information and Communication Technology
IFC	International Finance Corporation
IGV	Inlet Guide Vane
IHI	Ishikawajima-Harima Heavy Industries Co., Ltd
IoT	Internet of Things
IPP	Independent Power Producer
ISO	International Organization for Standardization
JAXA	Japan Aerospace Exploration Agency
JBE	John Brown Engineering
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
KPI	Key Performance Indicator
KS-sol	Kanden System Solutions Co., Inc
LDC	Load Dispatch Center
LEL	Lower Explosion Limit
LNG	Liquid Natural Gas
LO	Lube Oil
LSB	Low Speed Balancing
LTSA	Long Term Service Agreement
MCMA	Motor Current Multiplex Analysis
MD	Managing Director

METI	Ministry of Economy, Trade and Industry
MHI	Mitsubishi Heavy Industries
MHPS	Mitsubishi Hitachi Power Systems
MI	Major Inspection
MOEE	Ministry of Electricity and Energy
MOGE	Myanmar Oil and Gas Enterprise
MOL	Minimum Operation Level
MOM	Minutes of Meeting
MONREC	Ministries of Natural Resources and Environmental Conservation
MP	Master Plan
MT	Magnetic Particle Testing
NCAR	National Center for Atmospheric Research
NCC	National Control Center
NDI	Non Destructive Inspection
NG	Natural Gas
NOx	Nitrogen Oxide
NSDD	Non-Soluble Deposit Density
NTP	Notice to Proceed
OEM	Original Equipment Manufacturer
OJT	On the Job Training
ONAF	Oil Natural Air Forced
ONAN	Oil Natural Air Natural
OPS	Operator Station
O&M	Operation and Maintenance
P/C	Power Center
pH	Power of Hydrogen
PoE	Power over Ethernet
PPA	Power Purchase Agreement
P/S	Power Station
PSI	Pounds Square Inch
PT	Penetrant Testing
QMS	Quality Management System
RBOT	Rotating Bomb Oxidation Test
RCC	Roller Compacted Concrete
RFID	Radio Frequency Identification
RMC	Remote Monitoring Center
RO	Reverse Osmosis

ROMM	Rehabilitation Operation Maintenance Management
RT	Radiographic Testing
SAE	Sub Assistant Engineer
SDGs	Sustainable Development Goals
SESAME	Sensory data transmission Service Assisted by Midori Engineering laboratory
SEZ	Special Economic Zone
SMEs	Small and Medium sized Enterprises
SPC	Special Purpose Company
SRS	Skill Record System
ST	Steam Turbine
STG	Steam Turbine Generator
S+3E	Safety + Energy security, Environment, Economical efficiency
TA	Technical Advisor
TBM	Time Based Maintenance
TDS	Total Dissolved Solids
TQM	Total Quality Management
UT	Ultrasonic Testing
WRF	Weather Research and Forecasting

Chapter 1 Introduction

1.1 Backgrounds of the Study

In the Republic of the Union of Myanmar (hereinafter referred to as “Myanmar”), the demand for electric power has rapidly increased with recent economic development, and the maximum electric power demand, which was 1,371 MW in 2010, increased 3,189 MW in 2017. Myanmar's total power generation capacity was 4,878.8 MW as of July 2017. However, power generation capacity is less than the demand because of a shortage of water in the dry season at the hydroelectric power plant, reduced power due to aging of power generation facilities, and supply power export to other countries. Improvement to the electricity supply in Myanmar is an urgent issue to bridge the electricity supply-demand gap.

According to a "National Electricity Master Plan" (2014) and a "Project for Capacity Development of Power Sector Development Planning" (2016) implemented in the past, it was found that the thermal efficiency of existing combined gas-fired power plants is as low as about 30% because the facilities are not properly maintained and managed, so the capacity of the power plants is not fully used. In addition, it was confirmed that there are many tasks to be improved in terms of parts arrangement, maintenance planning, and troubleshooting. In order to promptly increase the power supply capability, it is urgent to establish operation and maintenance (hereinafter referred to as O&M) systems and to improve the technical capacity of staff.

Against this background, in the economic policy of Myanmar’s new government, which was announced in July 2016, the "rapid development of basic economic infrastructure such as electric power" is positioned as a priority policy. Also, in November 2016, the "Japan-Myanmar Cooperation Program" was formulated at the meeting with State Counselor Daw Aung San Suu Kyi and Prime Minister Abe, and "Energy cooperation to enable industrial development" was listed as one of the pillars. Japan has also announced that it will contribute to this program through funding investment of about 800 billion yen by public and private sectors over 5 years from FY 2016.

In this survey, the JICA study team will grasp the current issues, and aims to stabilize the supply of electricity in Myanmar by realizing more sophisticated O&M at power plants. Therefore, it coincides with the cooperation policy of both governments.

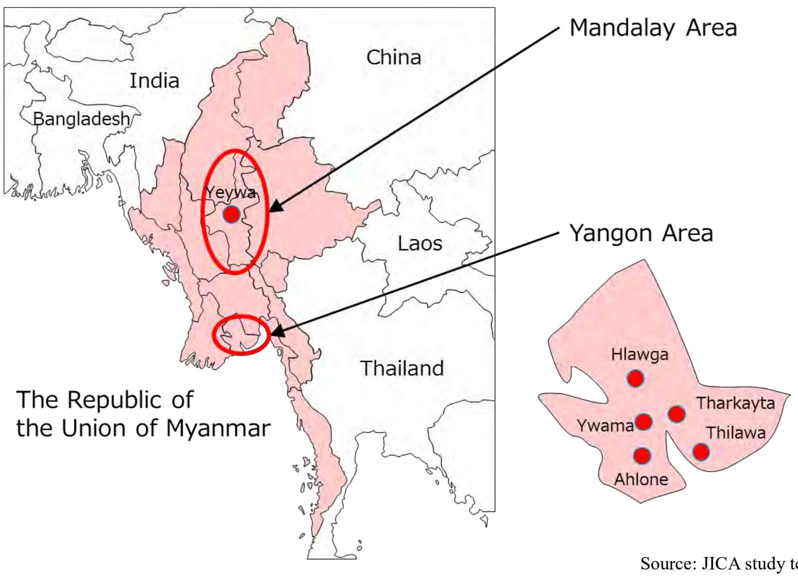
Furthermore, Japan is now aiming at improving the productivity of Japanese companies, including small and medium sized enterprises (hereinafter referred to as SMEs), through a "productivity revolution" that was named as a priority policy in the "Future Investment Strategy 2017" and "New Economic Policy Package". Therefore, the JICA study team will contribute to the development of Myanmar by finding possible ways to improve productivity by means of the latest technologies utilizing IoT and AI, as promoted by the Japanese government, and examining of the possibility of introducing technologies possessed by SMEs.

1.2 Purpose of the Study

Table 1-1 Purpose of the Study

Item	Contents
Purpose	Investigate the current state of O&M of the five thermal power plants (Thilawa, Hlawga, Ahlone, Ywama, and Thaketa) and one hydropower plant (Yeywa), and grasp the issues. The JICA study team will examine and make recommendations on improving power plant maintenance from the viewpoints of operation, facilities and organizational structure, by taking advantage of the latest technologies such as IoT and AI, and examining the possibility of introducing the technologies related to O&M of Japanese SMEs in particular.
Objective Area	Yangon (location of thermal power plant) Naypyitaw (location of headquarters of Electric Power Generation Enterprise of MOEE) Mandalay (location of hydropower plant)
Implementation Agency	Following organization of MOEE - Electric Power Generation Enterprise: EPGE
Scope of Works	(1) General information on the O&M systems of the power plants (2) Visit to each power plant and investigation of the O&M systems (3) Study of the possibility of applying the latest technologies such as IoT and AI (4) Improvement of O&M and proposal for the possibility of cooperation by JICA

Source: JICA study team



Source: JICA study team

Fig. 1-1 Target Power Plants

1.3 Schedule of the Study

1.3.1 Schedule of the Study

The JICA study team is conducting this survey from July 2018 to July 2019, during which will include four site surveys. During the site surveys, the JICA study team surveys the O&M structure of the power plants, installs the remote monitoring systems, and conducts trial training in O&M techniques.

Table 1-2 Schedule of the Study

Term / Work Scope	FY 2018									FY 2019			
	7	8	9	10	11	12	1	2	3	4	5	6	7
A. First Works in Japan													
A1 Confirm and analyze existing materials													
A2 Arrange equipment procurement, etc.													
A3 Prepare a questionnaire													
A4 Make an Inception Report													
B. First Site Survey													
B1 Kick-off meeting													
B2 Request for cooperation of information collection													
B3 Confirm support status of other donors													
B4 Investigate general informations related to O&M system of power plant													
B5 Visit each power plant and investigate O&M system													
B6 Install remote monitoring device(1st unit)													
C. Second Works in Japan													
C1 Report first site survey													
C2 Summarize and evaluate the result of general information investigation relating to O&M system for power plant.													
C3 Summarize and analyze the result of investigation for O&M system.													
C4 Digital solution													
C5 Consider adaptive possibility of the latest technology such as IoT・AI, etc.													
C6 Prepare a questionnaire													
D. Second Site Survey													
D1 Additional investigation of general information relating to O&M system for power plant													
D2 Visit each power plant and additionally investigate O&M system													
D3 Survey of the effect of digital solution · Install remote monitoring device (2nd unit)													
E. Third Works in Japan													
E1 Report second site survey													
E2 General items on O&M system at power plant Summary of survey results and discussion													
E3 Conclusion / analysis of survey related to the O&M system of each power plant													
E4 Consider adaptive possibility of the latest technology such as IoT・AI, etc.													
E5 Study O&M improvement points and make a proposal													
E6 Study possibility of cooperation by JICA and make a proposal													
E7 Prepare Interim Report													
F. Third Site Survey													
F1 Report / consultation on Interim · Report													
F2 Collect additional information / data													
G. Fourth Works in Japan													
G1 Report third site survey													
G2 Make a Draft Final Report													
H. Fourth Site Survey													
H1 Explan and discuss Draft Final Report													
I. Fifth Works in Japan													
I1 Report fourth site survey													
I2 Make a Final Report													

Site Survey Works in Japan △-△ Explanation of the Report, etc

Source: JICA study team

1.3.2 Results of the Site Survey

(1) First Site Survey

The JICA study team conducted the first site survey from August 15, 2018 to September 12, 2018.

The main themes were as follows.

a. Kick-off meeting with EPGE

b. Interview with EPGE

c. Interview with each power plant

d. Simple diagnosis (vibration, water quality, insulation resistance, gas leakage)

Table 1-3 First Site Survey Schedule

Date				Hidemasa Takashima (Kansai) Team Leader/Power Plant Operation	Junichi Kuwahara (MHPS) Power Plant (Mechanical Equipment)	Ryo Sato (Kansai) Power Plant(Electrical and Control)	Toshiyuki Hiraoka (MHPS) Remote Monitoring
8	15	Wed	1	Move to Myanmar			
	16	Thu	2	Preparation			
	17	Fri	3	Preparation			
	18	Sat	4	Preparation			
	19	Sun	5	Preparation	Move to Myanmar	←	
	20	Mon	6	Kick-off Meeting with MOEE (accompanied by JICA experts (Mr. Nakashima,JICA Myanmar office))	←	←	
	21	Tue	7	Discussion and Data Collection from MOEE/ EPGE	←	←	
	22	Wed	8	Discussion and Data Collection from MOEE/ EPGE	←	←	
	23	Thu	9	Site Survey at Yeywa (Interviews and document reviews)	←	←	
	24	Fri	10	Site Survey at Yeywa (Interviews and document reviews)	←	←	
	25	Sat	11	Site Survey at Yeywa (Interviews and document reviews)	←	←	
	26	Sun	12	Reporting	←	←	
	27	Mon	13	Site Survey at Thaketa (Interviews and document reviews)	←	←	
	28	Tue	14	Site Survey at Thaketa (Diagnosis of auxiliary equipment, leakage location)	←	←	Move to Myanmar
	29	Wed	15	Site Survey at Ywama (Interviews and document reviews)	←	←	←
	30	Thu	16	Site Survey at Ywama (Interviews and document reviews)	←	←	←
	31	Fri	17	Site Survey at Ywama (Diagnosis of auxiliary equipment, leakage location)	←	←	←
9	1	Sat	18	Site Survey at Hlawga (Interviews and document reviews)	←	←	←
	2	Sun	19	Reporting	←	←	←
	3	Mon	20	Site Survey at Hlawga (Diagnosis of auxiliary equipment, leakage location)	←	←	←
	4	Tue	21	Site Survey at Ahlone (Interviews and document reviews)	←	←	←
	5	Wed	22	Site Survey at Ahlone (Diagnosis of auxiliary equipment, leakage location)	←	←	←
	6	Thu	23	Site Survey at Ahlone (Preliminary survey of water quality, vibration and lubricating oil diagnosis)	←	←	←
	7	Fri	24	Site Survey at Thilawa (Interviews and document reviews)	←	←	←
	8	Sat	25	Site Survey at Thilawa (Diagnosis of auxiliary equipment, leakage location)	←	←	←
	9	Sun	26	Reporting	←	←	←
	10	Mon	27	Wrap-up Meeting with JICA (at JICA office)	←	←	←
	11	Tue	28	Courtesy Call to MOEE Materials collection	←	←	←
	12	Wed	29	Move to Japan	←	←	←

Source: JICA study team

At the beginning of this site survey, the JICA study team conducted a kick-off meeting with EPGE at Naypyitaw. The JICA study team outlined the survey (objectives, survey target, survey method, etc.) to EPGE, and EPGE approved the permission and cooperation request from the JICA study team.

In addition, EPGE and MOEE approved the installation of pilot equipment (remote monitoring equipment: MHPS-TOMONI®) to study the feasibility of introducing IoT technology.

After the site survey, the JICA study team conducted the wrap-up meeting at Naypyitaw and reported the findings. In this meeting, the president of EPGE requested the JICA study team to consider the possibility of installing the remote monitoring system at the hydroelectric power plant, specifically the Baluchaung power plant, which was constructed by Japanese companies. Based on this request, the JICA study team decided to add a survey of the Baluchaung power plant to the second site survey.

(2) Second Site Survey

The JICA study team conducted the second site survey from November 25, 2018 to December 20, 2018.

The main themes were as follows.

a. Interview with EPGE
b. Data acquisition from each power plant
c. Trial training
d. Lube oil sampling from GT and ST
e. Boiler water sampling

The JICA study team planned to install two remote monitoring systems (MHPS-TOMONI®) during the second site survey. However, the team found that it was difficult due to customs and EPGE approved the postponement of installation.

Table 1-4 Second Site Survey Schedule

Date				Hidemasa Takashima (Kansai) Team Leader/Power Plant Operation	Junichi Kuwahara (MHPS) Power Plant (Mechanical Equipment)	Ryo Sato (Kansai) Power Plant(Electrical and Control)	Toshiyuki Hiraoka (MHPS) Remote Monitoring
11	25	Sun	1	Move to Myanmar	←	←	←
	26	Mon	2	Kick-off Meeting with EPGE	←	←	←
	27	Tue	3	Kick-off Meeting with EPGE, Data Collection	←	←	←
	28	Wed	4	Meeting with EPGE, Data Collection	Baluchaung No1 Hydro power plant survey	←	←
	29	Thu	5	Baluchaung No2 Hydro Power Plant Survey	←	←	←
	30	Fri	6	Site Survey at Thaketa (Including research on rehabilitation)	←	←	←
12	1	Sat	7	Reporting	←	←	←
	2	Sun	8	Reporting	←	←	←
	3	Mon	9	Site Survey at Thaketa (Including research on rehabilitation)	←	←	←
	4	Tue	10	Site Survey at Hlawga (Including research on rehabilitation)	←	←	←
	5	Wed	11	Site Survey at Hlawga (Including research on rehabilitation)	←	←	←
	6	Thu	12	Site Survey at Ywama (Including research on rehabilitation and vibration diagnosis)	←	←	←
	7	Fri	13	Site Survey at Ywama (Including research on rehabilitation and vibration diagnosis)	←	←	←
	8	Sat	14	Site Survey at Yeywa	Reporting	Site survey at Yeywa	Reporting
	9	Sun	15	Site Survey at Yeywa	Reporting	Site Survey at Yeywa	Reporting
	10	Mon	16	Site Survey at Ywama (Including research on rehabilitation and vibration diagnosis)	←	←	←
	11	Tue	17	Site Survey at Ahlone (Including research on rehabilitation)	←	←	←
	12	Wed	18	Trial Training and Demonstrations on Portable Instruments at Ahlone			
	13	Thu	19	Trial Training and Demonstrations on Portable Instruments at Ahlone	←	←	←
	14	Fri	20	Myanmar Market Survey (local vendor and warehouse)	←	←	MHPS-TOMONI Installation at Thilawa
	15	Sat	21	Myanmar Market Survey (local vendor and warehouse)	←	←	MHPS-TOMONI Installation at Thilawa
	16	Sun	22	Reporting	Reporting	Reporting	MHPS-TOMONI Installation at Thilawa
	17	Mon	23	Wrap-up	←	←	←
	18	Tue	24	Wrap-up and Farewell	←	←	←
	19	Wed	25	Wrap-up	Move to Japan	←	←
	20	Thu	26	Move to Japan			

Source: JICA study team

(3) Third Site Survey

The JICA study team conducted the third site survey from March 10, 2019 to March 16, 2019.

The main themes were as follows.

a. Site survey at the Ywama Power Station
b. Explanation of the interim report to EPGE

At the time of explaining the Interim Report, the JICA study team received the opinion from the EPGE MD that system optimization was necessary to operate the power plant efficiently. Therefore, in order to confirm the system operation status, the JICA study team met with DPTSC engineers and visited NCC.

In addition, regarding the installation of a pilot equipment of digital solutions, which was not able to be carried out at the time of the 2nd site survey, support members installed the application platform between 2019.1.10 - 2019.1.15, and, to explain the operation method, a briefing session was held at the Thilawa power station in March 2019.

Table 1-5 Third Site Survey Schedule

Date				Hidemasa Takashima (Kansai) Team Leader/Power Plant Operation	Junichi Kuwahara (MHPS) Power Plant (Mechanical Equipment)	Ryo Sato (Kansai) Power Plant(Electrical and Control)	Toshiyuki Hiraoka (MHPS) Remote Monitoring
3	10	Sun	1	–	Move to Myanmar	–	Move to Myanmar
	11	Mon	2	Move to Myanmar	Site Survey at Ywama	Move to Myanmar	Site Survey at Ywama
	12	Tue	3	Site Survey at Ywama	←	←	←
	13	Wed	4	Site Survey at Ywama	←	←	←
	14	Thu	5	Wrap-up and Greeting	←	←	Site Survey at Thilawa (MHPS-TOMONI)
	15	Fri	6	Wrap-up Move to Japan	←	←	Site Survey at Ywama Move to Japan
	16	Sat	7	Move to Japan	←	←	←
	17	Sun	8	–	–	–	–

Source: JICA study team

(4) Fourth Site Survey

The JICA study team conducted the forth site survey from June 10, 2019 to June 15, 2019. The main themes were as follows.

a. Explanation of the draft final report to EPGE
b. Meeting with MOGE
c. Site survey at the Ywama Power Station

Table 1-6 Forth Site Survey Schedule

Date				Hidemasa Takashima (Kansai) Team Leader/Power Plant Operation	Junichi Kuwahara (MHPS) Power Plant (Mechanical Equipment)	Ryo Sato (Kansai) Power Plant(Electrical and Control)	Toshiyuki Hiraoka (MHPS) Remote Monitoring
6	9	Sun	–	–	–	–	–
	10	Mon	1	Move to Myanmar	←	←	←
	11	Tue	2	Wrap-up and Greeting	←	←	←
	12	Wed	3	Wrap-up and Greeting	←	←	←
	13	Thu	4	Meeting with EPGE and MOGE Move to Japan	Meeting with EPGE and MOGE	Meeting with EPGE and MOGE Move to Japan	←
	14	Fri	5	Move to Japan	Site Survey at Ywama P/S Move to Japan	Move to Japan	←
	15	Sat	6	–	Move to Japan	–	–
	16	Sun	–	–	–	–	–

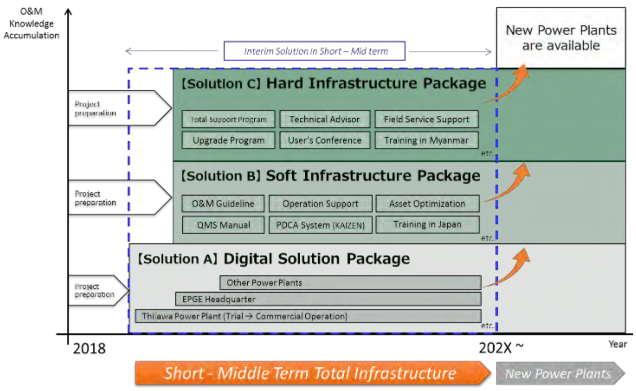
Source: JICA study team

1.4 Survey Implementation Structure

Four consultants, two from The Kansai Electric Power Co., Inc. (hereinafter referred to as KANSAI) and two from Mitsubishi Hitachi Power Systems Co., Ltd. (hereinafter referred to as MHPS), participate in this survey. Also, in order for studies and discussions to proceed effectively, EPGE and the JICA study team agreed to organize a joint study team in the second site survey.

Support programs, survey implementation structure, etc. are as follows.

Source: JICA study team



Source: JICA study team

Fig. 1-2 Support Programs

Table 1-7 Survey Members

Position	JICA study team	Study Team from EPGE
Leader	Team Leader / Power Plant Operation Hidemasa Takashima	Dr. Managing Director U Than Naing Oo
Solution C Hard Infrastructure	Power Plant (Mechanical Equipment) Junichi Kuwahara	Chief Engineer Dr. Maung Maung Kyaw Department of Renewable Energy and Hydropower Plants
Solution B Soft Infrastructure	Power Plant (Electrical and Control) Ryo Sato	Chief Engineer U Soe Win Department of Thermal Power
Solution A Digital Package	Remote Monitoring Toshiyuki Hiraoka	Deputy Chief Engineer Dr. Win Myint Department of Renewable Energy and Hydropower Plants

Minutes of Meeting

- Joint Study and Discussion for Operation & Maintenance Development Support Program -

This Minutes of Meeting ("MOM") is made on 27th November, 2018 by Electricity Power Generation Enterprise in Myanmar ("EPGE"), Kansai Electric Power Company, Incorporated ("KEPCO") and Mitsubishi Hitachi Power Systems, ltd ("MHPS")

EPGE, KEPCO, MHPS are hereinafter referred to as the "Parties" or individually a "Party", and KEPCO and MHPS are hereinafter referred to as the "Team Japan".

Whereas, the Parties will conduct study and discussion for realizing the Operation & Maintenance ("O&M") Development Support Program in order to develop Myanmar's O&M system by EPGE.

Now, therefore, the Parties agree as follows:

The following represents the preliminary understanding among the Parties and should not be deemed in any way to be a binding obligation of any of the other Parties with respect to the subject matter thereof:

The Parties intend to conduct further technical & commercial studies and discussions (the Studies and Discussions") within the framework established by this MOM for the purpose of realizing O&M Development Support Program by 3 three categories, as described below and mentioned in the attached documents.

Category A: Digital Solution Program:

Category B: Soft Infrastructure Program:

Category C: Hard Infrastructure Program:

In order to proceed the Studies and Discussions effectively, The Parties also agreed to organize the Joint Study Team as attached.

Parties herewith confirmed to target the Studies and Discussions based upon this MOM frame work as below.

January – February, 2018: Studies and Discussions by
March, 2019: 1st review by EPGE's executive
April-May, 2019: Further study and discussion reflecting by EPGE's comment
Jun, 2019: Final report review by EPGE's executive

For EPGE

U KHIN MAUNG WIN
Managing Director
Electric Power Generation Enterprise

For Team Japan

高島 英將

Mr. Hidemasa Takashima
General Manager, Thermal Power Division,
Kansai Electric Power Co., Inc.

Source: JICA study team

Fig. 1-3 MOM between EPGE and JICA Study Team

Table 1-8 Support Team

Company	Position	Name
Kansai	Thermal Power Plant (General)	Katsutoshi Yurugi
	Thermal Power Plant (General)	Naoki Fujimura
	Thermal Power Plant (Mechanical)	Yasuhiro Danno
	Thermal Power Plant (Control)	Shoji Takano
	Thermal Power Plant (Electrical)	Toshihiko Ogata
	Thermal Power Plant (Mechanical)	Keisuke Osaki
	Thermal Power Plant (Mechanical)	Hiroaki Matsuoka
	Thermal Power Plant (Control)	Kensuke Okumura
	Thermal Power Plant (Control)	Yukiko Ishihara
	Thermal Power Plant (Electrical)	Hidenobu Ichioka
	Thermal Power Plant (Electrical)	Yuhei Fujiwara
	Thermal Power Plant (Electrical)	Rie Taniguchi
	Contract / Budget Management	Noriyuki Ninomiya
	Hydro Power Plant (General)	Koichi Ota
	Hydro Power Plant (General)	Kenta Yanagishima
	Hydro Power Plant (General)	Tomonori Shitakata
	Hydro Power Plant (General)	Daisuke Naka

Company	Position	Name
MHPS	Contract / Budget Management	Shota Tsuboi
	Contract / Budget Management	Satsuki Konishi
	Contract / Budget Management	Yuichi Yamada
	Contract / Budget Management	Nozomu Miyazaki
	Third Party Equipment (Mechanical)	Akira Takahashi
	Third Party Equipment (Mechanical)	Kohei Tanaka
	Thermal Power Plant (General)	Hideki Nakashima
	Remote Monitoring System	Toru Tanaka
	Remote Monitoring System	Yoshiyuki Nagata
	Remote Monitoring System	Motoyoshi Shimizu
	Remote Monitoring System	Shunsuke Wada
	Remote Monitoring System	Masayoshi Kimoto
	Thermal Power Plant (General)	Hiroyuki Okazaki
	Thermal Power Plant (General)	Tomonori Kimura
	Thermal Power Plant (General)	Natchapon Luekiatphaisan
	Thermal Power Plant (General)	Nootprasert Apichart
MHI	Contract / Budget Management	Tomoko Nakano

Source: JICA study team

Chapter 2 General Survey Results of Operation, Maintenance and Management System of the Power Plants

2.1 Laws, Regulations, and Manuals Concerning the Operation and Maintenance of Power Generation Facilities

The laws concerning the power generation business are the Electricity Law 2014 and the Environmental Conservation Law 2012. Among the above laws, the contents related to the operation and maintenance of power plants are as follows, but there are no specific standards for compliance stipulated in the laws.

(1) Electricity Law 2014, Chapter 9 37.

It is stipulated that the relevant ministry must specify the norms and the inspection methods for electricity activities.

(2) Electricity Law 2014, Chapter 16 72. (a)

In order to fulfill the provisions based on the Electricity Law, it is stipulated that the relevant ministry may issue rules and regulations with the consent of the Union Government. Based on this content, Electricity Rules were formulated and approved with ADB's support in 2015.

In the Electricity Rules, it is stipulated as follows.

a. The ministry may establish training schools. （3.(xvi)）

b. The ministry shall issue regulations, which prescribe performance standards for the purposes of encouraging the safe, efficient and reliable delivery of electric power. (5.)

c. Ministers may exempt facilities that do not meet performance standards. (6.)

d. The ministry shall develop the following technical standards. (8.)

(a) safety, reliability and cost-effectiveness of generation

(b) construction of power generation equipment

(c) operating standards

(d) maintenance schedules

(e) quality of electrical equipment

e. Under the Electricity Law, the General Inspector (Chief Inspector) shall issue safety certificates, quality certificates, and skill certificates of the workers involved in the installation after inspection.

Also, if there is the danger of harm to life or equipment, the General Inspector must report to the ministry. (92.)

f. If the General Inspector acknowledges anything contrary to the Electricity Law or Electricity Rules in the inspection prescribed in Paragraph 92, the General Inspector shall report to the ministry to suspend the project. (94.)

Regulations and standards as described above have not been enacted at the present time and it was not possible to confirm on the site that the system was functioning usefully.

(3) Environmental Conservation Law 2012, Chapter 6 10.

The ministry may, with the approval of the Union Government and the Committee, stipulate the following environmental quality standards:

- suitable surface water quality standards in the usage of rivers in rivers, streams, canals, springs, marshes, swamps, lakes, reservoirs and other inland water sources of the public;
- water quality standards for coastal and estuarine areas;
- underground water quality standards;
- atmospheric quality standards;
- noise and vibration standards;
- emission standards;
- effluent standards;
- solid waste standards;
- other environmental quality standards stipulated by the Union Government.

2.2 Human Resource Development System Related to Facility Diagnosis Technology, Inspection and Maintenance Technology, etc.

A systematic human resource development system for power station staff has not been established, and most personnel are trained on the job (OJT). MOEE conducts training in facility diagnosis technology, inspection and maintenance technology, etc. at the Paunglaung training school. Staff is mainly educated in hydroelectric power plant technologies and less so in thermal power plants technologies. Of the people we interviewed, there were no power staff who could participate in the thermal power training course.

Table 2-1 shows the timetable for training held at the Paunglaung training school in October 2016. For training in thermal power plants, it was confirmed that GE lectures on thermal power generation facilities.

Table 2-1 Paunglaung Training School Training Schedule

MoEE
လျှပ်စစ်နှင့်စွမ်းအင်ဝန်ကြီးဌာန
ပေါင်းလောင်းသင်တန်းကျောင်း: PAUNGLON TRAINING SCHOOL (မူကြမ်း)
ဒုတိယညွှန်ကြားရေးမှူးများမွမ်းမံသင်တန်းအချိန်ဇယား → Dy. DIRECTORS TRAINING
(၃.၁၀.၂၀၁၆) နေ့မှ (၁၄.၁၀.၂၀၁၆) နေ့ထိ (ရက်သတ္တ (၂) ပတ်) 3/10/2016 to 14-10-2016

ရက်စွဲ	၉:၀၀ မှ ၉:၄၀ (9:00 – 9:40)	၉:၄၅ မှ ၁၀:၂၅ (9:45 – 10:25)	၁၀:၃၀ မှ ၁၁:၁၀ (10:30 – 11:10)	၁၁:၁၅ မှ ၁၁:၅၅ (11:15 – 11.55)		၁၃:၁၀ မှ ၁၃:၅၀ (13:10 – 13:50)	၁၃:၄၅ မှ ၁၄:၂၅ (13:45 – 14:25)	၁၄:၃၀ မှ ၁၅:၁၀ (14:30 – 15:10)	၁၅:၁၅ မှ ၁၅:၅၅ (15:15 – 15:55)
၃-၁၀-၂၀၁၆ (3-10-2016) (တနင်္လာနေ့)	သင်တန်းဖွင့်ပွဲ		Service Ethical (DEPP)		ထမင်းစားချိန်	Contracting (DEPP)			
၄-၁၀-၂၀၁၆ (4-10-2016) (အင်္ဂါနေ့)	Power System (DPTSC)					Power System (DPTSC)			
၅-၁၀-၂၀၁၆ (5-10-2016) (ဗုဒ္ဓဟူးနေ့)	Global Climate Change & Water Resources (DHPI)					Global Climate Change & Water Resources (DHPI)			
၆-၁၀-၂၀၁၆ (6-10-2016) (ကြာသာပတေးနေ့)	Environmental and Social Impact Assessment (REM/ MONREC)					Environmental and Social Impact Assessment (REM/ MONREC)			
၇-၁၀-၂၀၁၆ (7-10-2016) (သောကြာနေ့)	Construction Management-Machinery (DHPI)					ရေအားစက်ရုံများ၏ သိကောင်းစရာနှင့် ဓာတ်အားစနစ်ဆိုင်ရာ ဘာသာရပ် (EPGE)			
၈-၁၀-၂၀၁၆ (8-10-2016) (စနေနေ့)	စနေနေ့(ရုံးပိတ်ရက်)								
၉-၁၀-၂၀၁၆ (9-10-2016) (တနင်္ဂနွေနေ့)	တနင်္ဂနွေနေ့ (ရုံးပိတ်ရက်)								
၁၀-၁၀-၂၀၁၆ (10-10-2016) (တနင်္လာနေ့)	Renewable Energy (MOE/Science & Tech)				ထမင်းစားချိန်	Renewable Energy (MOE/Science & Tech)			
၁၁-၁၀-၂၀၁၆ (11-10-2016) (အင်္ဂါနေ့)	Thermal Plants (DEPP)					Power Generation (GE)			
၁၂-၁၀-၂၀၁၆ (12-10-2016) (ဗုဒ္ဓဟူးနေ့)	Power Generation (GE)					Power Generation (GE)			
၁၃-၁၀-၂၀၁၆ (13-10-2016) (ကြာသာပတေးနေ့)	သင်တန်းသား/သူများမှ Presentation တင်ပြခြင်း					သင်တန်းသား/သူများမှ Presentation တင်ပြခြင်း			
၁၄-၁၀-၂၀၁၆ (14-10-2016) (သောကြာနေ့)	သင်တန်းဆင်းပွဲ								

Source: Provided by EPGE

2.3 Quality Control and Safety Management System

Chapter 7 of the Electricity Law stipulates that the relevant ministries shall appoint a Chief Inspector and that he/she shall be in charge of quality control. But, as described in 2.1, related regulations and standards that stipulate quality have not been enacted, so we cannot confirm at the site how effectively quality control operations are.

2.4 Parts Procurement Management

Procurement of parts related to the operation and maintenance of power plants is managed for each project at the power plant, and there is no fixed management standard.

If the procurement amount is less than 5 million Kyat, EPGE opens competitive bidding and purchases parts with their budget. Authority for decision is stipulated as follows. (The January 2019 Foreign exchange rate is 1 Kyat = 0.07176 yen.)

- Less than 0.3 million Kyat: Plant manager
- 0.3 to 1.5 million Kyat: CE
- 1.5-3 million Kyat: EPGE Committee
- Over 3 million Kyat: MOEE

2.5 Document・Record Management

Documents and methods of record management are not defined, and there are many documents lost due to office relocation. Documents are kept in paper format, and staff cannot quickly find where documents are stored.

Chapter 3 Results of O&M System Survey of Each Power Plant

3.1 Outline of Power Plants

3.1.1 Outline of Facility

The facilities of the five thermal power plants (Thilawa, Hlawga, Ahlone, Ywama and Thaketa) and one hydropower plant (Yeywa) to be investigated in this survey are as follows.

Table 3-1 Outline of Thermal Power Plant (1)

Power Station		Thaketa	Hlawga	Ahlone
Location (Address)		9,ward,Ayayarwon Road,Thaketa power station,Thaketa,Yangon,Myanmar	161/2mile, Pyay Road, Mingaladon, Yangon, Myanmar	No.39, Kannar Road, Ahlone Township, Yangon, Myanmar
Configuration		3-3-1 CCGT	3-3-1 CCGT	3-3-1 CCGT
Plant Capacity		92MW	154.2MW	154.2MW
EPC		Marubeni- Kawasai (GT&GEN[Hitachi] , ST[Fuji] , HRSG[Kawasaki])	Marubeni- Kawasai (Boiler[Kawasaki] , Turbine[ABB])	Marubeni- Kawasai (Boiler[Kawasaki] , Turbine[ABB])
Commercial Operation Date		G T : 1990、S T : 1997	G T : 1995、1996、1996、S T : 1999	G T : 1995、1995、1995、S T : 1999
Connection to Transmission Line		Connect to Thaketa S/S (66kV⇒230kV)	Connect to Hlawga S/S（33kV）	Connect to Ahlone S/S (#1,2,3GT:33kV, ST:66kV)
Gas Turbine	Manufacture	GE	GE	GE
	Model	Frame5(PG5361)	Frame6	Frame6 PG6541B
	Design Condition	Ambient Temperature 45℃	Ambient Temperature15℃、Humidity 60%、Atmospheric Pressure 1013.25 hPa	Ambient Temperature 15℃、Humidity 60%、Atmospheric Pressure 1013.25hPa
	Output	23.915MW	38.34MW	38.34MW
	Fuel	Yadana Gas	Yadana Gas、Zawtika Gas	Yadana Gas
	Rotating Speed	5,100rpm	5,100rpm	5,100rpm
GT Generator	Manufacture	Hitachi	GEC ALSTHOM	GEC ALSTHOM
	Model	FEZBiL	T190-240	T190-240
	Output	23,915kVA	43,000kVA	43,000kVA
	Voltage	11.5kV	11kV	11kV
	Power Factor	0.8	0.8	0.8
	Rotating Speed	3000rpm	3000rpm	3000rpm
HRSG	Manufacture	Kawasaki	Kawasaki	Kawasaki
	Model	Vogt Natural Circulation	Vogt Natural Circulation Horizontal Gas Flow	Vogt Natural Circulation Horizontal Gas Flow
	Steam Flow	44.05 t/h	67.3 t/h	67.3 t/h
	Steam Temperature	470 ℃	485 ℃	485 ℃
	Steam Pressure	52.0 kg/cm2	42.9 ata	42.9 ata
	Feed Water Temperature	56.5℃	54.5 ℃	54.5 ℃
	Bypass Stack	Available	Available	Available
Steam Turbine	Manufacture	Fuji Electric	ABB	ABB
	Model	Single Casing Condensing	Inpulse,Multi-stage,Condencing	Inpulse,Multi-stage,Condencing
	Output	34.9MW	56.65 MW	56.65 MW
	Rotating Speed	3000rpm	3,000 rpm	3,000 rpm
	Steam Flow	131.69t/h	216 t/h	216 t/h
	Steam Temperature	468℃	464 ℃	464 ℃
	Steam Pressure	40.9ata	43.16 bar	43.16 bar
ST Generator	Manufacture	Fuji Electric	MEIDENSHA	MEIDENSHA
	Model	FTLR1484/55-2	TIC-AFT	TIC-AFT
	Output	43,625kVA	67,875 kVA	67,875 kVA
	Voltage	11.5kV	11kV	11kV
	Power Factor	0.8	0.8	0.8
	Roating Speed	3000rpm	3000rpm	3000rpm
Main Transformer	Manufacture	GT:Hitachi / ST:EKARAT-DAIHEN	GT:ALSTHOM / ST:MEIDEN	#1 ASIA GENERAL ELECTRIC/#2 GEC ALSTOM/ #3 ALSTHOM SHANGHI TRANSFORMER/ ST MEIDEN
	Model	Three Phase Power Transformer	GT:TTHRV / ST:BORSD-A	Oil Immersed conserator/Set-up/SF9-47500 36/BORSD-A
	Capacity	GT: 31MVA / ST:44MVA	GT:47.5MVA / ST:56/70MVA	GT: 35/47.5 / ST:56/70 MVA
	Voltage	11kV/66kV	GT:36/11kV / ST:33/11kV	GT:36/11kV ST:66/11kV
	Cooling Type	GT: ONAN / ST: ONAF	GT:ONAF / ST: ONAN/ONAF	ONAN/ONAF
Condenser	Manufacture	HOLTEC ITERNATIONAL	EDI（Evans Deakin Engineering）	EDI（Evans Deakin Engineering）
	Model	Shell and Tube Type	Shell and Tube Type	Shell and Tube Type
	Steam Flow	131.72t/h	216t/h	216t/h
	Cooling Water Flow Rate	9750m3/hr	4,165kg/s	4,165kg/s
Cooling Tower	Capacity	10000m3/h	15,340 m3/h	15,340 m3/h
	Number of Coolin Fan	4	4	4
Wastewater Treatment	Processing Capacity	120 m3/day	120 m3/day	120 m3/day
	Type	Reverse Osmosis	Reverse Osmosis	Reverse Osmosis
	Chemical	Chlorine Treatment(NaOCl)、PH Control（Na3PO4、NH4OH）、Antioxidant（Na2SO4）	Chlorine Treatment（NaOCl）、Coagulation Treatment（FeCl3)、reduction,PH Control（SBS）、 PH Control（H2SO4）	Chlorine Treatment（NaOCl）、Coagulation Treatment（FeCl3)、reduction,PH Control（SBS）、 PH Control（H2SO4）
	Designed Demineralized Water	Conductivity Less tha 10 μS/cm Silica Less than 0.5 ppm	Conductivity Less tha 10 μS/cm Silica Less than 0.5 ppm	Conductivity Less tha 10 μS/cm Silica Less than 0.5 ppm

Source: JICA study team

Table 3-2 Outline of Thermal Power Plant (2)

Power Station		Ywama			Thilawa
Location (Address)		ywama west ward,Insein Township,Ywama power plant, Yangon, Myanmar			Kyaunktan Township, Yangon, Myanmar
Configuration		GT(F5) 2 Simple Cycle	GT(M701D) 2 Simple Cycle	GT(H-25) 1-1-1 CCGT	GT: 2 Simple Cycle
Plant Capacity		36.9MW	240MW	33.4 MW	50MW
EPC		JBE	MHPS	MHPS	Sumitomo Corporation - MHPS
Commercial Operation Date		1980	2014	2004	2016
Connection to Transmission Line		Connect to 33kV Bus Distribution to each Load from 33kV Loop Bus	Connect to 230kV Bus Hlalngcharyar Line	Connect to 33kV Bus Distribution to each Load from 33kV Loop Bus	Connect to Thilawa S/S (33kV)
Gas Turbine	Manufacture	GE	MHPS	MHPS	Hitachi
	Model	Frame5	M701D	H-25(28)	H-25 C32
	Design Condition	Ambient Temperature 95F	Ambient Temperature 32.7℃	Ambient Temperature 30℃	Ambient Temperature 31℃
	Output	23.210MW	122.95MW	24MW	30.27MW
	Fuel	Yadana	Yadana	–	Yadana Gas. Zawtika Gas
	Rotating Speed	5,094rpm	3,000rpm	7,280rpm	7,258 rpm
GT Generator	Manufacture	BRUSH	Mitsubishi ELECTRIC	MEIDENSHA	BRUSH/HMA
	Model	BDAX 7084	MB-H	EP-AIT	DG215ZC-04
	Output	25,000kVA	181,820kVA	28,300kVA	39,090kVA
	Voltage	11kV	13.8kV	11kV	11kV
	Power Factor	0.8	0.85	0.85	0.8
	Rotating Speed	3000rpm	3000rpm	3000rpm	1500rpm
HRSG	Manufacture	–	–	BABCOCK HITACHI K.K.	–
	Model	–	–	Single Pressure, Horizontal Gas Flow	–
	Steam Flow	–	–	42.9 t/h	–
	Steam Temperature	–	–	469 ℃	–
	Steam Pressure	–	–	4.0 Mpa	–
	Feed Water Temperature	–	–	unknown	–
	Bypass Stack	–	–	N/A	–
Steam Turbine	Manufacture	–	–	Shin-Nippon Zoki	–
	Model	–	–	C6-R7-R	–
	Output	–	–	9.4MW	–
	Rotating Speed	–	–	7778rpm	–
	Steam Flow	–	–	unknown	–
	Steam Temperature	–	–	466 ℃	–
	Steam Pressure	–	–	3.7MPa	–
ST Generator	Manufacture	–	–	MEIDENSHA	–
	Model	–	–	EP-AFT	–
	Output	–	–	10,500kVA	–
	Voltage	–	–	11kV	–
	Power Factor	–	–	0.9	–
	Rotating Speed	–	–	1500rpm	–
Main Transformer	Manufacture	YORKSHIRE ELECTRIC	Mitsubishi ELECTRIC	FORTUNE ELECTRIC	HYOSUNG
	Model	Three Phase Power Transformer	SRB Three Phase Shell Type	SRB Three Phase Core Type	Three Phase Power Transformer
	Capacity	18.75/25 MVA	104/138/172 MVA	28 MVA	51/51/3MVA
	Voltage	33/11 kV	241.5/13.8 kV	33/11 kV	33/11/6.75kV
	Cooling Type	ONAN/ONAF	OA/FA/FA OA:Self Cooled, FA:Forced Air	ONAF	ONAF
Condenser	Manufacture	–	–	HITACHI	–
	Model	–	–	Shell and Tube Type	–
	Steam Flow	–	–	unknown	–
	Cooling Water Flow Rate	–	–	2060m3/h	–
Cooling Tower	Capacity	–	–	460,000kg/h	–
	Number of Coolin Fan	–	–	3	–
Wastewater Treatment	Processing Capacity	–	–	–	480 m3/day
	Type	–	–	–	Reverse Osmosis
	Chemical	–	–	–	-
	Designed Demineralized Water	–	–	–	TDS 2.0 mg/L pH 7～8.5 Conductivity Less than 10 μS/cm

Source: JICA study team

Table 3-3 Outline of Hydropower Station

Power Station		Yeywa
Location (Address)		Yeyemen village,Kyaukse Township,Mandalay Division,Myanmar
Configuration		Turbine 4 unit 、Dam Type
Plant Capacity		3550 GWh (Annual Power Generation)
EPC		Electromechanical:CITIC & CCYW Hydraulic Steel Structures:CITIC&CCYW、CNEEC Transmision Lines&S/S:CHMC
Commercial Operation Date		2010
Connection to Transmission Line		Connect to 230kV Belin, Meiktila Line
Hydro	Maximum Amount of Power Generation	780[MWh]@Sep.2014
	Annual Energy Production	3550[GWh] / 2581[GWh]
	Type	Dam Type
	Catchment Area	2,780,00m3
	River	Myitnge River
	Maximum Amount of Water	840m3/s
	Dam Type	RCC dam (Length/Height=690/132m)
	Effective Water Head	91m
Turbine	Type	Francis
	Manufacture	SINOHYDRO
	Model	HLV180-LJ-492
	Turbine size	49.20 dm
	Raiting Speed	142.86rpm
	Rated Water Discharge	213.7m3 / s
	Rated of Rotation(Upper Side)	Clockwise
	Rated Water Head	91.7 m
	Minimum Water Head	69.0m
	Maximum Water Head	106.3m
	Rated Output	178.5 MW
	Maximum Output	199.4MW
	Instantaneous Maximum Output	219.4 MW
	Maximum Intank Level	196.5m
	Maximum Discharge Level	95.8m
Generator	Manufacture	SINOHYDRO
	Model	1DH7951-3WE21-Z
	Rated Output	230 MVA
	Maximum Output	255 MVA
	Rated Voltage	16 kV
	Power Factor	0.85
	Ratede Current	8299 A
	Frequency	50 Hz
	Rated Speed	142.9 rpm
	Over Speed	285.0 rpm
	Elevation (Above Sea Level)	84.36 m
	Rated Exciting Current	2444 A
	No Load Rated Exciting Current	1380 A
	Rated Exciting Voltage	130℃(at 234 V)
	Exciting Type	Static Excitation
	Winding Temperature at Rated Output	Stator/Rotor 80/90℃
	Winding Temperature at Maximum Output	Stator/Rotor 100/115℃

Source: JICA study team

It was confirmed that there is no chemical analysis room in the power station to conduct water quality, lubricant, control oil, fuel management, etc.

Regarding the pure water system, it was confirmed that some power plants had buildings (including simple type with roof only) for the control system, and the water quality analysis was carried out with portable instruments.

The operation condition of each power plant during the first site survey is as shown in Table 3-4.

Table 3-4 Operating Status of Each Power Plant

Project	Type		COD	Installed Capacity(MW)		Conditions at the first site survey (2018.Aug to Sep)		
				Unit	subtotal			
Thaketa CCGT	#1GT	F5 3on1	1990	19	92	0MW	0MW	Stop in rainy season（Dispatching)
	#2GT			19		0MW		Due to heavy damage of IGV (2015.11 -)
	#3GT			19		0MW		Stop in rainy season（Dispatching)
	ST		1997	35		0MW		ST, GEN stopped due to bearing damage (Down time unknown)
Ywama GT	#1GT	F5	1980	18.45	36.9	0MW	8MW	During overhaul inspection (Corresponding to compressor damage after Upgrading)
	#2GT	F5		18.45		8MW		Output limitation due to rainy season（Dispatching)
	GT	H25	2004	24	33.4	0MW	0MW	Due to 2^{nd} stage rotor blade damage (2014 -)
	ST			9.4		0MW		According to the above
	#1GT	M701D	2014	120	240	0MW	80MW	Due to compressor surging damage (2018.7 -)
	#2GT	M701D	2014	120		80MW		GEN Bearing metal damage due to temperature rise (Down time unknown)
Hlawga CCGT	#1GT	F6 3on1	1996	33.3	154.2	22MW	51MW	Output limitation due to rainy season（Dispatching)
	#2GT			33.3		22MW		Output limitation due to rainy season（Dispatching)
	#3GT			33.3		0MW		Stop due to generator ground fault (Time unknown)
	ST		1999	54.3		7MW		ST partial load with GT partial load
Ahlone CCGT	#1GT	F6 3on1	1995	33.3	154.2	20MW	68MW	Output limitation due to rainy season（Dispatching)
	#2GT			33.3		23MW		Output limitation due to rainy season（Dispatching)
	#3GT			33.3		25MW		Output limitation due to rainy season（Dispatching)
	ST		1997	54.3		0MW		# 1 ~ 3 HRSG due to tube leakage (2018.3 -)
Thilawa GT	#1GT	H25×2	2015	25	50	0MW	15MW	Stop in rainy season（Dispatching)
	#2GT			25		15MW		Output limitation due to rainy season（Dispatching)
Yeywa	Hydro Fransis		2010	197.5	790	167MW	670MW	Dispatching
				197.5		177MW		Dispatching
				197.5		159MW		Dispatching
				197.5		167MW		Dispatching

Source: JICA study team

3.1.2 Outline of Operation System

The number of staff of each thermal power plant is as follows.

In Japan, maintenance of the substation nearby a power station is carried out by the transmission and distribution department, but in Myanmar, it is carried out by the power generation department (by power station staff) .

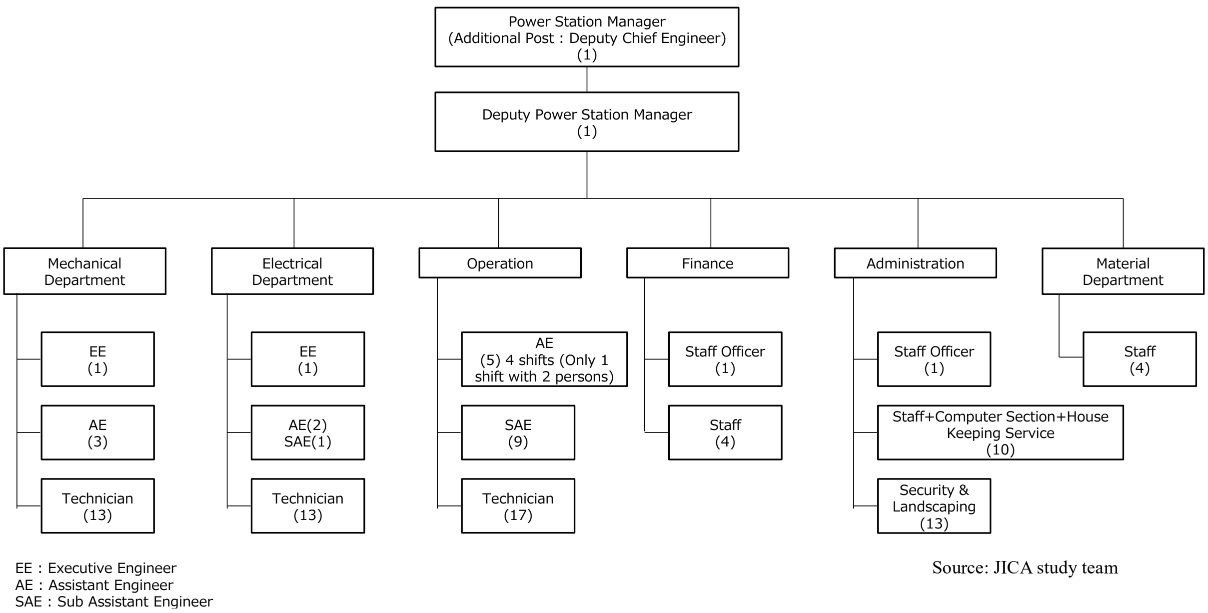
In Japan, although it depends on the output / equipment configuration, in the case of a 3-3-1 CCGT × 2 unit configuration, the total number of staff is about 110.

Table 3-5 Power Station Management System

Power Station	Thaketa	Hlawga	Ahlone	Ywama			Thilawa
Configuration	3-3-1 CCGT	3-3-1 CCGT	3-3-1 CCGT	GT(F5) Simple Cycle 2 unit	GT(M701D) Simple Cycle 2 unit	GT(H-25) 1-1-1 CCGT	GT (H25) Simple Cycle 2 unit
Plant Capacity	92MW	154.2MW	154.2MW	36.9MW	240MW	33.4 MW	50MW
Substation Maintenance	Included	Not Included	Not Included	Included			Included
Number of Staff	107	100	90	151			92
Shift	2 shifts 4 teams	2 shifts 4 teams	2 shifts 4 teams	2 shifts 4 teams			2 shifts 4 teams
Number of Staff / Shift	8～9	8	8～10	16			10

Source: JICA study team

As an example, the organization chart of the Hlawga power station is shown below.



Source: JICA study team

Fig. 3-1 Organization Chart of Hlawga Power Station

The power station consists of maintenance departments (mechanical and electrical), operation department, finance department, administration department, and materials department, with the power station manager as the responsible person.

The division of responsibilities is shown below. Although the organization chart differs somewhat depending on each power plant, the organization system can be regarded as almost the same.

Table 3-6 Division of Responsibilities

Division	Section		Kind of Work
Maintenance	Mechanical		Mechanical Equipment Maintenance checking & Filling for water supply, oil supply, vibration iinspection, etc. Repair
	Electrical		Electrical Equipment Maintenance Transformer inspection, S/Y inspection, battery inspection for UPS, battery bank inspection, security lighting, etc. Repair
Operation	Operation	AE(1)	Operation Management
		SAE(2)or(3)	Operation & Monitoring for GT, STG and Boiler
		Technician(4)or(5)	Site Work (BOP) / Site data recording and equipment patrols
Finance			Salaries & Wages Budgets & Drawing limit Pay Roll & Pention
Administration	Office & Other staff		Administrative Management
	Computer Section		Recording and reporting of official data, Recording of equipment data
	House Keeping Service		Housekeeping service for control room, meeting rooms, offices, etc.
	Security & Landscaping		Security for main gate, water intake and residential gate
Material	Material Planning		Receiving, issuing, stocking, monthly reporting

Source: JICA study team

3.1.3 Status of O&M

(1) Status of O&M at Thermal Power Plants

Manuals related to the operation and maintenance of power plants have not been prepared, so the power station staff is operating and maintaining power plants by referring to the manufacturer’s manual included in the construction documents.

Regarding operation and maintenance training, in the hydropower department, it is being implemented at the training center (Paunglaung), but in the thermal power division, the training center's facilities are not sufficient, so there is only OJT (on the job training) by the chief engineer. For this reason, opportunities for skill acquisition and skill improvement are limited.

Records of skill level and training achievements are not managed, as the power station manager confirms the skill and appoints the operators.

There are no manuals and training for power station staff is not sufficiently implemented. For this reason, due to a lack of technical capability, proper operation and maintenance has not been carried out, resulting in equipment damage, and output and efficiency degradation.

Operation data, maintenance, and accident response are recorded in the logbook and reported to EPGE. However, regarding maintenance and accident response, since the items and the events to be reported are not clearly stipulated, the maintenance manager or the recorder judges each event separately.

For this reason, analysis of the causes of accidents and countermeasures have not been sufficiently implemented.

In the [Dispatch Optimization] program, upon receiving the invitation from the EPGE for improvement consideration, visits to the National Control Center(NCC) and Generation Control Center(GCC) were made while at the EPGE headquarters.

As the result of visits, we confirmed that the EPGE's NCC is fully equipped with state of the art control system technology, but, on the other hand, their GCC is operating by issuing and managing hand-written dispatch signals. We also confirmed that the same optimized digital dispatch signal system as being used in Japan has not been installed yet at the EPGE.

(2) Status of O&M at Hydropower Plants

The Yeywa power station is an important base load power source that supplies electricity in the dry season by using the water stored in a reservoir with a storage capacity of 1.5 billion m^3 in the rainy season.

However, from the commencement of operation to the 2016, the Yeywa power station had supplied 2,637 GWh of electricity on average annually, which is significantly lower (equivalent to about 75%) than the plant's designed average annual energy production of 3,550 GWh.

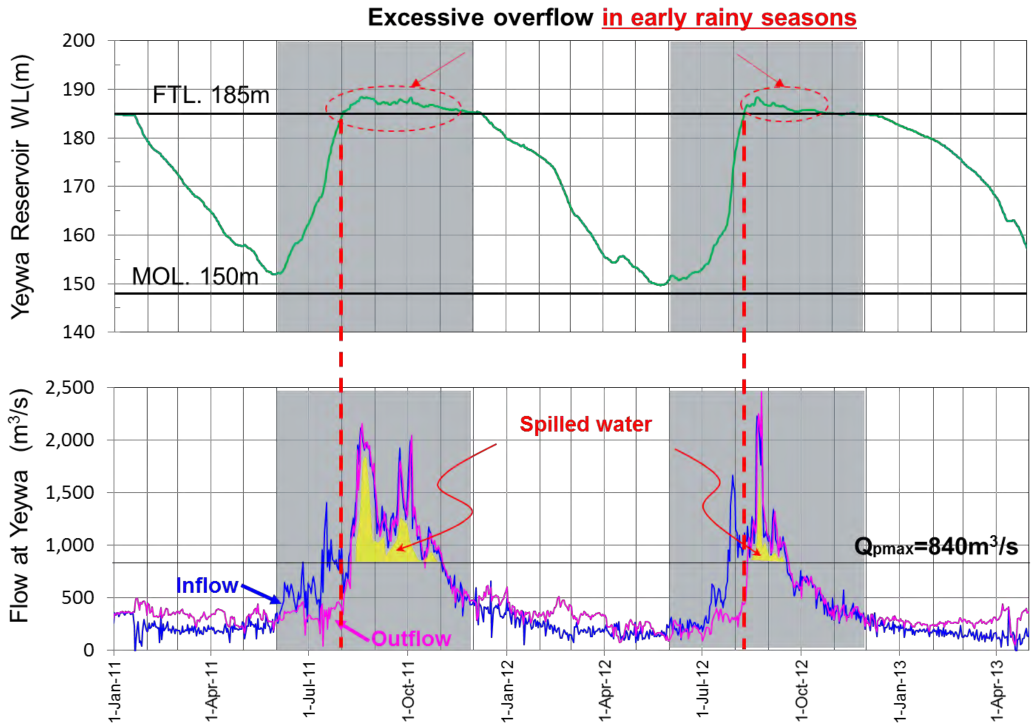
There are two reasons why electricity generation is low compared to the design value as follows.

a. Water discharge from the power plant is frequently limited due to the capacity shortage of the transmission line.
b. Reservoir operation is not properly and efficiently carried out.

The capacity of the transmission line is being improved mainly by the government. Therefore, the improvement of the transmission line is outside the scope of this report. More efficient reservoir operation is studied in this report together with the forecasting system for the further improvement of the reservoir operation.

Fig. 3-2 shows the reservoir water level and the inflow and outflow of the Yeywa dam from January 2011 to April 2013.

The vertical axis of the upper figure and lower figure shows the dam water level and the amount of water flow respectively, and the horizontal axis is a time line. The green line in the upper figure shows the seasonal fluctuation in water level. The blue line and pink line in the lower figure show the inflow amount and the outflow amount, respectively.



Source: JICA study team

Fig. 3-2 Current Reservoir Operation

Under the current operation practices, the water discharge from the power plant is limited so that the reservoir water level can rise to the full tank level (FTL) as soon as possible at the beginning of the rainy season from June to August. It means that power generation is cut back during this period.

As a result, the reservoir water level reaches the FTL of EL 185 m within three months, so the Yeywa power plant can generate electricity with a high water level from August.

As the inflow amount frequently exceeds the maximum plant discharge (Qmax = 840m^3/s) at Yeywa from August to November, a considerable amount of water is inevitably discharged from the spillway gate.

From December, the reservoir water level is lowered by discharging the water stored in the reservoir until the beginning of the rainy season. The water level does not fall to the minimum operation level (MOL) EL 150 m even in the beginning of the rainy season. It means that the water in the reservoir is not fully used for power generation during the dry season.

It is frequent that the inflow amount becomes more than Qmax in the rainy season at the Yeywa dam.

In the case that the reservoir water level always maintains the FTL, an inflow amount greater than Qmax, as shown by the yellow hatching in Fig. 3-2, will inevitably cause the discharge from the spillway gate. It results in the reduction of the total power generation.

It is necessary to keep the water level lower than the current operation level and ensure the room to store water in the case of floods in order to reduce spilled water.

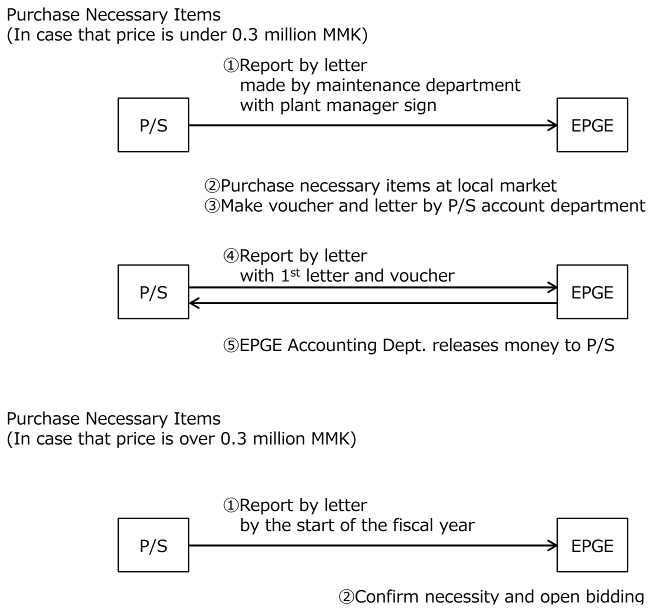
It is possible to increase electric power generation by reducing spilled water and using the water more efficiently.

3.1.4 Status of Parts Procurement

For necessary parts and consumable supplies such as chemicals and lubricants, the procurement department of the power plant submits a request list to EPGE. As the budget is managed by the EPGE head office, basically it is necessary to report or get approval for all procurements. (Less than 0.3 million MMK can be procured under the authority of the power station manager.)

Regarding the lubricants required at all power plants, EPGE purchases them collectively and distributes them to each power plant. When placing an order, specify the required specification and bid it. Currently, a lube oil made by Michang of Korea is used.

Rules for quality control (confirmation) of purchased or delivered goods are not stipulated, and quality is not confirmed.



Source: JICA study team

Fig. 3-3 Outline of Material Procurement

3.2 Daily Operation

3.2.1 Operation System

As shown in 3.1.2 Outline of Operation System (Table 3-5 Power Station Management System), the daily operation is based on a 2-shift, 4-team system. Shift time is based on a daytime shift from 8: 00 to 17: 00 and night shift from 17: 00 to 8: 00, and decided at each power plant.

With regard to the Thilawa power station, an employee dormitory is currently being constructed, and operation will be changed from a 1-shift system to a 2-shift system after completion.

The operator records the power generation amount, current, voltage, vibration, and temperature of each part in handwriting on the operation data sheet every hour using the monitoring screen of the central control room. Staff members are located on site so that the values of the local instruments that are not read in the control device can be recorded periodically (hourly).

For BOP, staff are also located to record data on water quality such as pH and conductivity.

As described, the role of operators and field inspectors is mainly to collect records.

3.2.2 Quantitative Records Related to Power Generation

Daily, monthly, and annual reports are submitted to EPGE regarding the amount of electricity generation and gas consumption, but thermal efficiency is not managed using the recorded data.

The daily data (MW, MWh, gas pressure, gas consumption) of the thermal power plants in Yangon is collected at the Hlawga power plant and reported to the EPGE by FAX.

Regarding the format for recording operation data, there is a format created by each power station manager in consideration of the data to be recorded.

At some power plants, the recording formats that manufacturers created at the time of construction were used. When recommended by the manufacturer, management values, design values, etc. are stated in the recording format.

Logbooks and records are not digitized; they are kept in paper format. Some power plants also lost many documents due to Cyclone Nargis in 2008.

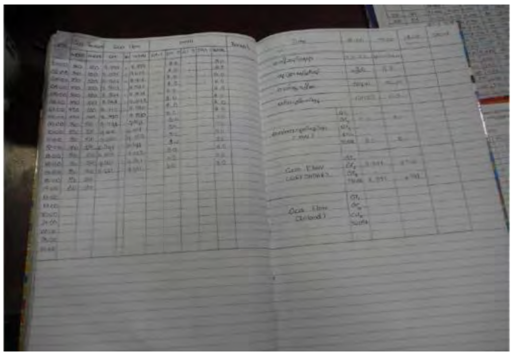
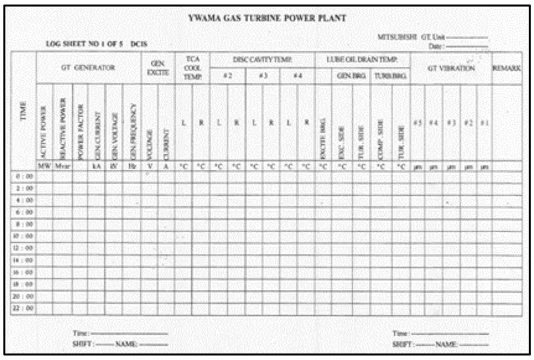


Fig. 3-4 Logbook



Source: Provided by EPGE

Fig. 3-5 Recording Format

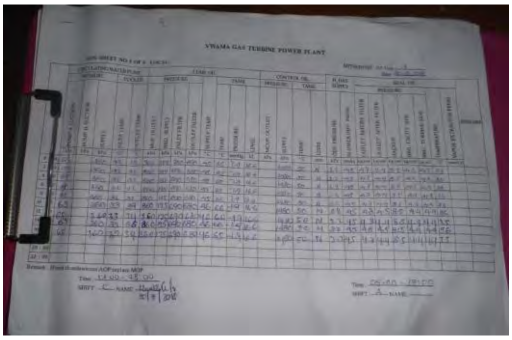
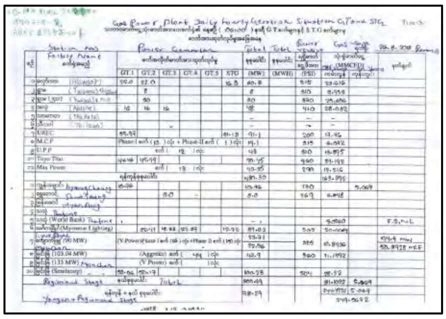


Fig. 3-6 Record of Power Generation



Source: Provided by EPGE

Fig. 3-7 Report of Power Plants in Yangon

3.2.3 Record of the Implementation Status of O&M

The operation information is recorded in each logbook.

The format of the logbook is not specifically defined, and general notes are used at each power station to record necessary information.

Table 3-7 Type of Logbook

Type	Contents
Operation Logbook	It is used for operators to take over between shifts. Shift members, Successors and the Instructions from LDC At the Ywama power station where the generator is of hydrogen gas cooling type, the purity of hydrogen gas is described as an important matter.
Maintenance Logbook	The maintenance department records defect events and repair results. Details on repair content, etc. are not included. Even with the same logbook, the criteria for items to be described are different depending on the person in charge. Therefore, there are cases where the details of the defect contents are not described.
Inspection Logbook	Inspection results are recorded. Power output, oil level, oil temperature, presence / absence of oil leaks, winding temperature, number of cooling fans in operation, GCB gas pressure, presence / absence of gas leaks, etc. * Depending on the power plant, there are cases where the logbook is used separately from the operation data recording sheet.

Source: JICA study team

3.2.4 Spare Parts Management

A certain amount of spare parts are stored in a warehouse on each site, and a stock list (Excel data or paper) is maintained.

However, no inventory management system is used. As a result, old parts and new parts are stored together, and are not arranged neatly.

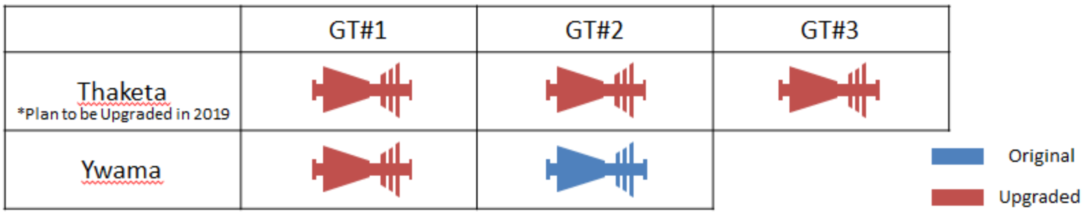
Table 3-8 shows the inventory management of expensive gas turbine hot gas parts. It is highly possible that extra costs are entailed.

Because the parts arrangement plan is not properly based on the expected operation in the medium- or long-term after rehabilitation or upgrade of power generation facilities as shown in Fig. 3-8 and Fig. 3-9, incompatible original parts are stored currently as idle inventory goods.

Table 3-8 GT Hot Parts Management Status

	Quantity Management	Life Management	Compatibility Management
GT Hot Parts Management	Not good	Not managed	Not good
Problem	Quantities are managed at each power plant. The usability and quantity of removed parts are unknown.	The accumulated operation hours of each part is not managed, so EPGE is not sure whether the parts can be repaired or not. It is possible that repairable parts may be disposed of wastefully.	Original hot gas parts are stocked for turbines whose efficiency and output have been upgraded. Compatibility management is unclear.

Source: JICA study team

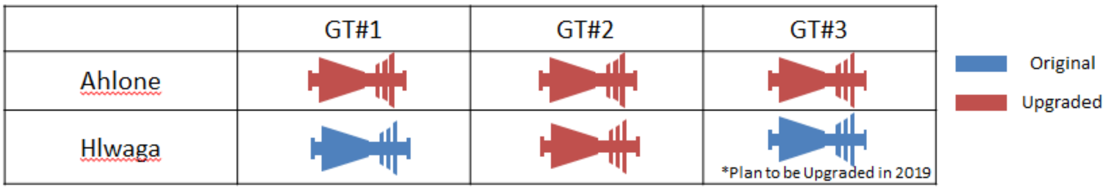


	Thaketa Stock	Ywama Stock	Total Original	Total Upgraded
Combustion Liner	Original	Original	36	0
Transition Piece	Original	Original	52	0
Turbine 1 Nozzle		Original	10	0
Turbine 2 Nozzle			0	0
Turbine 1 Bucket	Original	Original	240	0
Turbine 2 Bucket	Original		90	0
Turbine 1 Shroud Block		Original	36	0
Turbine 2 Shroud Block		Original	30	0

Dead Stock !! No Spare !!

Source: JICA study team

Fig. 3-8 Upgrade/Inventory Specification Information on Frame 5 Gas Turbine



	Ahlone Stock	Hlawga Stock	Total Original	Total Upgraded
Combustion Liner	Original	Original	18	0
Transition Piece			0	0
Turbine 1 Nozzle			0	0
Turbine 2 Nozzle	Original		16	0
Turbine 3 Nozzle			0	0
Turbine 1 Bucket	Upgraded	Original	92	92
Turbine 2 Bucket	Upgraded	Original	92	92
Turbine 3 Bucket		Original	92	0
Turbine 1 Shroud Block	Original		18	0
Turbine 2 Shroud Block	Original		36	0
Turbine 3 Shroud Block	Original	Original	45	0

Dead Stock !!

Source: JICA study team

Fig. 3-9 Upgrade/Inventory Specification Information on Frame 6 Gas Turbine

The Head Office tracks the stock of each power plant (because each power plant submits the stock list to the Head Office for auditing once in every 6 months), and arranges parts among power plants as necessary. When new parts become necessary, each power plant prepares the required parts list, and reports it to the

Head Office. Taking the budget into consideration, the Managing Director with the Head Office/EPGE makes the final decision to purchase required parts.

Each power plant has some inventory of third parties, which may be a contributing factor in the deterioration of the operation ratio.

စဉ်	ပစ္စည်းကုဒ်	ပစ္စည်းအမျိုးအမည်	ရေတွက်ပုံ	ယခင်လ လက်ကျန်	ရရှိ	သုံးစွဲ	လက်ကျန်	Contract No.	မှတ်ချက်
150	GTS/205	COMPOUND , ANTI - SEIZE (P,No -287A1397P001)	EA	6			6 ✓	Contract - 9/EPGE(GT) 16-17	[illegible]
151	GTS/205(A)	JOINTING COMPOUND SET (P,No-S018711115)	ST	2			2 ✓	-"-	-"-
152	GTS/205(B)	XFIRE TUBE MS6001 , FEMALE (P,No-178C6050P002)	EA	10			10 ✓	-"-	-"-
153	GTS/205(C)	6001B TRANS PIECE (P,No-101E2572G007)	EA	10			10 ✓	-"-	-"-
154	GTS/205(D)	CAP & LNR MS6001 (P,No-899E0116G024)	EA	4			4 ✓	-"-	-"-
155	GTS/205(E)	CAP & LNR MS6001 (P,No-899E0116G025)	EA	2			2 ✓	-"-	-"-
156	GTS/205(F)	CAP & LNR MS6001 (P,No-899E0116G026)	EA	3			3 ✓	-"-	-"-
157	GTS/205(G)	CAP & LNR MS6001 (P,No-899E0116G027)	EA	1			1 ✓	-"-	-"-
158	GTS/205(H)	SHROUD SET , 6001 STG1 F6B (P,No-329A3228G004)	ST	2			2 ✓	-"-	-"-
159	GTS/205(I)	SHROUD SET , 6001 2ND STG (P,No-329A3229G002)	ST	2			2 ✓	-"-	-"-
160	GTS/205(J)	SHROUD SET , 6001 3RD STG (P,No-329A3230G002)	ST	2			2 ✓	-"-	-"-
161	GTS/205(K)	SCREW , 12PT ALY STL (P, No-N733BP35032)	EA	10			10 ✓	-"-	-"-

Source: Provided by EPGE

Fig. 3-10 Stock List

Fig. 3-11 Parts Warehouse

3.2.5 Actions Against Events/Abnormalities and Record Management

When an event occurs, the power plant sends the event bulletin (power generation error situation) to the Head Office, the Head Office permits the shutdown work, and then the power plant starts actions against the event.

These processes are communicated on a paper basis, and the information is not accumulated. In addition, since the causes of each problems are not investigated, similar events occur repeatedly.

Possible causes are as follows.

1) The PDCA for operation and maintenance improvement is not managed.
2) The operation and maintenance budget is inadequate, and the approval process is complicated.
3) Due to an electricity shortage, shutdown for the periodic inspection of power generation facilities is not approved.

When big trouble occurs, the General Manager of other power plants may visit the plant where the big trouble occurred, confirm the situation and share the information. Because cause analysis is inadequate, however, occurrence of similar events cannot be prevented.

In addition, it is prohibited by the Head Office that each power plant directly communicate with the original equipment manufacturer. (In some opinions, this situation is affected by the period when communication with the original equipment manufacturer was prohibited due to sanctions.) The Head Office communicates with the original equipment manufacturer as necessary.

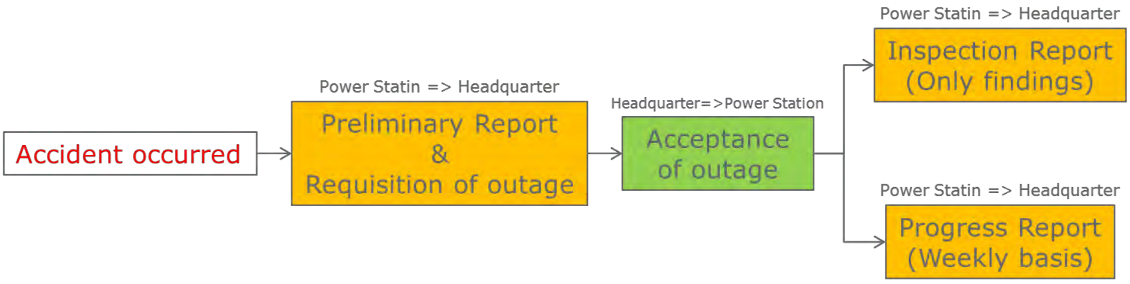
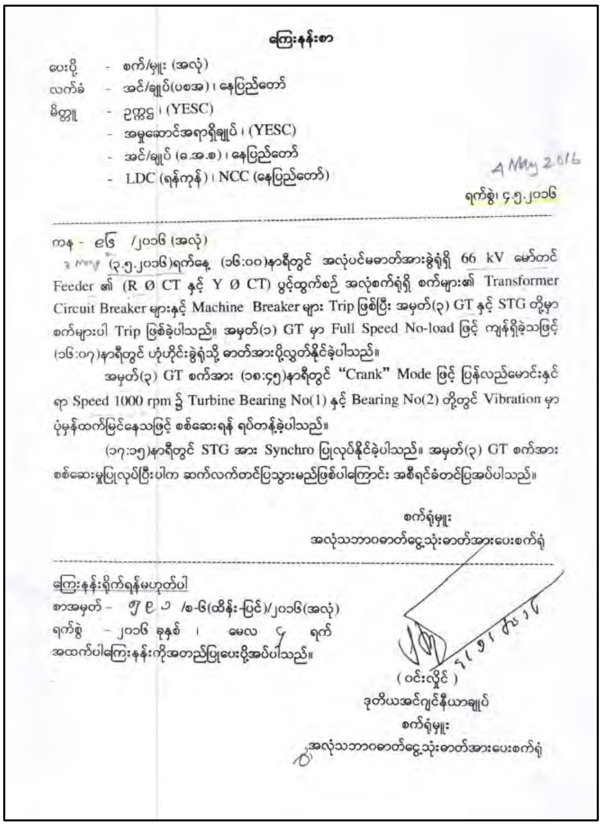


Fig. 3-12 Internal Procedure for the Accidental Report

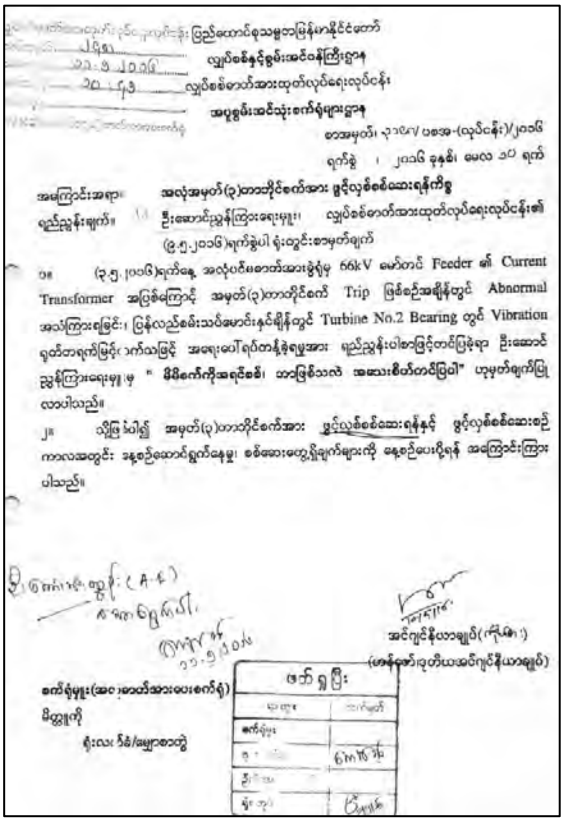
Source: JICA study team

Attached below is the letter issued for the countermeasures against shaft high vibrations that actually occurred in gas turbine No. 3 at the Ahlone power plant.



Source: Provided by EPGE

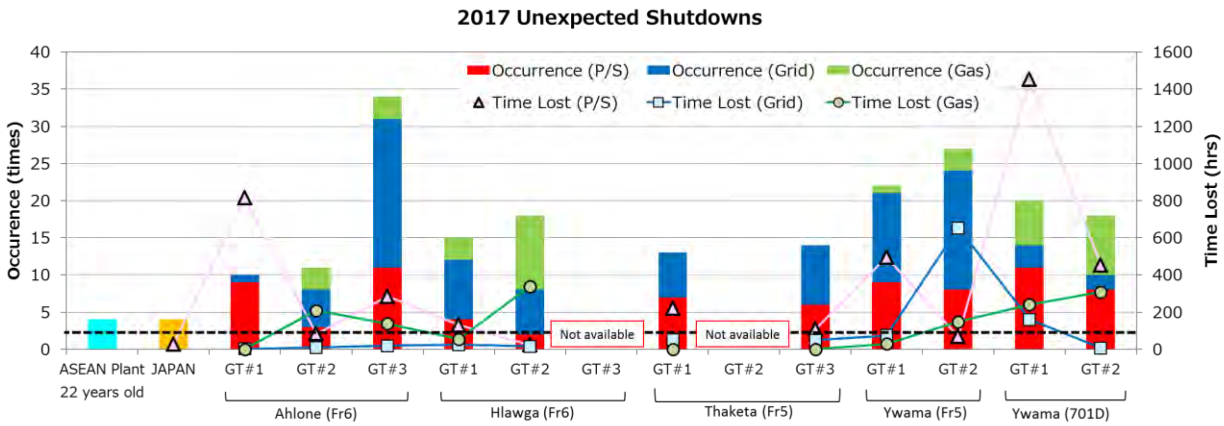
Fig. 3-13 Accident Quick Report (Power Plant=>HQ)



Source: Provided by EPGE

Fig. 3-14 Permission Report (HQ=>Power Plant)

Fig. 3-15 shows a comparison of the unexpected shutdown frequency and time between Japan and ASEAN. As shown in this figure, unexpected shutdowns occur frequently in Myanmar, compared to that in the ASEAN area and Japan.



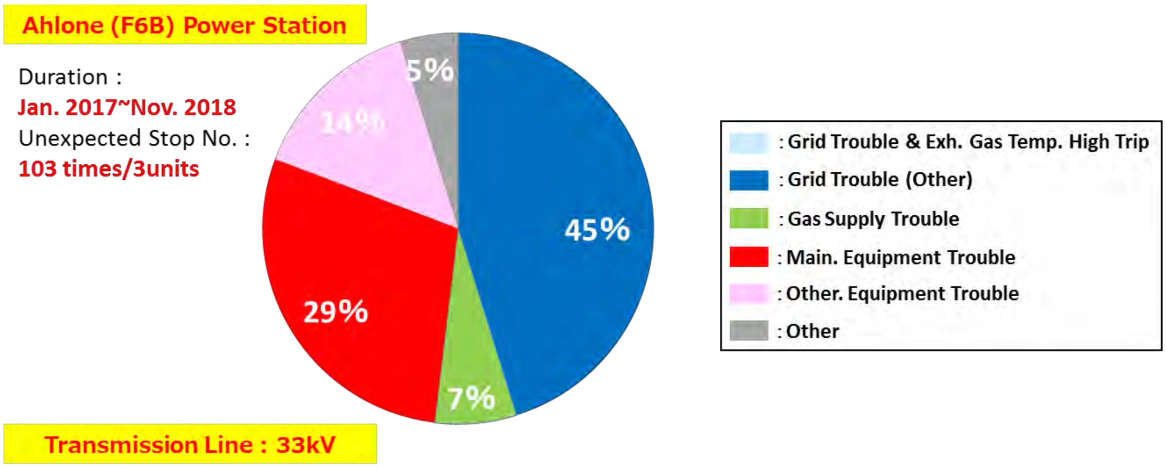
Source: JICA study team

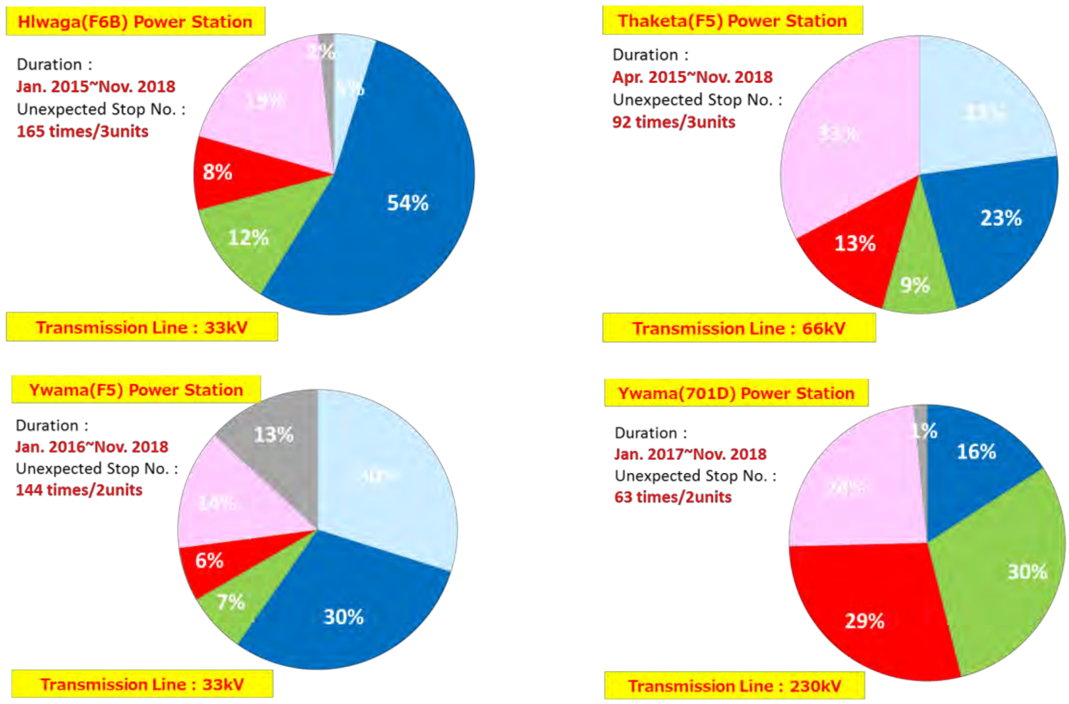
Fig. 3-15 Unexpected Power Plant Shutdown and Shutdown Period

The below pie charts show the analysis results of unexpected shutdown factors at each power plant.

In a comprehensive evaluation of all power plants, approximately 40% of all unexpected shutdowns were caused by inadequate operation and maintenance at the power plants.

Other major factors are environmental disturbances. Because an unexpected shutdown in any power plant may lead to power grid problem, it is confirmed that O&M must be urgently improved.





Source: JICA study team

Fig. 3-16 Analysis of Factors at Five Power Plants Owned by EPGE

3.2.6 Environmental Management

The Ministry of Natural Resources and Environmental Conservation (MONREC) has prepared guidelines referring to the IFC standards, and these guidelines will be applied in the future when a gas power plant is newly constructed. However, the existing thermal power plants have no regulatory values.

As a result of investigating each power station, it was confirmed that monitoring and management of exhaust gas were not carried out.

At the Tygit coal power plant, exhaust gas is being monitored to respond to people in the surrounding area that are concerned about the environmental impact, and the emission value is disclosed to the public at the guardian office.

3.2.7 Entry Management

The entry management of visitors at power plants is carried out by record books and security cards.

For staff members, employee cards are confirmed at the time of entry, but no confirmation has been made upon exiting.

Fig. 3-17 Security Card

Fig. 3-18 Guardian Office（Thilawa P/S）

At some power plants such as the Thilawa power station, the keys are managed by using a control book, and access to the transformer and the gas compressor area is restricted.
However, at other power plants, there is no identification of hazardous areas such as turbine lube oil facilities, GIS, NG stations, etc., and consciousness of safety management is low.

Fig. 3-19 Key Management BOX

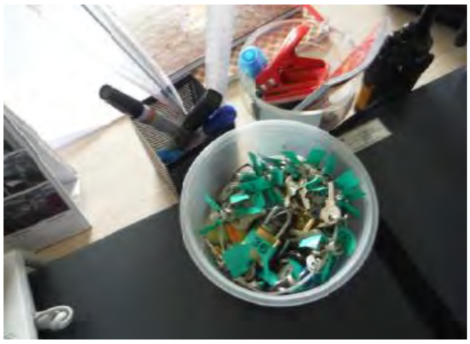


Fig. 3-20 Status of Key Management

In addition, security cameras are installed at the Thilawa power station, and it is possible to monitor the main gate and other places from the central control room.

Fig. 3-21 Surveillance Camera Monitoring Screen (Thilawa P/S)

3.3 Periodic Maintenance

3.3.1 Maintenance Plan Management

Periodic maintenance plans (implementation items, timing) of GT, ST and HRSG are reviewed by the power plant based on the schedule and plan recommended by OEM and reported to EPGE. Based on the contents reported by the power plant, EPGE decides the content and time of inspection in consideration of electricity demand and budget.

However, due to budget shortfalls, maintenance cannot be implemented according to the schedule and scope recommended by OEM.

Regarding BOP, periodic inspections are not conducted, as breakdown maintenance is carried out.

The repair results are not adequately recorded and record management is not sufficient.

3.3.2 Implementation Status

The inspection cycle recommended by the original equipment manufacturer is not observed due to budget deficits as described in Subsection 3.3.1. As a result, it is confirmed that a large event (that requires part replacement due to rotary machine damage, etc.) occurs approximately 10 times approximately every 10 to 15 years after the start of operation.

It is found in the periodic inspection result list shown below that periodic part replacement and maintenance are not performed even in gas turbine facilities requiring periodic part replacement, and that such omission of periodic part replacement/maintenance may lead to unexpected serious damage.

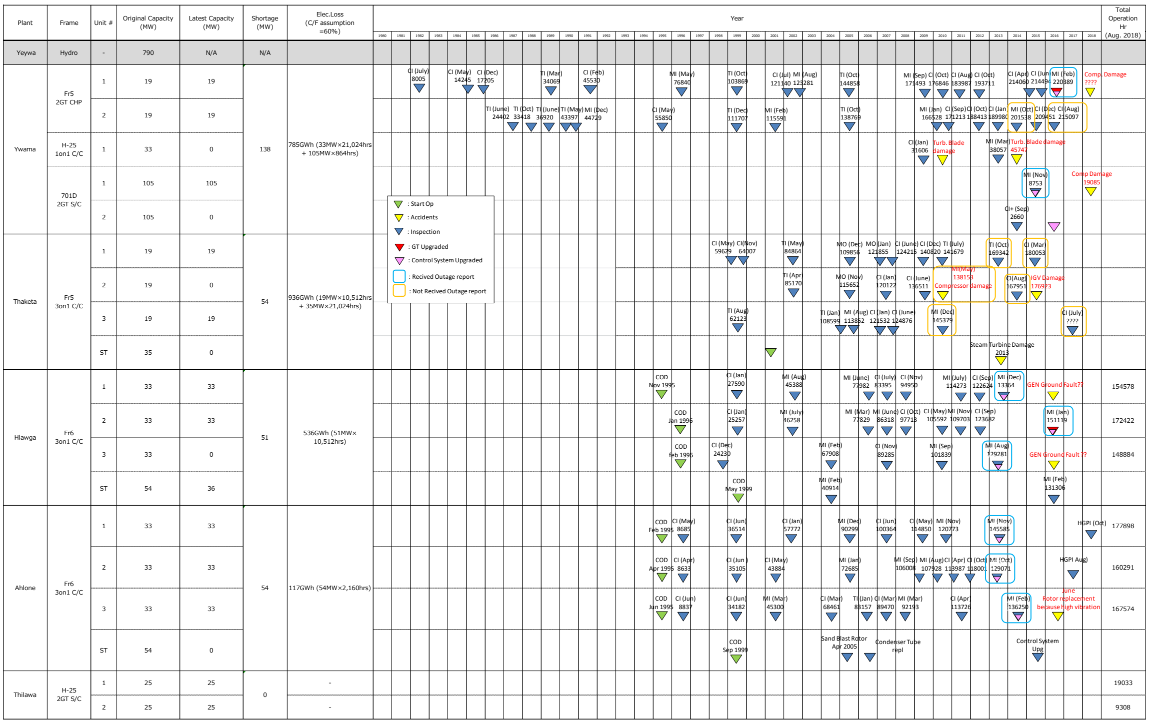
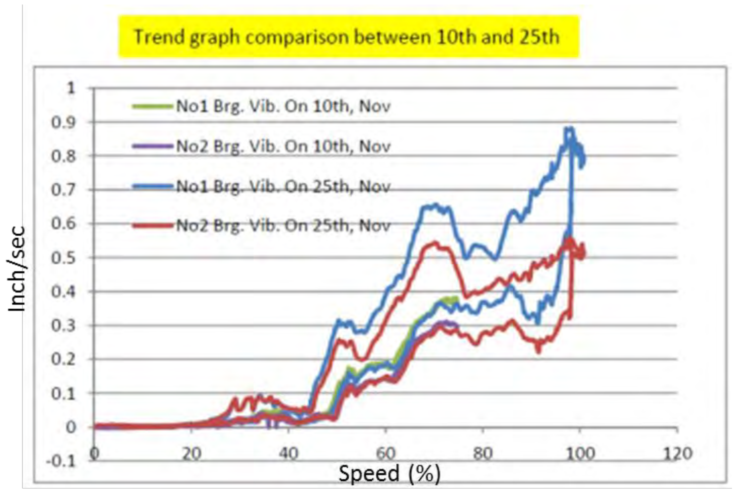


Fig. 3-22 Planned Maintenance Inspection Results

Source: JICA study team

Inspection works in medium- or small-scale (Fr5 or Fr6 class) thermal power plants are performed directly by EPGE staff stationed at the corresponding power plant and EPGE staff dispatched for help from other power plants.
Performance improvement works, rehabilitation works and periodic inspection works in large-scale (701D) thermal power plants (such as the Ywama power plant) are outsourced to the original equipment manufacturer or a third-party institution.

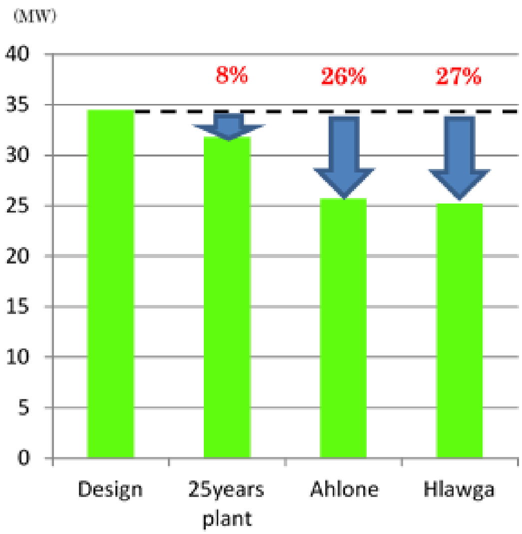
At the Ywama power plant (Frame 5), the maintenance work was executed using a gas turbine rotor repaired by a third party. As a result, shaft vibrations became high, and the plant had to be shut down for a long time (as of December 2018). It is considered that the operation and maintenance quality is deteriorated due to the adoption of third parties.



Source: JICA study team

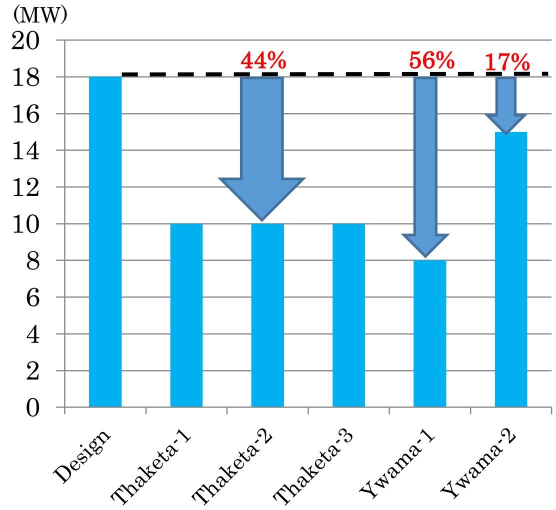
Fig. 3-23 GT Vibration Issue at Ywama Power Plant

Some outstanding output decreases and efficiency losses are confirmed to be caused by the absence of periodic maintenance and inspection. There are concerns related to tight budgets due to power generation opportunity losses caused by output decreases and fuel cost increases resulting from reduced efficiency.



Source: JICA study team

Fig. 3-24 Frame 6 Output Decrease



Source: JICA study team

Fig. 3-25 Frame 5 Output Decrease

3.3.3 **Initiatives for Continuous Improvement**

After the periodic inspection, the power plant submits the report to EPGE. EPGE then considers the items necessary for the next periodic inspection based on the contents.

When an OEM or a third party (Ethos, GE, etc.) conducts a periodic inspection or replaces a control system, a detailed report including various data was prepared by the manufacturer and reported to EPGE. However, when the periodic inspection is carried out only with the staff from EPGE, detailed records are not prepared and there is no accumulated data, so quantitative analysis and investigation cannot be carried out.

The table of contents of the report prepared by the manufacturer is shown below.

Detailed reports are made for each item.

3.3.4 **Status of Equipment**

(1) Status of Equipment at Thermal Power Plants

As a result of investigations at each power plant, the current available output is 448 MW, though the total output of thermal power plants is 760 MW. This means that 312 MW is shut down for a long time due to problems of some sort.

Table 3-9 Plant Operation Status (August, 2018)

Plant	Type	Plant Configuration	Original Capacity	Latest Capacity	Δ (Delta)	Main Reason
Yeywa	Hydro Power Plant		790MW	N/A	N/A	✓No Issue
Ywama	Fr5	2GT CHP	37MW	37MW	153MW	✓H-25 1on1 Was Stopped Due to Heavy Damage of Turbine Buckets From 2014. ✓701D Was Stopped Due to Heavy Damage of Compressor Bucket From July. 2018.
	H-25	1on1 C/C	33MW	0MW		
	701D	2GT S/C	240MW	120MW		
Thaketa	Fr5	3GT S/C	57MW(GT) 35MW(ST)	38MW(GT) 0MW(ST)	54MW	✓GT#2 Was Stopped From 2015 Due to IGV Damage. ✓ST Was Stopped From 2013 Due to High Vibration.
Hlawga	Fr6	3on1 C/C	100MW(GT) 54MW(ST)	67MW(GT) 36MW(ST)	51MW	✓GT#3 Was Stopped From 2013 Due to GEN Ground Fault Damage.
Ahlone	Fr6	3on1 C/C	100MW(GT) 54MW(ST)	100MW(GT) 0MW	54MW	✓ST Was Stopped From Mar. 2018 Due to HRSG Tube Leakage.
Thilawa	H-25	2GT S/C	50MW	50MW	0MW	✓No Issue
Total (Except Hydro)			760MW	448MW	312MW	

Source: JICA study team

Source: JICA study team

Fig. 3-26 Various Damage (August 2018)

Table 3-10 Deterioration Condition of Thermal Power Plants

<table>
<tr><th>Plant</th><th>Model</th><th>Unit</th><th>GT</th><th>GEN</th><th>GT AUX</th><th>HRSG</th><th>ST</th><th>ST AUX</th></tr>
<tr><td rowspan="5">Ywama</td><td rowspan="2">701D</td><td>1</td><td colspan="3">GT :Surging Accident (EPGE tried to operate GT with temporary repair. Comp. Blade might need replacing.)
Inlet Air Filter : Clogged Filter Element. EPGE did not monitor Inlet Filter Element differential pressure.</td><td colspan="3">NA</td></tr>
<tr><td>2</td><td colspan="3">Under Operation

GT : Operation time was exceeded from OEM's inspection interval and some Hot Gas Path Parts were operated beyond their life time.
GEN : Bearing Metal Temperature high alarm was detected. It will need to be inspected.
Inlet Air Filter : Clogged Filter Element. EPGE did not monitor Inlet Filter Element differential pressure.</td><td colspan="3">NA</td></tr>
<tr><td>H-25</td><td>1</td><td colspan="6">Plant was stopped due to GT turbine rotating parts damage. HRSG/ST/Condenser were kept without proper long-term storage.</td></tr>
<tr><td rowspan="2">Fr.5</td><td>1</td><td colspan="3">GT has been stopped since Sep. 2018 due to Compressor damage. EPGE tried to replace GT Rotor, however high Rotor vibrations occurred, and GT was not running at the end of December.</td><td colspan="3">NA</td></tr>
<tr><td>2</td><td colspan="3">Under Operation</td><td colspan="3">NA</td></tr>
<tr><td rowspan="3">Thaketa</td><td rowspan="3">Fr.5</td><td>1</td><td colspan="3">Under Operation</td><td colspan="3" rowspan="3">ST was stopped due to Bearing damage in 2013. After that, EPGE opened ST and kept it without proper long-term storage such as Nitrogen purging, preservation, etc.

EPGE maintains HRSG monthly based on explanation. However, Cooling Tower is heavily deteriorated and should be replaced.</td></tr>
<tr><td>2</td><td colspan="3">GT has been stopped since 2015 due to IGV damage. (Customer plans to implement rehabilitation work.)</td></tr>
<tr><td>3</td><td colspan="3">Under Operation</td></tr>
<tr><td rowspan="3">Hlwaga</td><td rowspan="3">Fr.6</td><td>1</td><td colspan="3">Under Operation</td><td>HRSG was stopped due to tube leakage.</td><td colspan="2" rowspan="3">Under Operation</td></tr>
<tr><td>2</td><td colspan="4">Under Operation</td></tr>
<tr><td>3</td><td colspan="4">GT was stopped due to GEN ground fault in Feb. 2015.</td></tr>
<tr><td rowspan="3">Ahlone</td><td rowspan="3">Fr.6</td><td>1</td><td colspan="3">GT was operated with #2 BRG vibration high. It needs to be inspected.</td><td rowspan="3">HRSG was stopped due to tube leakage.</td><td colspan="2" rowspan="3">ST was stopped due to HRSG tube leakage.

ST has not been maintained since 1999 (plant commencement time). It needs to b overhauled.</td></tr>
<tr><td>2</td><td colspan="3">Under Operation</td></tr>
<tr><td>3</td><td colspan="3">Under Operation</td></tr>
<tr><td rowspan="2">Thilawa</td><td rowspan="2">H-25</td><td>1</td><td colspan="3">Under Operation

GT : Operation time was exceeded from OEM's inspection interval.</td><td colspan="3">NA</td></tr>
<tr><td>2</td><td colspan="3">Under Operation

GT : Operation time was exceeded from OEM's inspection interval.</td><td colspan="3">NA</td></tr>
</table>

Source: JICA study team

In the first and second site surveys, we conducted simple diagnoses at the power plant to confirm the state of the equipment. The results of simple diagnosis are shown below.

a. Vibration Diagnosis

In the second site survey, we planned to temporarily install a vibration diagnostic device for vibration measurement and diagnosis of the GT and ST. However, the device that had been shipped as scheduled was stopped at customs, so the device could not be transported on time.

Therefore, JICA study team performed a quick verification and recommended a 1) field balance test at the site and a 2) low speed balance test in order to study this problem.

b. Water Quality Diagnosis

Water quality analysis was conducted to confirm the state of water quality management.

Results of water quality analysis at Hlawga power station using a portable analyzer in the first site survey are shown below.

Table 3-11 Results of Water Quality Analysis（at Local Site①）

■Measurement Date：3.9.2019 Measurer：KANSAI Sato, Fujiwara

Item, Criteria / Point	pH	Dissolved Oxygen (Reference)	Electric Conductivity (Reference)
	6.3(Myanmar)	―	≦0.3 (KANSAI)
Pure Water Equipment Outlet	6.64(29.5℃)	0.47 mg/L	5.90 ms/m(29.6℃)

Source: JICA study team

Table 3-12 Results of Water Quality Analysis（at Local Site②）

■Measurement Date：3.9.2019 Measurer：KANSAI Sato, Fujiwara

Item, Criteria / Point	pH	Dissolved Oxygen (Reference	Electric Conductivity
	JIS 9.8~10.7 (25℃)	―	JIS ≦40(25℃)
Boiler Water #2HRSG	10.14(38.1℃)	0.30 mg/L	12.18 ms/m(38.1℃)

Source: JICA study team

In the second site survey, we collected the boiler water, brought it back to the country, and carried out a detailed analysis. The results are shown below.

Table 3-13 Results of Water Quality Analysis（In Japan）

■Sampling date：4.12.2018 Sampler：KANSAI Sato MHPS Hiraoka

■Analysis date：20.12.2018 Analysis Place：Chemical Room of KANSAI P/S

Item, Criteria / Point	Silica	Chloride Ion	Phosphate Ion	Iron (Reference)	Turbidity (Reference)
	JIS ≦10	JIS ≦10	―	―	―
Boiler Water (#2-HRSG)	3.3 mg/L	4.5 mg/L	0 mg/L	12 μg/L	0 ms/m

Source: JICA study team

With the measured values, treatment was not immediately necessary, but proper water quality management through continuous operation of the chemical injection device and water analysis is necessary.

From the measurement results, the following can be said.

- ◆ Phosphoric acid injection is not done properly.
- ◆ Injection of Na_2SO_3 (sodium sulfite) may also be inappropriate.
- ◆ According to the dissolved oxygen measurement value of the boiler water, there is a possibility that the dissolved oxygen of the boiler inlet feed water is high.
- ◆ Since pH tends to be slightly higher, it is necessary to pay attention to corrosion.

c. Lubricating Oil Diagnosis

In the second site survey, GT and ST lubricants were collected, brought it back to Japan, and subjected to detailed analysis. The results are as follows.

Table 3-14 Results of GT Lube Oil Analysis

■Sampling date：12.12.2018 Sampler：KANSAI Sato MHPS Hiraoka

■Analysis date：12.2.2019 Analysis company：Kanden Engineering

Manufacturer of Lube Oil：Michang (Korea)-TURBINE OIL VG32

Item・Reference Value / Point	Acid Value [mgKOH/g]	RBOT [min]	Kinetic Viscosity [mm2/s(40°C)]	Moisture [%]	Pollution Degree [Mg/100ml]
	JIS 0.3 or Less	—	JIS 28.8～35.2	0.1 or Less	10 or Less
Ahlone P/S No.3 GT	0.07	220	31.94	0.003	0.6

Source: JICA study team

Table 3-15 Results of ST Lube Oil Analysis

■Sampling date：4.12.2018 Sampler：KANSAI Sato MHPS Hiraoka

■Analysis date：12.2.2019 Analysis company：Kanden Engineering

Manufacture of Lube Oil：Michang (Korea)-TURBINE OIL VG46

Item・Reference Value / Point	Acid Value [mgKOH/g]	RBOT [min]	Kinetic Viscosity [mm2/s(40°C)]	Moisture [%]	Pollution Degree [Mg/100ml]
	JIS 0.3 or Less	—	JIS 41.4～50.6	0.05 or Less	10 or Less
Hlawga P/S ST	0.08	410	47.22	0.0041	0.3

Source: JICA study team

As a result of analysis, no deterioration in performance was observed. However, with regard to the RBOT value, the value of new oil is not known, therefore the residual rate cannot be evaluated.
In order to operate safely and economically, it is necessary to conduct lube oil analysis regularly and manage oil appropriately.

d. Auxiliary Machine Diagnosis（Vibrations, Insulation Resistance and Electric Current）

a) The results of vibration measurement at Hlawga power station using the portable vibration meter in the first site survey are as follows.

Title	Vibration Measurement		
Power Station	Hlawaga		
Object	F6 GTCC A-Feed Water Pump		
Measurer	Hiraoka (MHPS)		
Observer	Ozaki (Kansai)		

Equipment Specification

Type	Centrifugal Pump	Capacity	48 kgf/cm2
Roating Speed	2980 rpm	Serial Number	RW08432-01 1/3
Current	24.3A	Voltage	6,600V
Manufacturer	EBARA	Made Date	2010

Measurement Result

Measurement Date		9.1.2018
Measurement Tool	Type	Portable Vibrometer
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD
Pump Bearing (Free Side)	V	20 μm
	H	50 μm
	A	37 μm
Pump Bearing (Coupling Side)	V	35 μm
	H	70 μm
	A	20 μm
Motor Bearing (Coupling Side)	V	15 μm
	H	15 μm
	A	14 μm
Motor Bearing (Free Side)	V	20 μm
	H	40 μm
	A	35 μm

Vibration Reference Value（JIS B 8301): 35μm

Source: JICA study team

Fig. 3-27 Vibration Measurement of A-Feed Water Pump

Title	Vibration Measurement		
Power Station	Hlawaga		
Object	F6 GTCC C-Feed Water Pump		
Measurer	Hiraoka (MHPS)		
Observer	Ozaki (Kansai)		

Equipment Specification

Type	Centrifugal Pump	Capacity	48 kgf/cm2
Roating Speed	2980 rpm	Serial Number	RW08432-01 3/3
Current	24.3A	Voltage	6,600V
Manufacturer	EBARA	Made Date	2010

Measurement Result

Measurement Date		9.1.2018
Measurement Tool	Type	Portable Vibrometer
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD
Pump Bearing (Free Side)	V	15 μm
	H	35 μm
	A	25 μm
Pump Bearing (Coupling Side)	V	25 μm
	H	40 μm
	A	30 μm
Motor Bearing (Coupling Side)	V	30 μm
	H	60 μm
	A	20 μm
Motor Bearing (Free Side)	V	18 μm
	H	40 μm
	A	50 μm

Vibration Reference Value（JIS B 8301): 35μm

Source: JICA study team

Fig. 3-28 Vibration Measurement of C-Feed Water Pump

As a result of the vibration measurement, it was confirmed that the vibration exceeded the JIS management standard in some places, but since there is no disassembly inspection, adjustment record, etc., the detailed cause of the vibration could not be pinpointed.

b) In order to confirm deterioration of the electric motor, insulation resistance measurement and current measurement were carried out in the first site survey.
The insulation resistance measurement result of the No. 3 GT lubricating oil cooler fan at the Hlawga power station and the current measurement result of the B condensate pump are as follows.

Title	Insulation Resistance Measurement of Low Voltage Motor		
Power Station	Hlawaga		
Object	#3GT FIN FAN Cooler #3		
Measurer	Sato (Kansai)		
Observer	Fujiwara (Kansai)		
Motor Specification			
Type	Totally-enclosed Fan-cooled	Capacity	7.5kW
Number of Poles	8	Serial Number	K11R315S4 TWS
Rotating Speed	720 rpm	Voltage	400V
Current	16.6A	Insulation Type	F
Manufacturer	ELECTROMO	Made Date	–
Measurement Result			
Measurement Date		9.3.2018	
Measurement Tool	Type	Insulation Resistance Measuring Device 500V Type	
	Serial Number (Model)	YOKOGAWA MY40-01	
	Calibration Date	2017.8	
Condition	Weather	Cloudy after Rain	
	Temperature (℃)	27.3℃	
	Humidity (%)	51%	
Insulation Resistance	MΩ	0.026 MΩ	
		Reference Value: more than 1MΩ	

Source: JICA study team

Fig. 3-29 Insulation Resistance Measurement of Oil Cooler Fan

Title	Motor Current Measurement		
Power Station	Hlawaga		
Object	F6 GTCC B-Condensate Pump		
Measurer	Sato (Kansai)		
Observer	Fujiwara (Kansai)		
Motor Specification			
Type	Totally-enclosed Fan-cooled	Capacity	110kW
Number of Poles	4	Serial Number	K11R315S4 TWS
Rotating Speed	1480 rpm	Voltage	400V
Current	195A	Insulation Type	–
Manufacturer	VEM motors	Made Date	1998.5
Measurement Result			
Measurement Date		9.1.2018	
Measurement Tool	Type	HIOKI 3285	
	Serial Number	80523503	
	Calibration Date	2009.8	
Phase Current	A	169.8 A	
	B	164.8 A	
	C	165.1 A	

Source: JICA study team

Fig. 3-30 Current Measurement of B-Condensate Pump

The insulation resistance measurement result of the No.3 lubricating oil cooler fan was 0.026 MΩ, which was confirmed to be deteriorated. The B-Condensate pump current measurement result was less than the rated current and there was no unbalanced current, so it was confirmed that there was no abnormality.

e. Leakage Location Diagnosis

The results of diagnosis such as exhaust gas leaks, steam leaks, valve seat leaks, equipment heat generation, etc., at Hlawga power station using the thermal camera in the first site survey are as follows.

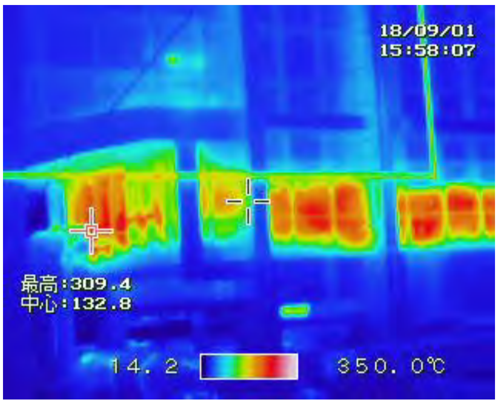


Fig. 3-31 HRSG Casing Overheating

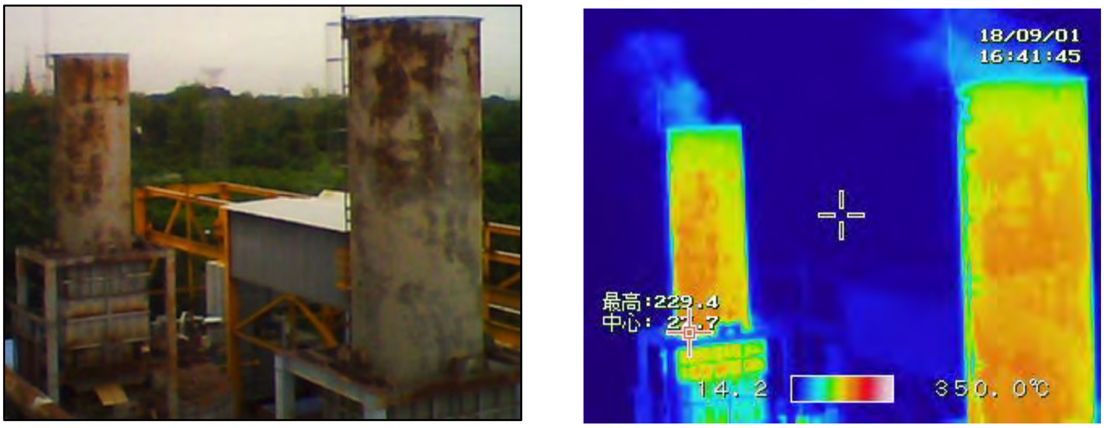
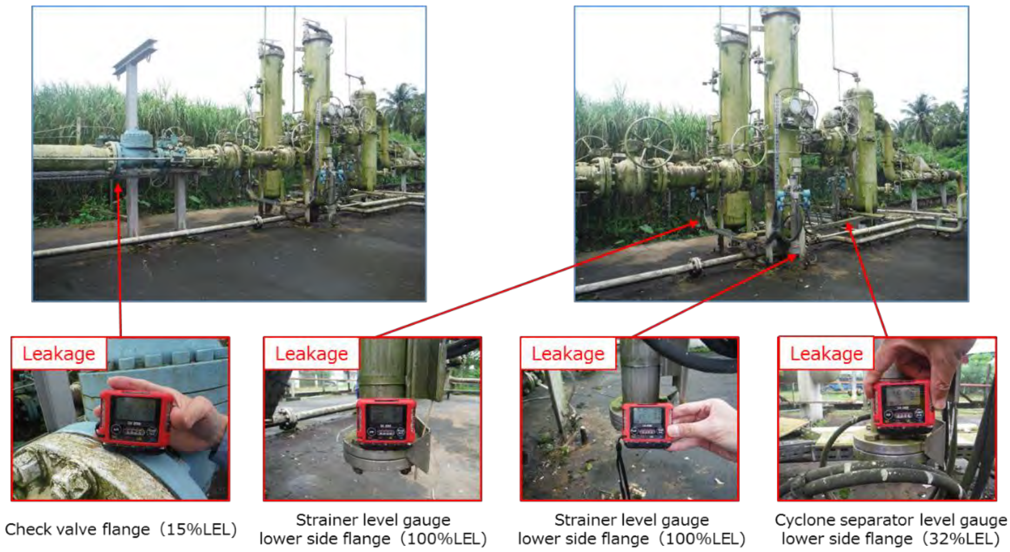


Fig. 3-32 HRSG Bypass Damper Gas Leakage

It was confirmed that the maintenance condition of the thermal insulation coating of the HRSG casing was not sufficient and it overheated. At the time of the investigation, the bypass damper was closed and operated as a combined cycle, but it was confirmed that the bypass stack overheated. From this, it is considered that there is a leak in the bypass gas damper and the exhaust gas flows to the bypass stack side.

We investigated gas leakage points using portable gas detectors at each power station.

As an example, the results from the Ahlone power station are as follows.



Source: JICA study team

Fig. 3-33 Gas Leakage Investigation

In Myanmar, a gas detector is not kept at power plants, gas leakage investigations are not carried out even during equipment inspections, and the gas leakage situation cannot be grasped.

In leakage investigations, it was confirmed that leaks exceeded 100% LEL in several places. This situation is not only an economical loss stemming from efficiency reduction due to gas leakage but also a serious problem in safety management.

(2) Status of Equipment at the Hydropower Plant

a. Site condition

At the Yeywa switchyard, outdoor equipment such as circuit breakers and disconnectors are dirty with splashes of spilled water from the spillway during the rainy season. Although the insulators of the circuit breakers and disconnectors are cleaned in the dry season, there is a discharge from the spillway in the rainy season, so insulators in the switchyard in front of the spillway get dirty every year. The dirt in the switchyard is confirmed in the site survey of March 2019. The cause of the dirt on the outdoor equipment was the adhesion of algae. The whole switchyard is noticeably dirty with algae adhesion, and the upstream side is dirtier than the downstream side. As a finding of the site survey, the dirt status of switchyard equipment is given in Table 3-16, and photos of the switchyard dirt condition are shown in Fig. 3-37.

Table 3-16 Dirt Status of Switchyard Equipment

Location	Equipment	Dirt Status
Yeywa switchyard	Transformer	Although it is installed at the most upstream point, it is protected by a steel wall, so it is less dirty with algae compared to other equipment.
	Circuit breaker	The appearance is quite dirty with algae. The inside of the operation box is not dirty with algae. The insulator had been cleaned a year ago, but it is quite dirty with algae.
	Disconnector	The appearance is quite dirty with algae. The inside of the operation box is not dirty with algae. The insulator had been cleaned a year ago, but it is quite dirty with algae.
	Lattice steel structure	It is quite dirty with algae. The high places are assumed to be noticeably dirty because they have never been cleaned.
	Wires	Confirmed from the ground, it is assumed to be noticeably dirty.
	Floor	The whole switchyard is quite dirty with algae
	Outer fence	Noticeably dirty with algae
	Cable pit	The pit cover is quite dirty with algae. The inside is not so dirty with algae.

Source: JICA study team

Fig. 3-34 Switchyard Dirt Condition Photos

b. Confirmation of influence on outdoor equipment

In order to confirm the effects of river water and algae on outdoor equipment in the site survey in March 2019, the sample of river water of the Minge River and the algae of the switching station were collected. The chemical analysis was conducted in Japan. The results are shown in Table 3-17 and Table 3-18.

(a) Analysis of River Water

Analysis results of river water are shown in .Table 3-17

Table 3-17 Results of Analysis（River water）

■Sampling date：19 March 2019

Sampler : KANSAI Shitakata, Naka

■Analysis date：1 Apr 2019 - 3 Apr 2019

Analysis location：Kansai Electric Power Research and Development Center

Item	Unit	Numerical value
pH	—	8.4
Conductivity	µS/m	328
Calcium ion (Ca)	mg/L	43.5
Magnesium ion (Mg)	mg/L	21.8
Sulfate ion (SO4)	mg/L	6.5

Item	Unit	Numerical value
Sodium ion (Na)	mg/L	1.9
Chloride ion (Cl)	mg/L	1.0
Phosphorus concentration	mg/L	0
Nitrogen concentration	mg/L	0.18
COD (Reference value)	mg/L	5.0

Source: JICA study team

The point of the analysis result is the conductivity. The higher the conductivity is, the easier electrical current flows. The conductivity of the river in the Minge River was 328 μS / m. In general, the average conductivity of Japanese river water is 110 μS / m (water on the upper stream is 50 to 100 μS / m, and downstream water is 200 to 400 μS / m) and seawater is 45,000 μS / m. Rainwater is 10 to 30 μS / m.

(b) Analysis of Algae

Analysis results of algae are shown in Table 3-18.

Table 3-18 Results of Analysis（Algae）

■Sampling Date: 19 March 2019

Sample collector: KANSAI Shitakata, Naka

■Analysis Date：1 Apr 2019 - 3 Apr 2019

Analysis location：Kansai Electric Power Research and Development Center

Item	Unit	Numerical value
Equivalent Salt Deposit Density (ESDD)	mg/cm^2	0.519
Non-soluble Deposit Density (NSDD)	mg/cm^2	45.2

Source: JICA study team

① Equivalent Salt Deposit Density（ESDD）

The component is defined with the following formula: ESDD = Salt content equivalent to the component of algae / Surface area. The higher the number is, the easier the electrical current flows. ESDD was 0.519 mg/cm^2. It exceeds the value of "D" of the Classification of Contamination and estimated amount of salt deposition as shown in Table 3-19.

Table 3-19 Estimated Amount of Salt Deposition

(Electrical cooperative research Vol.20 No.2
Countermeasures against salt damage in transmission and transformation facilities)

Classification of Deposit Density		A	B	C	D	E
Expected maximum equivalent salt adhesion density (mg/cm^2)		0.03	0.06	0.12	0.35	3% salinity, 0.3 mm / min water injection assumed for direct splashing of seawater.
Distance from the coast	In typhoons	50 km or more	10 km to 50 km	3 km to 10 km	0 km to 3 km	0 m to 300 m or 0 m to 500 m depending on the topography conditions
	In seasonal winds	10 km or more	3 km to 10 km	1 km to 3 km	0 km to 1 km	0 m to 300 m depending on the topography conditions

Note: The numerical values shown as the distance from the coast in the above table are given as a rough guide, therefore it is desirable that corrections should be made based on the results of the amount of salt deposition depending on the topography conditions.

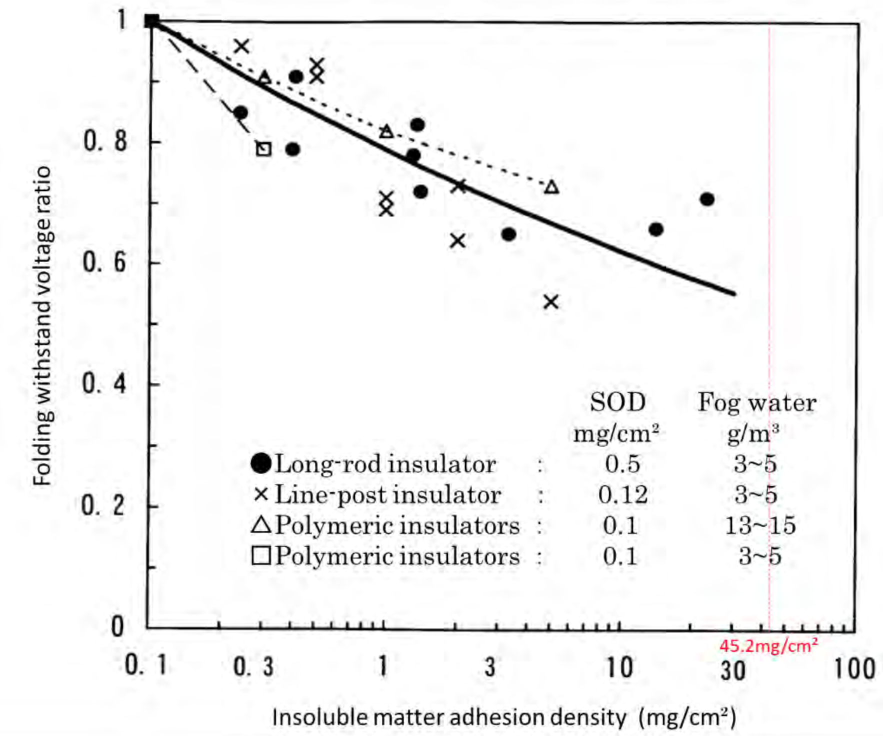
Source: JICA study team

② Non-Soluble Deposit Density (NSDD)

The weight of the component that is not soluble in liquid is measured, and the value divided by the surface area is called the NSDD. The higher the number is, the lower the withstand voltage is, the result being that the risk of grounding fault is high. The NSDD is 45.2 mg / cm^2. The fouling withstand voltage ratio decreases to about 0.5 due to the relationship between the insoluble matter adhesion density and the fouling withstand voltage. The relationship between the insoluble matter adhesion density and the fouling voltage resistance is shown in Table 3-20.

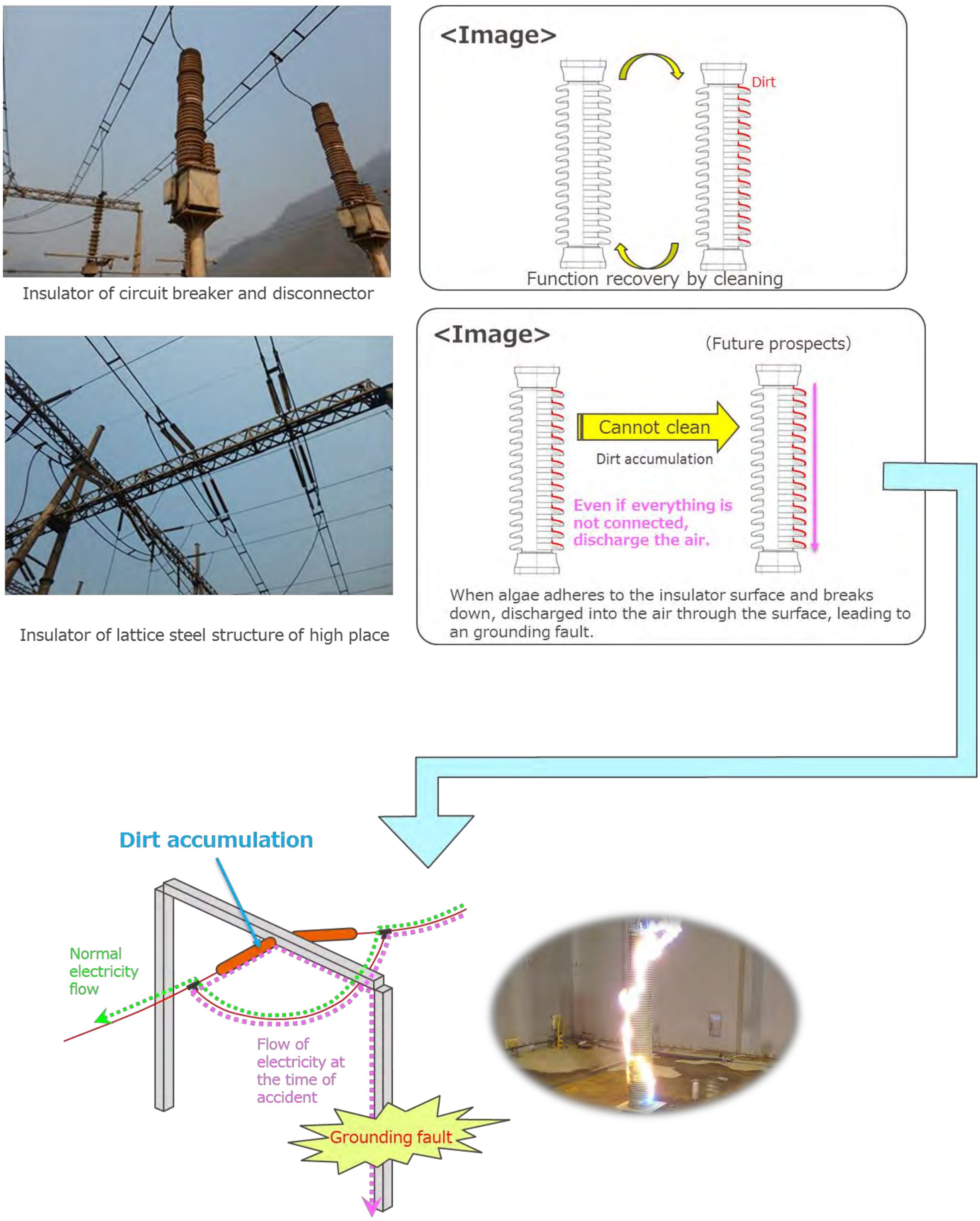
Table 3-20 Relationship Between Insoluble Matter Adhesion Density and Fouling Voltage Resistance

(Basic research on electrical insulation properties of polymer insulators (Nagoya Institute of Technology doctoral thesis))



c. Evaluation of site survey and analysis results

When the surface of the insulator is dirtied, the electrical current flows easily. When the voltage applied to the surface of the insulator exceeds the withstand voltage limit, it will lead to an insulation breakdown and grounding fault. The circuit breaker and disconnector are cleaned every year, so the insulation performance of the insulator is restored. However, insulation performance cannot be recovered because the insulators in high places have never been cleaned. It was found that river water and the algae cause electrical current to flow, and they lowered the withstand voltage of equipment. From these findings, it is evaluated that the adhesion of algae to the insulators is in a very dangerous situation, which may cause grounding faults in the near future. An example of the assumed situation should a grounding fault occur is shown in Fig. 3-38.



Source: JICA study team

Fig. 3-35 Expected Risk of Occurrence of Grounding Fault

3.4 Predictive Maintenance

Basically, they do not practice either predictive maintenance or follow-up maintenance. Equipment is operated until it breaks down. If the equipment breaks down, the plant is forced to shut down and renovation work is executed. In addition, if an alarm is issued or an instrument is damaged, equipment is kept running by bypassing the control logic.

When equipment breaks down and is impossible to be operated, the power station contacts EPGE, and executes renovation work or repairs broken equipment.

For reference, we would like to report an event that actually happened.

=Ahlone Power Station=

Even though disc cavity temperature (measuring point: temperature of a clearance between rotating parts and stationary parts, purpose: gas turbine rotor temperature measurement) exceeded the alarm value, the alarm was ignored and the units were kept running. The rotor would not be damaged in a short amount of time, but taking no action for the alarm is a very serious problem from safe operation and predictive maintenance viewpoints. The service lifetime of the turbine rotor is consumed, and in the worst case, the gas turbine rotor is at risk of eventually being ruptured by high temperature creeping.

It is very important to 1) take measures if an alarm is issue, 2) build an organization and a system to strictly follow 1), and 3) understand the risks of continued operation when ignoring the alarm.

One of the causes of the alarm occurrence is a lowering of compressor efficiency. Once the compressor efficiency decreases, the cooling air volume supplied to disc cavities lowers, thereby the temperature in this zone increases. Compressor water washing is an effective way of recovering compressor efficiency and the facility, therefore, exists at the power station but is not used. It is important to educate staff about the importance of regular maintenance and backgrounds thereof.

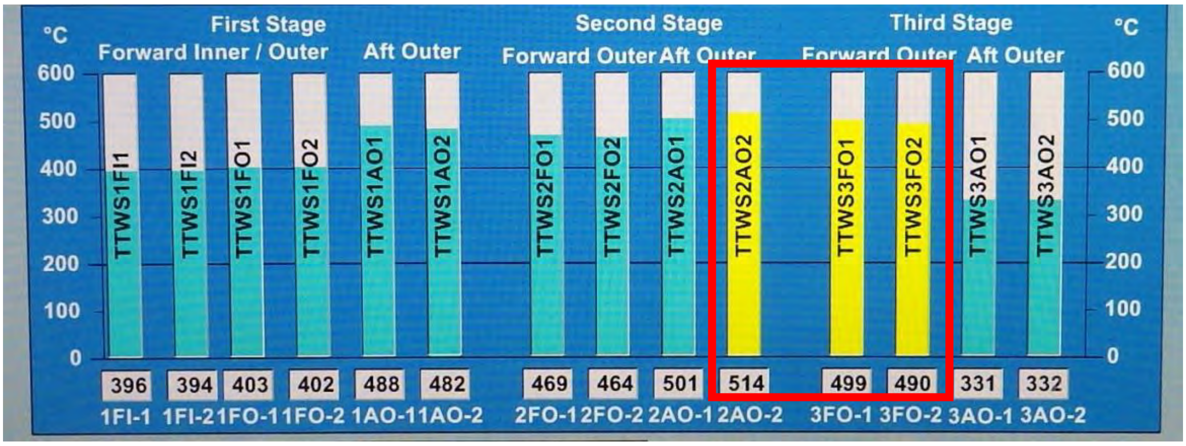


Fig. 3-36 Alarm Ringing Situation

=Ahlone Power Station=

It was confirmed that the power plant is operated while the following setting is changed in the Ahlone power station. Fig. 3-40 is a display of Ahlone power station's control unit. Although intentions to change the setting are unknown, there might be a problem in operation.

(1) Setting change of LK3IGVF2 (IGV opening)

『Normally, it is fixed at 34° during operation, but it is now "36.0°F"= being fixed at 36° forcibly.』

This setting change is presumed to satisfy the startup conditions.

This is not particularly a problem in normal operation, but it is very dangerous to leave this situation as is because there is a possibility that the compressor cannot be protected when it has to be protected during GT load increase.

The measure is IGV valve readjustment.

(2) Setting change of L33CB1O (bleed air valve opening)

『"False" = close is set during operation, but "True" = open is set forcibly.』

This signal indicates that the bleed air valve is opened, and that the close-state is normal and correct during operation. Presumably, this is also forcibly set to "Open" to meet the startup conditions. In any case, since this signal is used for an alarm and trip, leaving the setting as is means that the trip does not function when the unit has to be tripped. This is a very big problem.

(3) Setting change of L33CSE (torque converter/accessory gear clutch)

『"False"= clutch disengage is set during operation, but "True"= clutch engaged is set forcibly.』

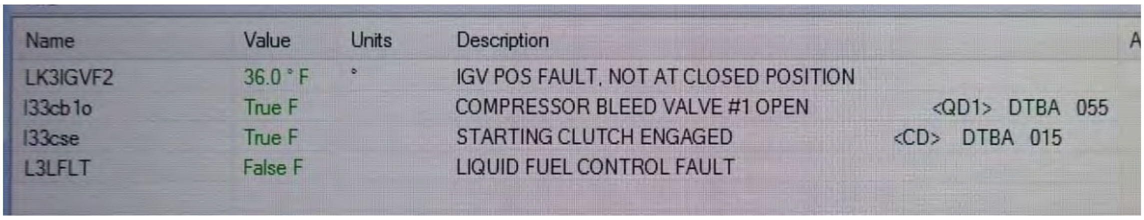
This signal indicates that the clutch between the torque convertor and accessory gear is engaged. To start the diesel engine, a startup device for starting the GT, the signal of the clutch engagement is essential. Despite our various investigations, we could not find reasons why this signal is forcibly set at the clutch engagement. The system in which the diesel engine is stopped when the clutch is disengaged may not work properly. If the diesel engine is kept running while the clutch is disengaged, the torque converter heats up, leading to damage.

(4) Setting change of L3LFLT (fuel oil control line servo valve)

『"True"=Servo valve OPEN is set with fuel oil operation, but "False"＝Servo valve CLOSE is set forcibly. 』

This signal trips the GT due to malfunction of the servo valve on the fuel oil control line. Currently, there is no servo valve and use of the fuel oil line is not planned, so actually it will do no harm now. However, it is important that operation engineers are aware that this signal is used to the trip circuit and is a very important circuit.

＊ (2), (3), and (4) remind us of the importance of training.



Name	Value	Units	Description	A
LK3IGVF2	36.0 ° F	°	IGV POS FAULT, NOT AT CLOSED POSITION	
l33cb1o	True F		COMPRESSOR BLEED VALVE #1 OPEN <QD1> DTBA 055	
l33cse	True F		STARTING CLUTCH ENGAGED <CD> DTBA 015	
L3LFLT	False F		LIQUID FUEL CONTROL FAULT	

Fig. 3-37 Logic Bypass (This could lead to equipment breakdown.)

3.4.1 Sampling Status of Operation Data

<Main parameter>

For the main parameters such as temperature, pressure, vibration, etc., data are sampled once every hour. Sampled data are recorded on paper by hand.

<Periodic report>

The electric energy and fuel gas flow rate (integrated value) are reported to EPGE once a day.

Sampled data are recorded on paper by hand every hour.

Data every hour are integrated or averaged (arithmetic average) and reported to EPGE by telephone or fax.

<Logbook by operator>

The time of startup, stopping, and parallel and main events are recorded. However, the details of the events cannot be identified. For example, even if a gas turbine trip occurred, the reason why the trip occurred is not recorded. These are recorded in a notebook (H 40 cm x W 20 cm).

(Refer to Fig. 3-4.)

3.4.2 Operation Data Accumulation and Analysis Status

As mentioned above, the paper-based data are stored, however analysis has never been performed.

The features of data accumulation are as follows.

Table 3-21 Comparison of Data Accumulation Status Before and After Updating of Control Panel

	Analog control panel	Digital control panel (after updating)
Data sampling method	Reading the meter on the panel	Reading values on the maintenance tool
Data accumulation	Stored as paper (Not transferred to Excel, etc.)	Stored as paper (Not transferred to Excel, etc.)
Automatic data storage function	Not provided	Provided (Possible to be converted to Excel, etc.)
Control panel comparison		

Source: JICA study team

Even after the expensive control panel is updated, the data accumulating method is unchanged and the equipment is not effectively utilized.

For the data utilization method, a comparison in the case of a trip is made between power plants in Japan and Myanmar as follows.

In Japan: Occurrence of trip -> Cause investigation (data analysis) => Countermeasures => Recurrence prevention => Restart

In Myanmar: Occurrence of trip -> Restart

Important events are overlooked, resulting in serious accidents because of prompt restart without investigating the cause.

[Ex: Ywama power plant, damage of compressor]

<June 2018>

During gas turbine load operation, the compressor inlet guide vane (IGV) suddenly closed, which changed operation conditions and generated an alarm, however the turbine was operated continuously for about 11 hours despite the alarm.

(If the IGV is suddenly closed during operation, surging is generated, which may cause loads to be applied to the compressor vanes and damage the vanes. Therefore, in the case of power plants in Japan, the turbine is stopped immediately after an alarm is generated, and the cause is investigated.)
It is possible that high-cycle fatigue is accumulated within 11 hours, finally resulting in damage to the vanes. In order to identify whether the damage to the vanes is triggered by high-cycle fatigue or corrosion pitting, it is necessary to inspect the actual parts in detail.
The following is assumed to be a cause of sudden closure of the IGV: the solenoid valve is provided to operate the IGV, however it is assumed that the coil winding in the solenoid valve did not function due to wire breakage, etc., which caused the solenoid value to be in the non-excited state (that is, the IGV is closed). It is also assumed that sudden closure of the IGV increased the exhausting temperature and decreased the compressor outlet pressure.
(The evidence that the IGV is suddenly closed is as follows.)

Time	Ex. Gas Temp. degC
21:00	354
22:00	480
23:00	530
24:00	522

Time	Comp. Discharge Press. PSI
03:00	96
04:00	61
05:00	64
06:00	66
07:00	66
08:00	65

Source: JICA study team

Fig. 3-38 Operation Status After Alarm Generation (Recorded on Paper)

If analysis was made and proper actions were taken, it is possible that long-term suspension and unplanned repair costs could be avoided.

<August 2018 (2 months after generation of the alarm)>
After the alarm was generated in June, starting/stopping repeated several times, finally resulting in damage to the compressor vanes.

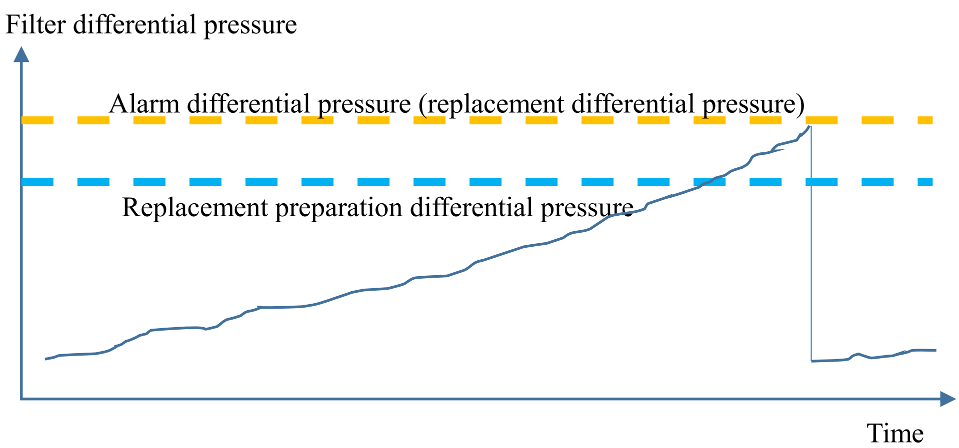
Fig. 3-39 Compressor Vane Damage

3.4.3 Implementation Status of Predictive Maintenance

As mentioned above, no predictive maintenance is performed because equipment is used until breaking. In the case of power plants in Japan, some actions are taken before alarms generate.

[Example of predictive maintenance: Cases when the filter differential pressure increases]

When the differential pressure reaches the replace preparation differential pressure, spare filters are prepared (arranged) and when the differential pressure reaches the alarm differential pressure, the filters are replaced.



Source: JICA study team

Fig. 3-40 Example of Predictive Maintenance
(Actions when filter differential pressure increases)

3.4.4 Control Status of Records

The paper-based records are stored in the book store room at the power plant. However, they are not filed or controlled on a time basis, but are simply stacked.

The logbooks are controlled in the same manner.

Fig. 3-41 Control Status of Operation Data, etc.

Chapter 4 Study of Adaptability of the Latest Technology such as IoT and AI

4.1 Implementation Status of Remote Monitoring in the Electric Power Industry

4.1.1 Digitalization in the Electric Power Industry

In recent years, along with the development of digital technologies such as IoT and AI, the development of new digitalization mechanisms and services has been actively carried out in various industries and fields all over the world. This trend has been bringing about major changes in the electric power industry. Especially in the thermal power generation industry, from the viewpoint of global environmental conservation, the surrounding environment has undergone significant changes such as mass introduction of renewable energy power generation with less CO2 emissions and electricity liberalization. While, against this backdrop, low-cost O&M of power generation equipment is still required, digital technology is expected to maintain high efficiency, flexible operability and high reliability.

From power generation facilities, we have collected plant operation data such as the power output of generators, steam and fuel temperatures, pressures and flow rates, and maintenance / repair records. Also, we have accumulated a large amount of know-how and business experience. Recently, the latest technologies for using these data, such as IoT and AI, have been applied, installed, tested and actually put to use at many power generation facilities. Specifically, we analyze and use collected data to detect abnormalities early on and appropriately manage equipment, with the aim of improving plant maintenance and operation. This digitization effort is indispensable for the future of the thermal power generation industry.

4.1.2 Remote Monitoring of Thermal Power Plants

Conventionally, at thermal power plants, many measuring instruments have been installed to manage power generation system operation, and these operation data were recorded. In recent years, progress in digital technologies has made it easier to collect more data and centralize management of plant data not only at local power plants but also at headquarters and other places. Other industries are utilizing data for ICT applications, and big data analysis, etc. In combination with equipment such as remote monitoring and tablets, it is possible to improve work efficiency, maintain equipment reliability and improve operating rate. These services have been deployed in a variety of industries.

In response to the above recent trends, a Japanese electricity company introduced OSIsoft's PI System that has been widely adopted overseas and in other industries. Conventionally, monitoring of facilities for abnormalities depended heavily on the awareness and experience of on-site duty personnel and maintenance personnel, but the PI System makes it possible to uniformly predict and detect equipment trouble. In addition, it makes it possible to unify and manage the operation data in real-time between the head office and all the thermal power plants, as well as to standardize monitoring (Fig. 4-1).

Source: JICA study team

Fig. 4-1 Monitoring Screen (an example of KANSAI)

Meanwhile, with regard to GT, a service for remotely monitoring GT process data from a Remote Monitoring Center (RMC) has been offered by GT manufacturers since the 1990's, as a part of long-term maintenance. The RMC identifies potential problems in advance while confirming the operation soundness of the GT, and makes it possible to provide appropriate advice and support in the event of a problem. Even without crews in the field, real-time or prompt response is realized.

AI technology, which has made remarkable progress recently, is applied to O&M of power generation facilities. It is applied to abnormality prediction and the digital twin that reproduces / predicts the state of the power plant. By predicting potential abnormalities, measures can be taken before equipment fails, which helps to improve availability. Using the digital twin, the RMC investigates economic operating conditions and operating conditions in consideration of equipment lifetime. It can present the optimum operating conditions for reducing fuel consumption, etc. Furthermore, it is possible to monitor the cause of past failures and unplanned stoppages, and to speed up maintenance correspondence by accumulating and analyzing various process data.

In this way, it is expected that the integration of IoT and AI technology and O&M know-how of power generation facilities can optimize operation and maintenance of the entire power plant. Also, thanks to progress in AI technology, improvements in diagnosis and prediction accuracy are expected in the O&M of power generation facilities. Remote monitoring that provides such technologies and knowledge is an effective way to optimize operation, streamline maintenance, and improve the technical skills of operators in Myanmar where the forced outage rate and operation management are problems.

4.2 Outline of Actual Demonstration of IoT and AI Using a Pilot Equipment

The accuracy of detecting abnormal signs increases when a large volume of data is collected via remote monitoring that employs IoT and AI.

Therefore, we will introduce pilot equipment for data collection and remote monitoring in this survey, and verify the effectiveness of these digital solutions for the issues in Myanmar by actually operating the equipment.

Source: JICA study team

Fig. 4-2 A Pilot Equipment

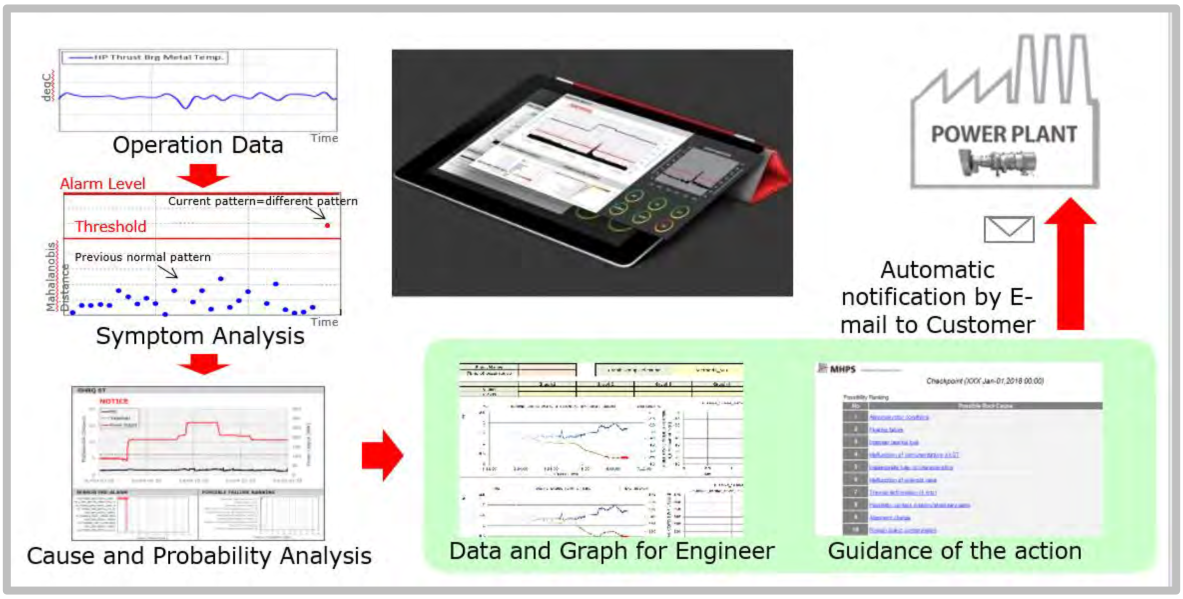
The Thilawa power plant, to which the demonstration program was applied using pilot equipment, commenced commercial operation later than other power plants and is expected to provide a large amount of data because of high availability, for which reason it was guessed that the pilot equipment can be installed and operated smoothly and effectively.

For this, we will provide a pilot equipment, and then will start monitoring experimentally at a certain period/time to identify O&M improvement and implementation system-related lessons from installation of applications considered to be effective. The following applications were experimentally installed.

Table 4-1 Trial Digital Applications

No	Application	Explanation
1	GT abnormal sign detection application (Pre-ACT)	Detects abnormal signs of critical trouble that could lead to a unit trip, and contributes to availability enhancement and minimization of unexpected maintenance fees. It also supports quick response by predicting the cause and presenting necessary actions against the possible cause.
2	KPI visualization application (KPI Analyst)	Visualizes the plant's major operational parameters and management indexes (thermal efficiency, output, and unplanned shutdown). Doing this realizes optimum operation and maintenance, and helps EPGE manage their power generation business.
3	Operator support application (Post-ACT)	Displays information related to handling procedures online to support quick response when an alarm is issued. Moreover, it can record and store unit-specific information, so it contributes to information-sharing and technical transfer.

Source: JICA study team



Source: JICA study team

Fig. 4-3 Pre-Act

Always keep you up to date with power plant's real-time performance, monthly report and how to improve it.

Operating parameters:
MW, speed, Fuel flow, DCT
BPT, Exhaust gas temp. etc.

Capacity and Generation parameters:
Operating hours, Number of starts,
MW, etc

Availability and Reliability parameters:
Trips, Starting Reliability,
Service Factor,
Estimated Reliability, etc

Performance parameters:
Power output, Heat rate, Performance
Degradation, Compressor efficiency, etc.

KPI Analyst sample screen

Source: JICA study team

Fig. 4-4 KPI Analyst

A step-by-step guide to resolve alarms during operation.
Each countermeasure will be stocked on specialized server to make sure that new operators can quickly learn

- Events and Alarms linked to Netmation OPS
- Recommends countermeasures for current events
- Accumulates know-how from user input

Screen samples

Specific Alarm

Alarm Search

Alarm & Solution

Source: JICA study team

Fig. 4-5 Post Act

4.3 Results of Actual Demonstration

4.3.1 Start of Services

In January, 2019, hardware was installed at the Thilawa power plant and started operation as a digital solution.

In March 2019, meetings took place at the Thilawa power plant and in order to explain the usage of the initial data collected from the power plant.

Below are the key points.

[Summary]

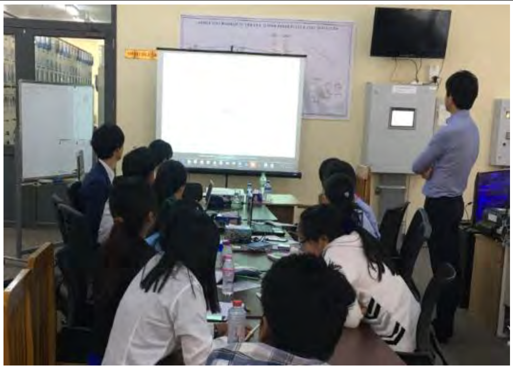
Place	Thilawa power plant
Participants	20 participants including head of power plant.
Schedule	22nd &25th Mar., 2019

[Content]

・Access and log-in to customer portal site, the basic functions of Pre-ACT, Post-ACT, KPI, and Dashboard were explained at the meeting.

・The meeting was not a one-way explanation from trainers, as the participants gained a deep understanding of a pilot equipment by actually operating the system.

1. MHPS-TOMONI Outline Explanation



2. Demonstration

3. EPGE Staff Login

4. EPGE Staff Actual Training

Fig. 4-6 Instructions on How to Use a Pilot Equipment at Thilawa Power Station

4.3.2 Effectivity of the Supplied Applications

We validated the effectiveness of the pilot equipment for the Thilawa power plant.

1. KPI Visualization App.

   The operators in Thilawa are mostly using KPI Visualization App. for monitoring the output and heat rate, while other parameters are also available in the system. KPI Visualization App. is used to grasp the operational parameters trend, and to know the condition of the equipment as the result. Another example of the success is the compressor efficiency. KPI Visualization App. visualizes the compressor efficiency that is used as the input information to set up the blade washing schedule. This is a key activity to minimize performance degradation, and now the Thilawa power plant is enabled to do this in an optimum manner. KPI Visualization App. also displays an operational diagram of the current condition, which is also often used.

2. Operator Support App.

   Operator Support App. is a system that provides guidance to the operator in case of alarms, and the guidance includes instructions on how to react to the alarms, as well as the reasons behind them.

   Operator Support App. provides the pre-installed guidance for major alarms, while a series of guidance documents will also be used as text books to improve operator knowledge.

   Another key aspect of Operator Support App. is that it is a self-growing application, where guidance can be added, from now on, every time the operators face new issues and need to learn new things. In other words, Operator Support App. will work as a knowledge pool management environment, by which the learning of one operator will be shared among other team members by uploading the event description and learned guidance, and by Operator Support App. timely sharing such knowledge to the right people in case of an alarm event.

3. GT Abnormal Sign Detection App.

   GT Abnormal Sign Detection App is designed to detect certain anomalies and email the supporting information to the power station immediately. This will enable the Thilawa power plant to work on the issues, when the issues are at a premature level, and remedy the condition before such issues grow into serious trouble.

   GT Abnormal Sign Detection App will also minimize recovery time in case of an incident, by skipping the time to collect operating data for cause analysis, and instantly sharing issues with the specialists at MHPS.

   Other benefit was also proved as described in section 4.3.3 herein, where GT Abnormal Sign Detection

App. discovered a malfunction of the calorie meter together with the cause, and provided the countermeasure and follow-up notifications. The function to discover the malfunctions of sensors and instruments is a critical factor for properly monitoring equipment conditions and for discovering issues in a predictive manner.

4.3.3 Experimental References

Below are 2 reference examples of the training from soon after the installation of pilot equipment.

Reference 1: Fuel calorie disruptions

As the event, a fuel gas calorie meter displayed irregular calorie values. An alert email was sent by Pre-ACT to the operator.

URL : https://aiguardian.diasysnetmation.com/?datetime=20190319113100&plantid=S03492&unitid=8624&mttype=1&lang=en

Varied data

Varied data	SN [dB]
GT FUEL GAS LOW HEATING VALUE	48.29
GT FFD	13.87

Source: JICA study team

Fig. 4-7 Email Contents by Pre-ACT

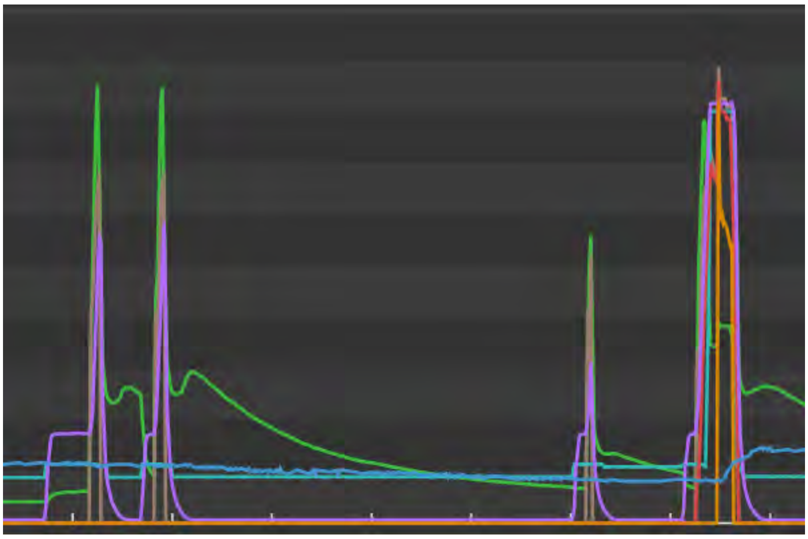
After receiving the alert, the meter itself was manually checked and was found showing a "Failure" message.

Fig. 4-8 Display of Calorimeter Showing "FAILURE"

The reason for the meter failure was the stop of nitrogen supply into the meter.
Once the supply of nitrogen was recovered, the meter was reset and resumed operation. The operator was instructed to check the facility regularly.

This is a good example of how pilot equipment can detect abnormalities, assess failures, and suggest possible troubleshooting with the same piece of information that the EPGE has and how a potential trouble was avoided by taking quick and appropriate actions.

Reference 2: Oil start failure
Pilot equipment checked the data involving a combustor abnormality. In oil startup, the ignition flame was half deteriorated and could not reach the rated speed. Gas starting did not have any problem. The local operator called the manufacturer of the pressure meter and a high possibility of a combustor abnormality was detected. After pulling the nozzles out of the combustor, it was found that 3 out of the 10 nozzles were broken. For reliable operation, it was decided to replace not the broken 3, but all 10 nozzles.



Source: JICA study team

Fig. 4-9 Fuel Oil Startup and Fuel Gas Startup

Fig. 4-10 Damaged Nozzle

Digital solutions made it possible to solve the problem in minimal time by sharing the same data with the local manufacturer and the operator.

4.4 Quantitative and Qualitative Analysis of Actual Demonstration Results

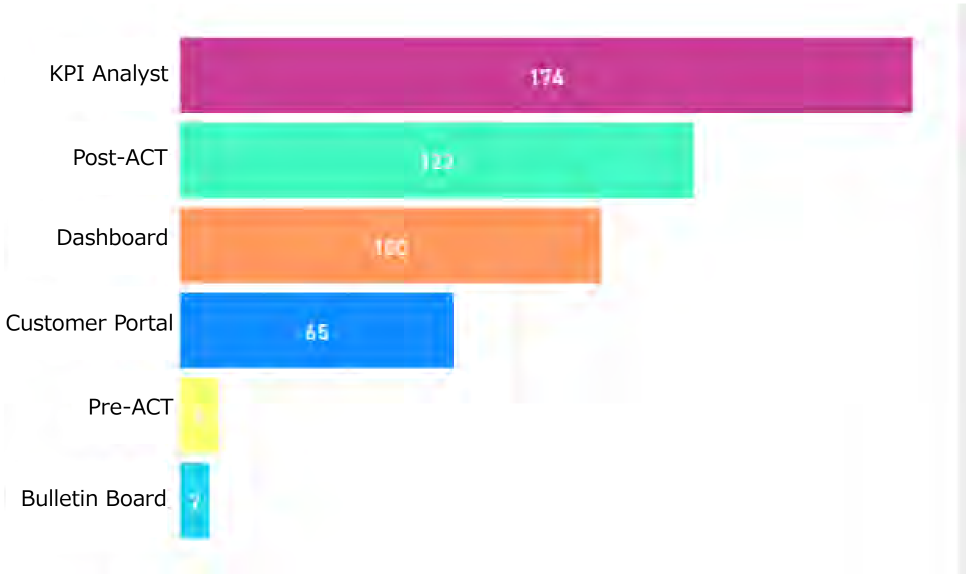
There are 7 persons registered in Thilawa Power Station as below.

Thilawa Station Manager	1person
Executive Engineer	2persons
Assistant Engineer	2persons
Sub-Assistant Engineer	2persons

As two more persons were additionally registered, it seems that the Thilawa power plant users recognized the effectiveness.

Furthermore, EPGE's headquarters is also examining the registrations and further usage expansion is expected.

Access numbers per application over the last 2 months from March 22 to May 29 are shown below.



Source: JICA study team

Fig. 4-11 Number of Accesses to Each App

The digital solution Apps. seem to be evaluated as helpful tools at the Thilawa power plant as they are accessed very frequently.

User's Comments

The followings are the opinions and feedbacks received from the users of the power plant.

① Operator:
I mainly use the tools at home to check the operational condition of the power plant. Operator Support App. and KPI Visualization App. are used frequently. KPI Visualization App. is also used to monitor the trend of the output and the heat rate. The digital solutions are being used effectively.

② Mechanical engineer:
I mainly access the tools from my cellphone and use the KPI Visualization App. (power output, heat rate and compressor efficiency, etc.). These applications are also used in the field. I realized the

convenience of online applications and requested to add some additional functions. I feel it is convenient even though monitoring from the cellphone is limited.

Chapter 5 Issues in O&M and Improvement Methods

In this chapter, we will describe the issues confirmed in Chapters 2 and 3, and propose improvement methods.

Table 5-1 Issues in O&M

Issues in O&M		Improvement Method
Laws, Regulations, Manual Preparation	Laws are regulations related to O&M of power plant are inadequate.	Regulation, Manual Preparation, Training
	Water quality, lubricating oil, control oil, and fuel management are inadequate.	Regulation, Manual Preparation, Training, Equipment Installation
	There are no manuals on the O&M of the power plant.	Regulation, Manual Preparation, Training
	The scope of responsibility of the operators in the central control room and the site inspectors is not clarified.	Regulation, Manual Preparation
	Rules for hazardous areas are not established.	Regulation, Manual Preparation, Training
Human Resource Development System	A human resource development system for O&M is not established.	Regulation, Manual Preparation, Training, System Construction
	Maintenance of instrumentation is inadequate.	Regulation, Manual Preparation, Training
	Not sensitive to alarms Change the control logic and prioritize operation.	Digitalization、Training
	Utilization of control device tools is inadequate.	Digitalization, Regulation, Manual Preparation, Training
Quality Control and Safety Management System	A system for quality control and safety management is not established.	Regulation, Manual Preparation, Training
	Calibration management standards for portable field instruments are not established.	Regulation, Manual Preparation, Training
Procurement Procedures	Procurement management procedures are not established.	Regulation, Manual Preparation, Training
	Procedures for quality confirmation of procurement parts are not established.	Regulation, Manual Preparation
Document and Record Management	Document and record management is inadequate.	Digitalization, Regulation, Manual Preparation, System Construction
	The reporting method to the EPGE head office is not digitalized.	Digitalization, Regulation, Manual Preparation, System Construction

Issues in O&M		Improvement Method
Quantitative Records	Readings collected from local instruments are not utilized for operation management.	Digitalization, Regulation, Manual Preparation, Training, System Construction
	Quantitative records related to power generation are not properly preserved.	Digitalization, Regulation, Manual Preparation, Training, System Construction
	Quantitative records related to power generation are not utilized.	Training
Maintenance Planning and Management	Recorded items at the time of maintenance are not clearly defined.	Digitalization, Regulation, Manual Preparation, Training
	A maintenance plan management system is not established.	System Construction、LTSA
	Criteria for periodic maintenance are not defined.	Regulation, Manual Preparation, Training, LTSA
	Records of periodic maintenance are inadequate.	Regulation, Manual Preparation, Training, LTSA
	Maintenance checks are being conducted by third parties due to budget constraints. (Eg rotor CRI)	LTSA
	Because individual services are separated, there is no optimization / integration as a whole, so it is difficult to identify the cause when a problem occurs.	LTSA
Spare Parts Management	Spare parts inventory is not being properly managed.	Digitalization, Regulation, Manual Preparation, Training, System Construction, LTSA
Accidents Correspondence and Records	Correspondence at the time of an accident or abnormality is not clarified.	Regulation, Manual Preparation, Training
	Records of accidents and abnormalities are not properly created or managed.	Digitalization, Regulation, Manual Preparation, Training
Environmental Management	Environmental management items are not defined.	Digitalization, Regulation, Manual Preparation, Training, System Construction
Access Management	Access management is inadequate because entry and exit are confirmed only with a record sheet and card.	Digitalization, Regulation, Manual Preparation, Training, System Construction
	Security measures are inadequate.	Digitalization, Regulation, Manual

Issues in O&M		Improvement Method
		Preparation, System Construction
Equipment Maintenance	Equipment maintenance is inadequate.	Regulation, Manual Preparation, Training, System Construction, Rehabilitation

Source: JICA study team

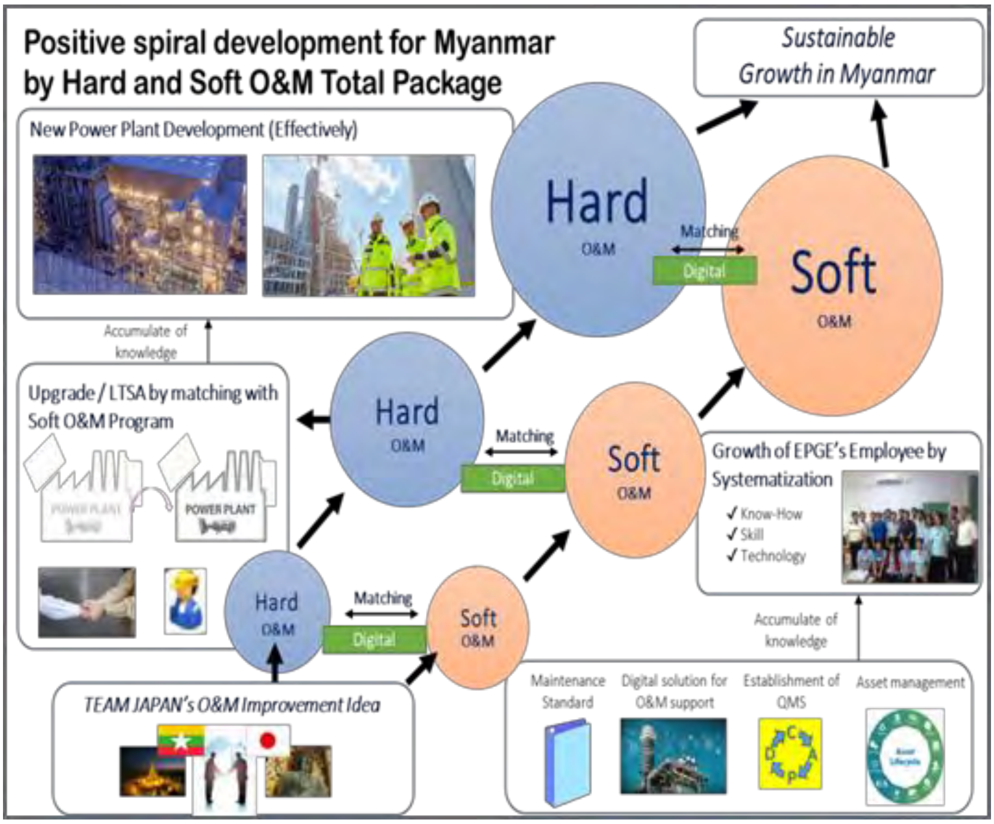
Table 5-1 shows the identified issues. As a result of identifying issues focusing on the O&M of thermal power plants, improvement methods can be categorized as (1) Digitization, (2) Regulation, Manual Preparation, (3) Training, (4) System Construction, (5) LTSA, (6) Rehabilitation, and (7) Equipment Installation.

In order to achieve stable growth and improvement of the Myanmar electric power business in which new power plants will be launched in the future, as shown in Fig. 5-1, the following contents are required.

a. Hard infrastructure support such as equipment supply, rehabilitation and LTSA
b. Soft infrastructure support such as manual maintenance, training and system construction
c. Combined support of both hard and soft infrastructure utilizing digital solutions

Development of this multifaceted power O&M infrastructure should make use of the strengths of Japanese companies.

By providing such support, EPGE officials should be able to autonomously manage new power stations using this package.



Source: JICA study team

Fig. 5-1 O&M Infrastructure Support Image Utilizing Soft, Hard, Digitization

As described in the implementation framework of 1-4, the EPGE Managing Director and the JICA study team have agreed to classify support in digitization, and soft and hard infrastructure as Solutions A, B, and C respectively, jointly review and promote concrete solutions thereof.

The relationship between improvement proposals ① to ⑦ and these Solutions is as follows.

Table 5-2 Improvement Proposal Classification

Support Program	Improvement Proposals
Solution A （Digital Package）	①Digitization
Solution B （Soft Infrastructure）	②Regulation, Manual Preparation ③Training ④System Construction
Solution C （Hard Infrastructure）	⑤LTSA ⑥Rehabilitation ⑦Equipment Installation

Source: JICA study team

Details of the issues and improvement proposals for each item ① to ⑦ concerning the O&M of thermal power plants and the O&M of hydropower plants are shown below.

Specific solutions for EPGE are described in Chapter 7.

5.1 Digitalization

We visited each power plant for investigation and found that operation and maintenance data were used and managed in paper format, and that troubles and measures were also recorded on paper. In addition, the data and records are not stored but disposed of after a certain period of time. Knowledge is not accumulated and action for improvement based on learning from past lessons is not taken.

When we visited the EPGE HQ, we heard that operation data such as the output of each plant were not managed in real-time at the EPGE HQ and that output commands for output control were analog.

Because information transfer between the EPGE HQ and each plant is analog and slow, it takes much time to make an appropriate decision, and the required time to recover from damage cannot be secured. Digital solutions are part of a package of solutions for improving the current situation in Myanmar.

As described in Chapter 4, the pilot equipment (remote monitoring equipment) was installed at the Thilawa Power Station through this survey to verify the effectiveness of the digital solutions, and based on this result, it is expected that the development of digital solutions will proceed effectively.

5.2 Manual Preparation

5.2.1 Current Status and Necessity of Manuals

As described in Chapters 2 and 3, appropriate regulations and manuals concerning the O&M of thermal power plants have not been established. In the absence of rules and manuals, work gradually diversifies and becomes complicated and disorderly, making it difficult to operate smoothly. Therefore, it is necessary to decide rational and necessary matters for carrying out business in order to be able to operate efficiently. The regulations / manuals currently made by KANSAI are as follows.

Table 5-3 Rules / Manual List Established by KANSAI (Common Matters)

Business plan item		Head office functions	Thermal power plant
Common	Competence management (training)	・Procedures for planned training and training related to the acquisition of knowledge, skills, etc. (special skills) necessary for the execution of thermal power work such as design, construction, inspection, repair and operation of thermal power generation equipment ・Make criteria for judging competence to drive, operate, etc. thermal power plants or supervise persons who operate / drive them.	—
	Document / record management	・Procedures for properly maintaining and managing records that result from implementing documents and tasks used for business	—
	Evaluation and improvement of work	· Matters concerning the following management items necessary for continuous improvement of thermal power operations (1) Internal audits (2) Corrective actions, preventive actions (3) Management reviews	—
	Lead engineer	・Details of the duties of the chief engineer of electrical business facilities at thermal power plant	・Submit papers concerning electrical facilities for private use to chief engineers.
	Legal inspection	· Procedures for legal inspections of thermal power plant (before use,	—

Business plan item		Head office functions	Thermal power plant
		welding, regular) · Evaluation and improvement procedures for the above procedures	
	Subcontract management	· Procedures for outsourcing · Our requirements described in construction or purchase specifications · The following matters to ensure the quality of delivered equipment (1) Review of new manufacturers Procedures for managing approved vendor lists (2) Inspection procedure at the time of equipment delivery	–
	Environmental protection	· The following matters for environmental conservation at thermal power stations (1) Wastewater management (2) Smoke management (3) Waste treatment	· Wastewater treatment standards and treatment methods · Waste management system, industrial waste loading and unloading method
	Measures against abnormalities such as accidents	· The following matters concerning measures at times of accidents such as accidents at thermal power stations (1) Prevention of accidents and other abnormalities (2) Prevention of expansion, restoration, prevention of recurrence in case of accident or other abnormality (3) Information-sharing about such as accidents	–

Business plan item		Head office functions	Thermal power plant
	Disasters and other emergency measures	· How to cope with disasters at thermal power plants · The following matters concerning how to cope with disasters, etc. (1) Procedures for preventing widespread damage at and recovering thermal power plants (2) Procedures for preventing chemical disasters, accidents, etc.	· The following matters that require individual regulations (1) Organization in order to take countermeasures against disaster (2) Initial contact list (3) Checklist of equipment in an earthquake (4) List of outside disaster prevention agencies (5) Evacuation Place / Evacuation Route (6) Self-defense fire brigade organization table (7) How to cope with natural gas conduit abnormality
	Health and safety	· The following matters concerning safety and health at thermal power stations (1) Safety measures at work (2) Safety and health training and training (3) Environment improvement	· Restricted area drawings
	Business Administration	· The following matters are necessary for business management (1) Budget of a thermal power plant managed within the total budget (2) Data management to evaluate thermal power plant operation, such as thermal efficiency (3) Other matters necessary for business management	· The following matters that require individual regulations (1) Daily management standard values related to thermal efficiency (2) Study on actual thermal efficiency (as total power plant, by unit)

Source: JICA study team

Table 5-4 Rules / Manual List Established by KANSAI (Maintenance / Operation)

Business plan item		Head office functions	Thermal power plant
Power generation management and shift	Power generation management	· In order to prevent accidents, etc. and to maintain the performance of the equipment, the following items are necessary for generating electricity according to the load dispatching instructions. (1) Duty system, how to hand over the duties between shift members (2) Jurisdiction classification of work (3) How to carry out load dispatch instructions (4) Reporting and business communications (5) Operation records (6) Operation monitoring (7) Equipment operation (8) Efficient operation (9) Exams (10) Operation maintenance (11) Work slips, stoppages (12) Treatment of chemicals (13) Fuel test management (14) Water quality management (15) Management of lubricating oil, etc.	· The following matters that require individual regulations (1) Operating parameters of fuel oil equipment (2) List of control values in operation and safety logbooks (3) Operation (4) Operation during accidents (5) Periodic tests (6) How to cope with alarms (7) How to hand over between chief duties (8) How to hand over between management department and shift members (9) Operation logbooks (for unit computer shutdown) (10) Unit start and stop record (check list) (11) Locking management book of valves and equipment (12) Fuel oil burner management table (13) Water supply treatment method and water quality standard value (14) Allowable amount of adhering scale in boilers (15) Treatment method of cooling water for condensers (16) Chemical internal inspections during periodic inspections (17) Upper and lower limit levels of fuel oil tanks in operation (18) Fuel test methods (19) Management method of equipment operation (20) EH governor oil test frequency (21)

Business plan item		Head office functions	Thermal power plant
			Chemical management system chart
	Long-term planned suspension	· Stop of long-term plan, etc. The following matters for securing equipment security when stopping operation for a considerable period (1) Storage treatment (2) Treatment of remaining fuel and operating oil (3) Separation of suspended parts and operating parts, separation of connecting parts (4) Inspection and commissioning for restart of operation	–
	Patrol inspection	· Procedures for patrol inspection to ensure necessary security of thermal power generation equipment and to prevent accidents by early detection of abnormalities	· Patrol inspection chart
	Management of identification method	・Matters concerning identification to ensure fire-fighting safety and to surely carry out load dispatch instructions (1) Identification of equipment failure points (2) Identification of work sites	–

Business plan item		Head office functions	Thermal power plant
Maintenance	Planning and implementation of maintenance work	· The following matters to carry out construction necessary for the prevention of accidents and maintenance of facility functions (1) Construction plan (2) Construction preparation (3) Implementation of work · Inspection standards and repair standards for securing the safety of thermal power facilities - Basic requirements quality (design standards, product standards, standard specifications, etc.) for ensuring equipment installation and medium- to long-term reliability	·Maintenance standards for each facility of the power plant
	Inspection	· In order to assure the safety of thermal power generation facilities, inspection and inspection procedures necessary for confirming that they conform to the technical standards during construction or at the end of construction and that there is no obstruction to safety	–
	Management of inspection and measurement equipment and test equipment	· Management procedures for inspection / measurement equipment and test equipment necessary to carefully inspect, measure, test and ensure that equipment performance is maintained	· Periodic inspection table for measurement equipment that is likely to change considerably in function over time
	Management of identification method	Matters concerning the identification of the following items to ensure thermal power safety, to prevent from mis-operation and to surely carry out	–

Business plan item		Head office functions	Thermal power plant
		load dispatch instructions (1) Identification of work place (2) Identification of equipment name, etc.	
	Equipment management	In order to ensure necessary safety of thermal power generation equipment and to prevent accidents, etc. by early detection of abnormality, rules concerning the formulation of an appropriate construction plan (1) Inspection of equipment (2) Improvement of facility management data (3) Maintenance of drawings (4) Management of spare parts and accessories (5) Facilities defect · problem management (6) Other necessary items	· Interval of patrol inspection by maintenance department, scope of inspection ·Format of inspection records

Source: JICA study team

5.2.2 Proposal of Manuals for Each Task

Of the aforementioned items prescribed by KANSAI, it is desirable to define all matters excluding items that do not need to be managed in the country, via manuals. However, it is difficult to determine all manuals in one go. Also, since Myanmar and Japan have different legal systems and social environments, effective manuals may not be exactly the same.

As described in Chapter 2, electricity rules have been established in Myanmar, but there are no regulations on performance standards against these electricity rules.

Regarding regulations and technical standards (① safety, reliability, cost of power generation, ② construction of power generation facilities, ③ operation standards, ④ maintenance schedule, ⑤ quality of electrical equipment) on performance that currently do not exist, we propose establishing regulations and technical standards for the current situation of Myanmar using the following three steps, as a technical cooperation project.

<u>Step 1 Selection of technical standard to be established</u>

Based on Japanese technical requirements and standards, we will select regulations and technical standards necessary for Myanmar. In addition, we will also organize the regulatory system of regulations based on law or private standards.

Step 2 Review of regulation creation process

Not only knowledge of manufacturers and users but also participation of academics and experts is indispensable for establishing technical standards. For this reason, we will create a process for establishing technical requirements, i.e., organization including the establishment of committees, and schedule.

Step 3 Establishment of standards

Based on the regulation and technical requirement formulation process discussed in Step 2, government and academics will together establish necessary regulations, etc. for Myanmar.

The establishment of regulations, etc. as mentioned above will be a long-term technical cooperation project. Therefore, based on the results of the survey, we propose the following rules and manuals in advance for the tasks that we think should be resolved.

(1) General Operation and Maintenance of Power Generation Facilities

Table 5-5 Manuals on General Matters of Operation and Maintenance of Power Generation Facilities

Present situation	Proposed rule / manual	
	Name	**Contents / Aim**
Water quality, lubricating oil, control oil not properly implemented	Water quality management manual	It is known that troubles will occur due to scale and corrosion caused by water quality in each facility of the power plant. If early detection of these abnormal symptoms can be done, there are the following merits. · Prevention of non-scheduled suspension by prevention of obstacles · Reduction of repair costs ·Reduction of fuel costs by maintaining optimum power generation efficiency of the plant In order to manage water quality properly, this manual defines the following items. · How to handle feed water · Treatment at the time of leakage of condenser seawater, treatment during suspension and startup · Chemical cleaning method of boilers
	Lubricant management manual	Various oils used in the main power plant equipment such as main the turbine are used for power transmission, lubrication, process control, etc., and their role is crucial. However, these oils degrade over time, which may invite performance deterioration and troubles such as mechanical troubles. Therefore, in order to prevent malfunction caused by lubricating oil or the like in advance, a maintenance / management method is determined as follows. Management at the time of acceptance, management during driving · Management standards, testing, replacement, oil flushing method

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Manuals related to operation and maintenance of power plants have not been produced	Establishment of quality management system (QMS)	It is necessary to systematically improve the rules and manuals concerning the operation and maintenance of power stations and to continually improve these regulations in order to carry out works smoothly. Here, we will establish a QMS so that the power plant can be operated more efficiently. QMS: To establish quality policy / objectives and to do the following activities to achieve those goals. We will improve this power generation quality by building this QMS. ① Establish organizational quality policy and goals based on it, ② define division goals / action plans, etc. to achieve it, ③ carry out operations as planned (in a managed state: documented), ④compare the work results against targets (evaluate the effectiveness), analyze the cause in the case goals are not achieved, ⑤ devise and implement measures to achieve the goals based on the cause (improve effectiveness). Specifically, internal audits, corrective and preventive measures, management review methods, etc. shall be established.
Job contents of the central control agent and the shift member are not clarified	Provision of job contents of shift members	By clarifying the duties of the shift members, the following merits are obtained. · Homogenizing work (raising the business capability of inexperienced watchmen) · High quality (application of experienced personnel's skill to similar job) · Prevention of accidents (prevention of misoperation, early detection of defects) Therefore, the following items are defined here. · Shift system · task-sharing, job content

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Rules for hazardous areas are not established	Creation of hazardous areas	It is important for workers on the premises to know where dangerous areas are, from the viewpoint of preventing serious accidents such as fire and explosion, and securing one's own safety. For this reason, we classify the premises of the power station by the next three regulated areas, and establish the regulations shown on the map of the power station. Specifically, the following items are defined. · Designation of restricted area, content of regulations, rules concerning in-house work

Source: JICA study team

(2) Human Resource Development Management

Table 5-6 Manual on Human Resource Development Management

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Human resource development system for facility operation / maintenance has not been established There is no maintenance department related to instrumentation (specialist absent)	Manual defining human resource development system	In order to operate the power plant, personnel with knowledge of each task is needed. Such human resources cannot be cultivated overnight. It is important to give appropriate training based on each person's ability and degree of understanding. Therefore, we devise measures to acquire the knowledge and skills necessary for work according to the competence level, and plan to maintain human resources and improve their technical skills. Specifically, the following items are defined. · Setting of specialized skills, skill training system by level of skill, training plan, target at each competence level · Development · Training period and method, record of specialized skills In addition, regarding the training to be conducted at the training center, the following items shall be established so that the work can be carried out smoothly. · Training management method (planning, implementation) · Training records, goals of learning special skills according to each one's ability, training plan, learning method

Source: JICA study team

(3) Safety Management

Table 5-7 Manual on Safety Management

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Details of the safety management system have not been established	Safety management manual	When a worker is injured, rescue is required and the workforce may be decreased. It may delay the work process. Therefore, in addition to securing the safety of workers, it is necessary to establish rules for quality and safety in order to conduct work in a planned manner. Therefore, the following items and others shall be defined. · About safety and health (Safety measures at work, preliminary assessment of safety before construction work, revision of specifications based on the assessment) ·Identification management (Identification of - defects in facilities or work sites - inert gas inflow points - name of equipment before we work.)
Criteria for calibration of portable measuring instruments, etc. are not established	Instrument management manual	Instruments and sensors will not perform at the same level forever. The performance of the measuring instrument gradually changes due to aging, environment, usage situation, etc. For that reason, it is necessary to periodically calibrate them to maintain performance and the reliability of the measurement. Therefore, the following items are defined. · Instrument management method (-instrument error setting, -management of each instrument and its installation, -management of storage media, inspection -correction of abnormalities) · Management of standard equipment (Preparation, operation, signage, usage history management, inspection, correction at time of abnormality)

Source: JICA study team

(4) Parts Procurement Management

Table 5-8 Manual on Parts Procurement Management

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Details of parts procurement and management rules are not established Procedures for quality confirmation of procurement parts are not established	Parts Procurement Manual	In order to maintain the soundness of each facility of the power plant, it is necessary to procure a lot of things from parts to consumables. By setting such part procurement work, there are the following merits. · Labor-savings by simplifying business · Maintaining of quality of procurement parts by homogenizing inspection method · Cost reduction Therefore, the following items and others shall be defined. · Simple procurement type setting, inspection method, storage / non-use sale, estimate, specification items etc.

Source: JICA study team

(5) Document / Record Management

Table 5-9 Manual on Document / Record Management

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Document / record management is not sufficient	Document management manual	Even at power plants, operations such as recording, handover, reporting, etc. require many documents. Therefore, determining the operation method and improvement method of these documents leads to an improvement in quality and efficiency of the overall operation of a power plant. Here, the following general items regarding document management are defined. · Responsibility and authority · Regulations concerning document work (correction / prevention, provisional operation, settlement / revision / abolishment, correction / dissemination, registration, storage, lending, record renewal, deletion, retention)

Source: JICA study team

(6) Power Generation Record Management

Table 5-10 Manual on Power Generation Record Management

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Records of local instruments are not utilized for operation management	Manual of recording at site	At a power plant, not all measured values can be checked in the central control room. Some of them can be confirmed only on a local panel, and need to be managed for the sake of equipment operation. By organizing the values to be locally recorded into a manual, there are the following merits. · Streamlining of the recording process · Improvement in the quality of equipment management
Quantitative records on power generation are not properly preserved	Generation data management manual	A large amount of data is collected daily at a power plant. Among them, by using typical parameters related to power generation, management has the following merits. · Improvement of power generation quality · Reduction of unplanned outages owing to early detection of defects · Pinpointing of the cause when trouble occurs For this reason, the following basic data matters relating to statistical data processing are defined. · Data type to be managed Actual operation data required for management, fuel consumption records, start / stop records, security log data such as maximum power, pressure and temperature of key units, in-house electric energy data ·Management method Grasping of achievements, reporting to the top organizations · Standard value management ・ Management of -reference parameters in start / stop operation -reference thermal efficiency
	Thermal efficiency	The purpose of O&M is to maintain the performance of the power plant and a stable power supply. Thermal efficiency is one

Present situation	Proposed rule / manual	
	Name	Contents / Aim
	management manual	indicator of the performance of a power plant. The following advantages can be gained by managing thermal efficiency. · Factors of performance degradation, early detection of abnormal symptoms, application to countermeasure planning · It is possible to maintain and improve thermal efficiency by early recovery. · Efficient operation by accurately reflecting the generation reference value In this section, basic items related to thermal efficiency management as described below are defined. · Establishment of thermal efficiency management standards · Management of thermal efficiency (daily, monthly) -Confirmation of actual thermal efficiency - investigation of deviations - reporting - countermeasures if trouble is detected · performance testing Test type, method of implementation (condition, frequency, recording format, etc.), response if a failure is detected

Source: JICA study team

(7) Maintenance Planning and Management

Table 5-11 Manual on Maintenance Planning and Management

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Recorded items of maintenance record are not clearly defined	Periodic inspection manual	It is important to set inspection methods, judgment criteria, recording method, etc. for maintenance. For example, if the inspection method is not defined, there is a possibility that the inspection quality differs depending on the inspector and the inspection timing, and the parts to be checked correctly cannot be

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Determination criteria of periodic inspections are not defined Records of periodic inspections are inadequate		inspected. In addition, if the judgment criteria are not defined, problems could clear investigations despite the fact that the parts should actually be replaced, and maintenance such as parts replacement might be carried out even when there are no problems. So, there is a possibility that maintenance cannot be properly done. Also, if the records are not appropriately stored, it is not possible to fully grasp the amount of deterioration over time and inspection results, and it is impossible to plan a maintenance schedule and take appropriate countermeasure if trouble occurs. Therefore, as described below, items common to all power plants and necessary items for each power plant are determined. (1) Common to all power plants / general In addition to prescribing detailed inspection items, in order to ensure both the reliability of thermal power plants and a reduction in maintenance cost, implementation guidelines concerning the establishment and review of equipment inspection standards based on risk assessment are defined. In addition, the inspection method and criteria are shown, and, for overhauls, the items to be checked and the criteria are shown. (2) Each power plant The installed facilities depend on each plant. EPGE should maintain the performance of these facilities at each power plant and determine how to maintain performance in order to prevent accidents caused by deterioration. Also, based on inspection standards, the inspections to be carried out at the power plant and the criteria for judgment at the time of overhaul will be stipulated.

Source: JICA study team

(8) Spare Parts and Accessories Management

Table 5-12 Manuals on Spare Parts and Accessories Management

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Spare parts are not being properly managed	Spare parts / accessories management manual	If the spare parts are not adequately managed, the following problems may occur, which may cause extra costs. Particularly, hot gas path parts of gas turbines are expensive and the disadvantage is great when not properly managed. · Extra storage (Each power station may store spare parts that can be shared with others.) · Extra storage (Some power station may store old parts.) Here, as described below, the aims are to specify details such as management and storage of spare parts, and properly manage spare parts. Also, regarding equipment accessories (special tools, special trolleys), similarly, the aims are to determine management methods and maintain accessories properly. · Items of spare parts · Standard quantity, management method (storage, individual management), management system operation method - Item name of the accessory, standard quantity, management method (storage, loan, retirement, individual management)

Source: JICA study team

(9) Accident / Abnormality Response

Table 5-13 Manual on Accident / Abnormal Hours Handling

Present situation	Proposed rule / manual	
	Name	Contents / Aim
How to respond to accidents / abnormalities is not clarified	Accident handling manual	Regarding accidents and abnormalities, it is better to organize the countermeasures according to circumstances beforehand, because it will be easier to deal with and minimize the trouble. Also, by organizing the handling of related accident information and information expected to occur such as accidents, it is possible to prevent such accidents and their recurrence. Here, the following actions for accidents and in-house troubles are determined. (1) Prevention of accidents and other abnormalities Near-miss case sheet, report, discussion, sharing within the workplace "Near-miss" means, although there was a possibility of an accident, it was discovered and prevented before the accident occurred. (2) How to respond when an accident/abnormality occurs a. Prevention of expansion, restoration Information on each accident event (probable cause, setting rationale for each alarm, etc., details of phenomenon), treatment / operation method, logic diagram and flow chart b. Information sharing / reporting Report on accidents, relevant work / operation status records, report preparations, internal higher ranking organizations, etc. c. Prevention of recurrence, horizontal deployment Examination (by stakeholder interview, FT diagram etc.), preservation of study records, horizontal development including to other sites
Records of accidents / abnormalities are not properly created / managed	Accident recording manual	It is difficult to completely prevent accidents and abnormalities, but it is possible to enhance the response capability in the event of an accident, by properly managing information such as accidents that have occurred so far. Here, we describe the following method of recording and managing the situation at the time of the accident.

Present situation	Proposed rule / manual	
	Name	Contents / Aim
		· Form and operation flow of various types of records (near-miss case sheet, accident, etc. preliminary report · in-house breaking news, horizontal deployment, examination on measures to prevent recurrence)

Source: JICA study team

(10) Admission Control

Table 5-14 Manual on Access Control

Present situation	Proposed rule / manual	
	Name	Contents / Aim
Entry / Exit confirmation relies entirely on entry / exit cards; management is inadequate	Access Control Manual	A power plant is operated by many people. In order to properly operate a power plant, it is necessary to manage the entry and leaving of these people. For example, if you cannot provide information on safety such as the location of dangerous goods to visitors, the safety of visitors cannot be ensured in case of an emergency such as a disaster. Also, if you do not manage the number of visitors, you will not be able to confirm the safety of visitors in the event of an emergency, etc., and the response will be delayed. Here, items necessary for conducting access control are defined as follows. · Entry training (Visitors are not allowed to go anywhere other than their planned destination.) · Methods of access control
Inadequate security measures	Security Manual	Although the equipment of the power plant operates stably, malicious behavior may cause a dangerous situation, and it may have an influence on power generation as well. For that reason, we set countermeasures in the event of invasion by a suspicious individual and prepare for unforeseen circumstances.

Source: JICA study team

(11) Equipment Repair

Table 5-15 Manual on Equipment Repair

Present situation	Proposed rule / manual	
	Name	**Contents / Aim**
Equipment repair is inadequate	Maintenance standards	Equipment consists of many parts, and it is difficult to inspect all parts within a limited budget. Also, the probability of failure occurrence and the ripple effect depend on each failure. Therefore, from the viewpoint of the possibility of failure and influence therefrom, there is a method for determining the scope and frequency of inspections. By using this method, it is possible to omit inspections of certain parts if the possibility and influence of trouble is expected to be little. On the other hand, it is possible to enhance the inspection if the frequency of trouble and its influence expected to be large. In this way, it is possible to achieve both high reliability and low maintenance cost. In this manual, inspection standards based on risk assessment are established by specifying inspection equipment and parts, inspection method (NDI type, etc.), inspection cycle, facility refurbishment criteria and so on.

Source: JICA study team

5.3 Training

5.3.1 Issues

As mentioned in Chapters 2 and 3, training is being conducted at the Paunglaung training center in the hydropower department, and training materials and systems are established to some extent. However, in the thermal power department, training facilities are inadequate, so training opportunities are limited.

Regarding training centers for the thermal power department, although it is permitted to create training centers in the Electricity Rule, none has been established as of yet.

In addition, training opportunities are often only for head office members, and training for power station staff is not sufficient. Training for power station staff is basically only OJT, but, due to the lack of training materials, there are differences in the content and quality of training depending on instructors.

Even when a problem occurs, the power plant cannot communicate directly with the OEM, and opportunities to acquire knowledge and skills from the OEM are also limited.

Human resource development and training management systems have not been established, so it is difficult to continuously improve knowledge and skills. First of all, after reforming the awareness of training and recognizing that training of each item is important, it is necessary to impart training in specialized skills.

Table 5-16 shows a list of problems and necessary training contents that are caused by the inadequate training system confirmed in this site survey.

Table 5-16 Training Issues

Item	Issues	Necessary Training
Laws, Regulations, Manual Preparation	✓The need to maintain manuals is not understood. ✓The importance of water quality, lubricating oil, control oil, and fuel management is not understood. ✓The need to specify hazardous areas is not understood.	✓Necessity of manuals ✓Necessity of documentation ✓Systematic way to create laws and regulations
Human Resource Development System	✓The importance of human resource development and skill checks is not understood. ✓There are no experts (chemistry, measuring instruments, and control equipment). ✓The contents and urgency of alarm items are not understood.	✓Importance of managing human resource development and skill checks ✓Skills of specific fields ✓Necessity and method of water quality management, instrument calibration, control device utilization
Quality Control and Safety Management System	✓Awareness of quality and safety management is low.	✓Necessity and method of quality control and safety management
Procurement Procedures	✓Awareness of procurement management is low.	✓Necessity and method of procurement management
Quantitative Records	✓The need for records related to power generation is not understood. ✓Awareness of fuel consumption and power generation efficiency is low. ✓Awareness of instrument maintenance is low. ✓Data utilization methods are not understood.	✓Necessity of records related to power generation ✓Reforming the awareness of cost-performance ✓Necessity and method of instrument calibration ✓Necessity and method of performance management
Maintenance Planning and Management	✓The need for maintenance standards is not understood. Judgment is based on experience. ✓Awareness of periodic maintenance records is low.	✓Necessity of maintenance standards ✓Concept of judgment criteria ✓Necessity and method of maintenance records
Spare Parts Management	✓Awareness of spare parts management is low.	✓Necessity of spare parts management

Item	Issues	Necessary Training
	✓Items to be managed regarding inventory are not understood.	✓Items to be managed and method
Accident Response and Records	✓Awareness of abnormal states (alarms) is low. ✓Awareness of cause analysis and measures to prevent recurrence is low.	✓Reforming the awareness of response to alarms ✓Necessity and method of cause analysis ✓Necessity of countermeasures ✓Past failure events and lessons
Environmental Management	✓Awareness of environmental management is low.	✓Necessity and method of environmental management
Access Management	✓Awareness of access management is low.	✓Necessity and method of access management
Equipment Maintenance	✓Awareness of equipment maintenance is low. ✓There is a lack of expertise in discovering trouble.	✓Necessity of equipment maintenance ✓Impact on power plant operation ✓Expertise in each device

Source: JICA study team

5.3.2 Trial Training

In consideration of the applicability of JICA technical cooperation projects, based on the results of the first site survey of the situation of O&M, the JICA study team conducted trial training at the Ahlone power station during the second site survey from December 11 to 13, 2018.

Trial training items and timetable were as follows.

Table 5-17 Trial Training Items

No	Items	Contents
1	GT Training	GT Structure and Necessity of Maintenance
2	Operation Simulation	Troubleshooting during CCGT Operation
3	QMS	Necessity of Quality Management System and Outline of Management
4	Safety Measures	Necessity of Safety Activity and Outline of Safety Measures
5	Performance Management	Necessity of Performance Management and Outline of Management Methods of Performance
6	Vibration Diagnosis Technology	Necessity of Diagnosis and Outline of Diagnosis Methods
7	Lube Oil Treatment	Necessity of Diagnosis, Outline of Diagnostic Methods and Necessity of Treatment
8	Feed Water Treatment	Necessity of Water Quality Management and Outline of Management Methods

9	Facility Diagnosis Technology	Necessity of Non-Destructive Inspection and Outline of Inspection Methods

Source: JICA study team

Time	December		
	11th(Tue)	12th(Wed)	13th(Thu)
9:00 – 9:50	GT Structure and Necessity of Maintenance	QMS Quality Management System	Facility Diagnosis Technology
Break			
10:00 – 10:50	GT Structure and Necessity of Maintenance	Safety Measures	Tablet Tool
Break			
11:00 – 11:50	GT Structure and Necessity of Maintenance	Performance Management	Remote Monitoring
Lunch Break			
13:00 – 13:50	Troubleshooting during CCGT Operation	Vibration Diagnosis Technology	Portable Gas Detector
Break			
14:00 – 14:50	Troubleshooting during CCGT Operation	Lube Oil Treatment	Portable Thermal Camera
Break			
15:00 – 15:50	Troubleshooting during CCGT Operation	Feed Water Treatment	Interview
Break			
16:00 – 16:50	Interview	Interview	Venue : Ahlone Power Station

Source: JICA study team

Fig. 5-2 Trial Training and Demonstration Timetable

In this trial training program, 14 engineers participated from each power plant. The participants were as follows.

Table 5-18 Participants List

No.	Position	Department	Power Station
1	Assistant Engineer	Electrical	Thilawa
2	Assistant Engineer	Electrical	
3	Executive Engineer	Electrical	
4	Assistant Engineer	Electrical	Ywama
5	Executive Engineer	Mechanical	
6	Assistant Engineer	Electrical	
7	Executive Engineer	Electrical	Thaketa
8	Executive Engineer	Mechanical	
9	Assistant Engineer	Mechanical	
10	Assistant Engineer	Mechanical	Ahlone
11	Assistant Engineer	Electrical	
12	Assistant Engineer	Mechanical	
13	Assistant Engineer	Electrical	Hlawga
14	Assistant Engineer	Mechanical	

Source: JICA study team

From a questionnaire that was submitted to participants after the training program, we checked the overall satisfaction level and the desired training menu, and obtained the following results.

Table 5-19 Result of Participants Questionnaire

Participants：14 名

No.	Impression	number
1	Highly Satisfied	10
2	Somewhat Satisfied	1
3	Neutral	3
4	Somewhat Dissatisfied	0
5	Highly Dissatisfied	0

Fig. 5-3 Trial Training

Source: JICA study team

Desired Training Menu

- ✓ Practical training
- ✓ Practical training using a simulator
- ✓ State-of-the-art CCGT technology (high power, high efficiency)
- ✓ Details of inspection contents of gas turbine H-25
- ✓ Power plant operation, etc.

As a result of the trial training, it was confirmed that it is necessary to carry out continuous training, including awareness reform, regarding safety measures, performance and quality control, etc. where there are few opportunities to learn only with regular OJT. As individual skills and aspirations are at a high level, it is considered possible to construct a system to properly perform O&M and improve the ability of staff by preparing learning materials and opportunities according to each person's level.

Also, as in the desired training menu, it is more effective to conduct not only theoretical training in the classroom but also practical training.

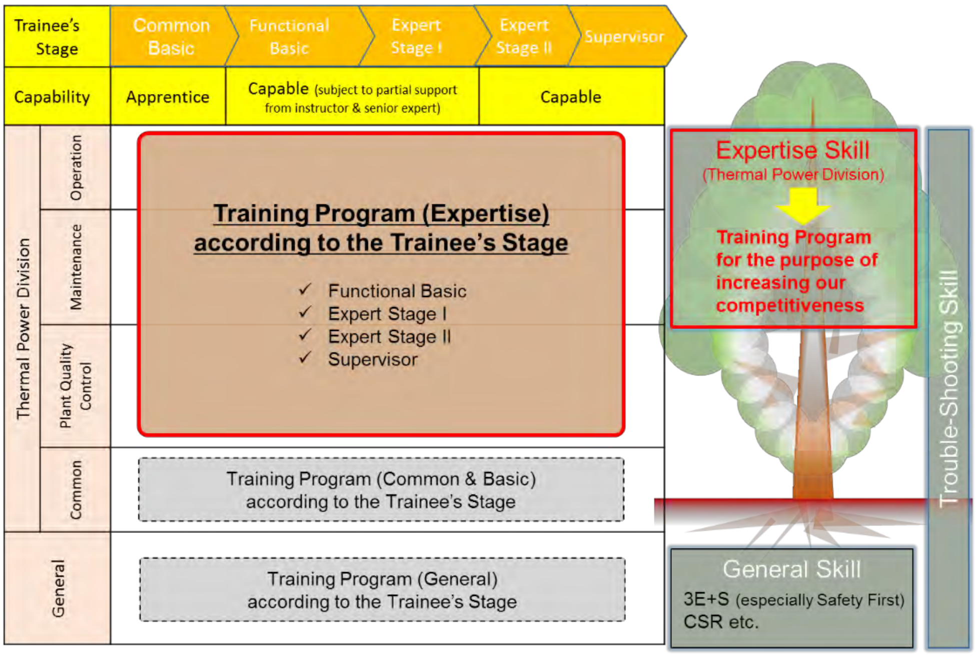
5.3.3 Improvement Proposals

(1) Human Resources Development Management System

Since a human resource development and training management system is not established, we firstly propose to establish human resource development and management mechanism, and implement step-by-step basic training and expertise training according to the target level.

Electric utilities in Japan have established a training system to gradually acquire specialized skills in order to efficiently operate thermal power plants. Examples of the level-based training system and the specialized skill training program for a maintenance engineer are shown in Fig. 5-4 and Fig. 5-5.

Considering the power station organization and employment system in Myanmar, it is important to construct an effective training system and training programs.



Source: JICA study team

Fig. 5-4 Overall Structure of Training Program in the Thermal Power Department

Trainee's Stage	Common Basic	Functional Basic	Expert Stage I	Expert Stage II
Capability	Apprentice	Capable (subject to partial support from instructor & senior expert)		Capable
Mechanical	Beginners' Course	Boiler & Turbine Basic Course	Boiler & Turbine Expert Stage I Course	Residual Life Assessment Expert Stage II Course
		Fan/Valve/Pump Basic Course	Technical Regulation Expert Stage I Course	
		Gas Turbine Basic Course	Metallic Material Expert Stage I Course	Gas Turbine Expert Stage II Course
			Combustion Expert Stage I Course	Boiler Expert Stage II Course
			Welding Expert Course	
Electrical		Electrical Basic Course	Electrical Expert Stage I Course	AVR Expert Stage II Course
		Motor/Valve Basic Course	Transformer Expert Stage I Course	Generator Expert Stage II Course
		Gas Turbine Basic Course		
Instrumentation		Instrumentation Basic Course	Instrumentation Expert Stage I Course	Gas Turbine Expert Stage II Course
		Gas Turbine Basic Course	Digital Calculator Expert Stage I Course	Combustion Expert Stage II Course

Legend
: In-house
: Outsourced (Manufacturer etc.)

Source: JICA study team

Fig. 5-5 Maintenance Main Training Program

In order to follow up on the weak points of trainees, the basic and specialized skills acquired through these training programs are checked, recorded and managed. The skill record system, abbreviated as SRS, is described in section 5-4 "System Construction" in detail.

By properly managing records, it is possible to continuously provide the necessary training even when the trainee is transferred between power plants.

In the next step, it is necessary to select MOEE 's counterpart, dispatch experts from Japan, and support them so that they can build the necessary training systems for MOEE by themselves.

As a part of the development of a training system, it is also important to build a training facility that can conduct practical training in Myanmar.

(2) O&M Training (Invitation to Japan)

In the future, it is hoped to build a mechanism of human resources development as described above in Myanmar, build a training environment including training facilities, and carry on continuous training. However, at the present stage, O&M management skill, training facilities, and training materials are not sufficient.

Given the circumstances, we propose training in operation and maintenance for core members at power plants in Japan, where training programs and facilities are in place.

The image of the training program is as follows.

Source: JICA study team

Fig. 5-6 Training Program

In addition, in order to effectively implement training, it is possible to propose training contents suitable for the skill of each trainee (engineer, technician).

The training contents for engineers and technicians are as follows.

Table 5-20 Training Contents

a) Engineer Training
・Method for fostering thermal power plant engineers ・Maintenance technology of CCGT power generation (GT・ST・HRSG・electricity・control system) ・Equipment diagnosis technology (non-destructive inspection・remaining life evaluation) ・Quality management (TQM) and efficiency management of thermal power plant ・Instruction in action plan preparation ・Factory tour of thermal power plant and equipment manufacturers ・Instruction in IoT/AI utilization methods
b) Technician Training
・Quality management・safety management (physical training) ・Equipment inspection maintenance technology (piping・valve・electric motor・welding・electric equipment・control equipment, etc.) ・Equipment diagnosis technology (non-destructive inspection・remaining life evaluation) ・Instruction in action plan preparation ・Factory tour of thermal power plant and equipment manufacturers ・Instruction of IoT/AI utilization methods

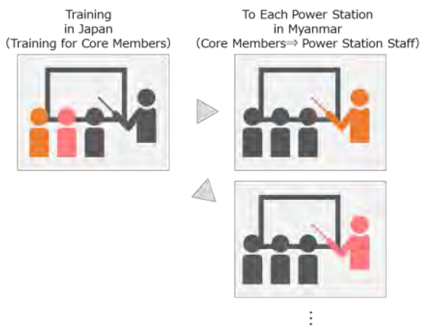
Source: JICA study team

(3) Operation Support at Local Sites

To follow up after training in Japan and support OJT, we propose local operation support by dispatching engineers.

The target persons invited to Japan are supposed to be core members from each power plant.

In order to reform awareness, improve knowledge and skills for the EPGE organization and each power station as a whole, it is necessary to utilize what the participants learned in the training for power plant O&M in Myanmar. In addition to that, it is also important to educate other power station staff.



Source: JICA study team

Fig. 5-7 Development of Local Training

In order to follow further development at the site, we will periodically dispatch engineers in each field to one selected power station, and plan to confirm the implementation status of training for other members and the improvement situation of O&M.

5.4 System Construction

In this section, we describe the system construction that is considered to be effective for efficient use of maintenance manuals explained in 5.2.

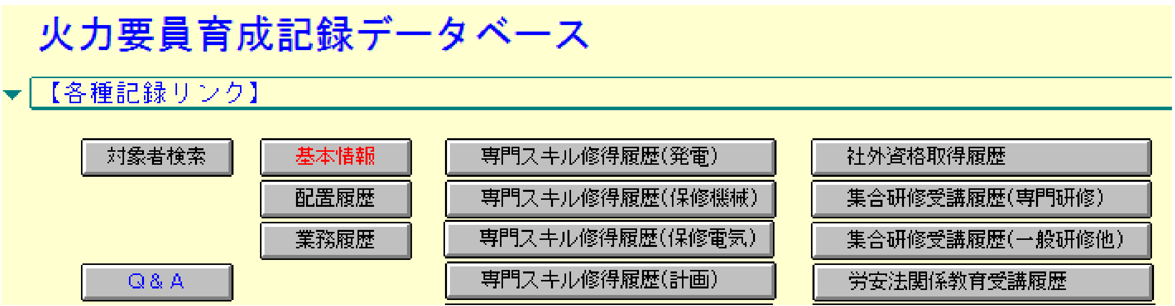
Based on the following system, we are supposing support including establishment of operational system suitable for the country, and its remote operation.

5.4.1 Proposal of Human Resource Development Management System

We properly grasp the skills learned by the human resource development program explained in 5.3.3 (1), and propose a system (database conversion) for nurturing human resources in a "systematic manner".

Management items and database examples are shown below.

- Basic Information
- Deployment History
- Business History
- Professional Skill Acquisition History
- External Qualification Acquisition History
- Training Course History



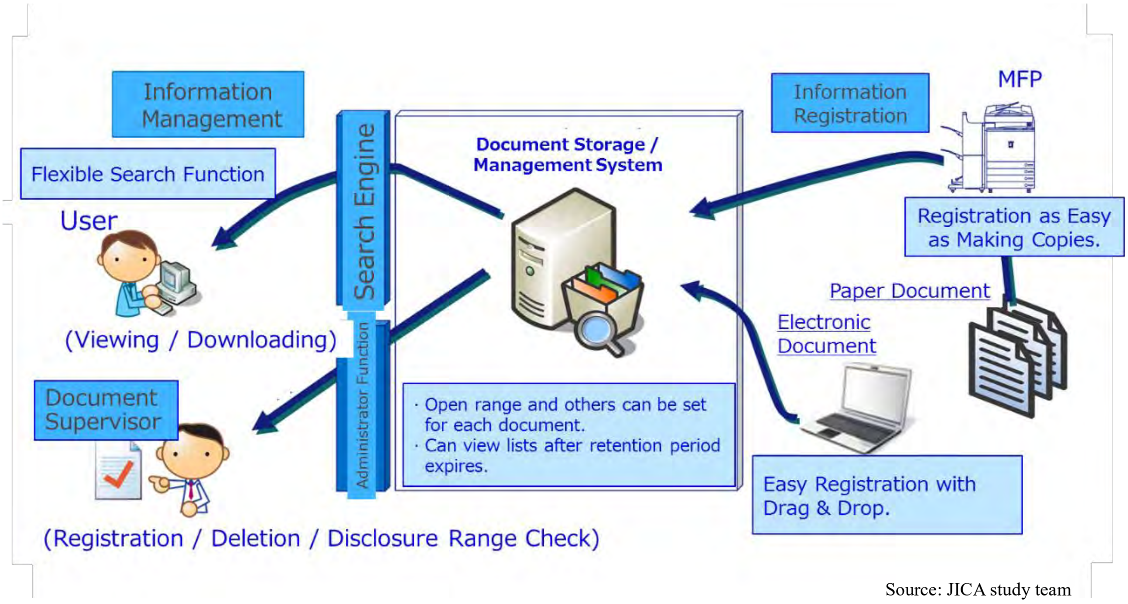
Source: JICA study team

Fig. 5-8 Example of Recorded Items in Training Database

5.4.2 Proposal for Digitalization of Documents

We propose a system that digitizes records, periodic inspection records, etc. collected by patrol inspections, etc., and can be saved and viewed.

An example of the management system is shown below.



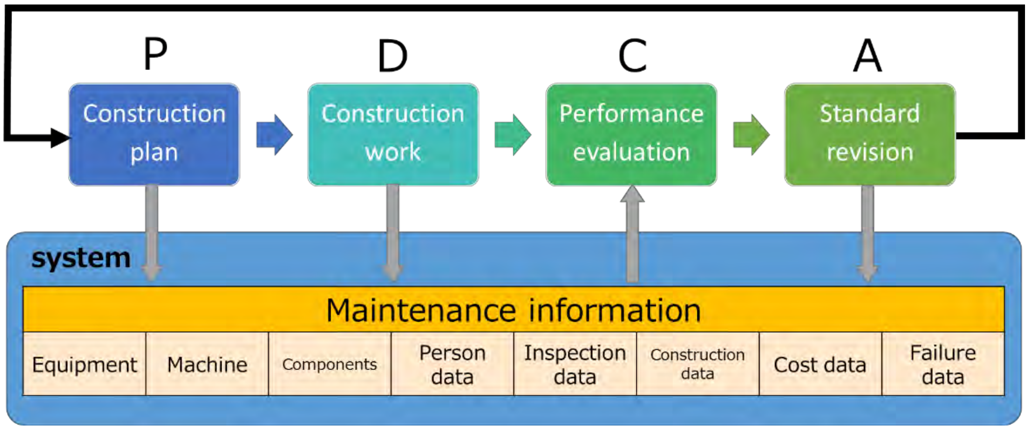
Source: JICA study team

Fig. 5-9 Document Electronic System

5.4.3 Proposal of Maintenance Plan / Actual Result Management System

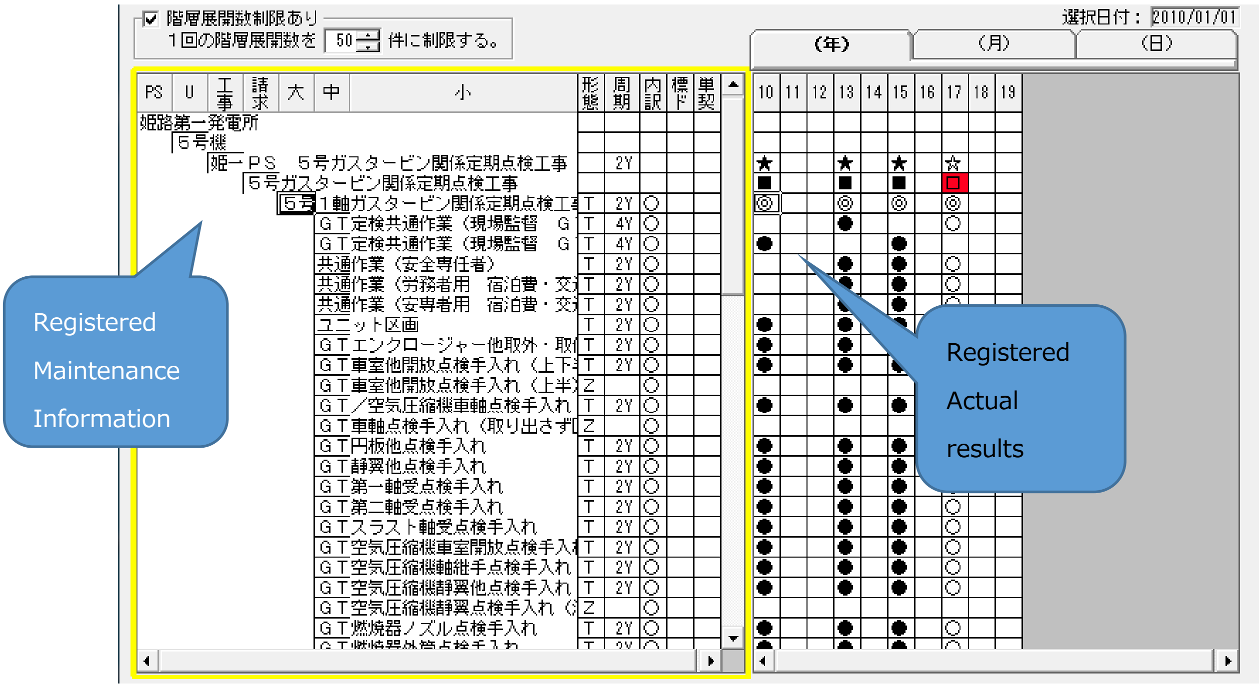
We propose a system that allows periodic inspection results to be appropriately applied to the next maintenance plan.

A conceptual view of system utilization and an example of the system are shown below.



Source: JICA study team

Fig. 5-10 Conceptual View of System Utilization



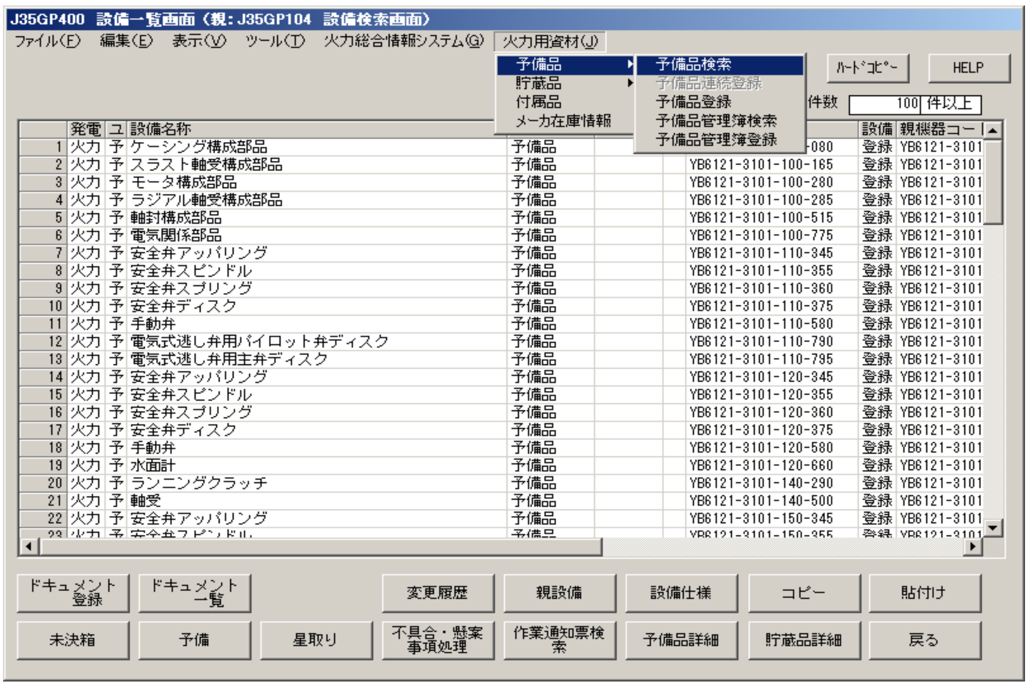
Source: JICA study team

Fig. 5-11 Management System Example

5.4.4 Proposal of Spare Parts Management System

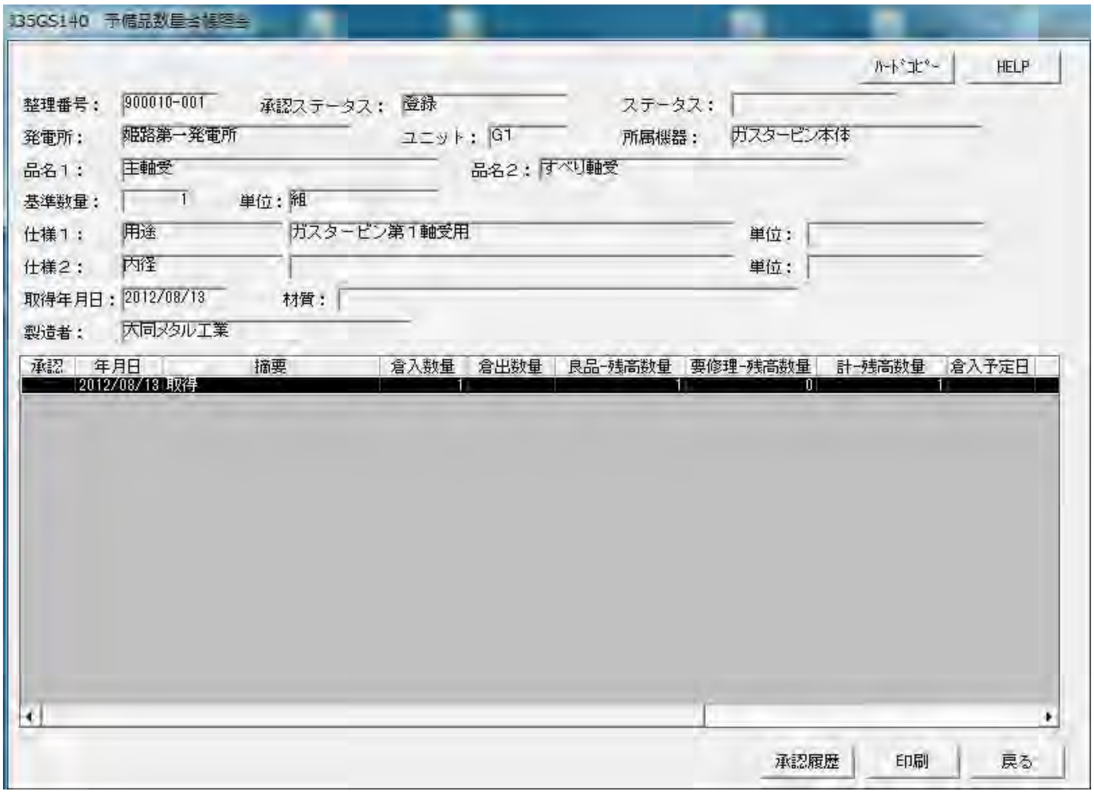
We propose a system that centrally manages specifications and stocks of spare parts.

A system example is shown below.



Source: JICA study team

Fig. 5-12 Screenshot of Spare Parts List Management Window



Source: JICA study team

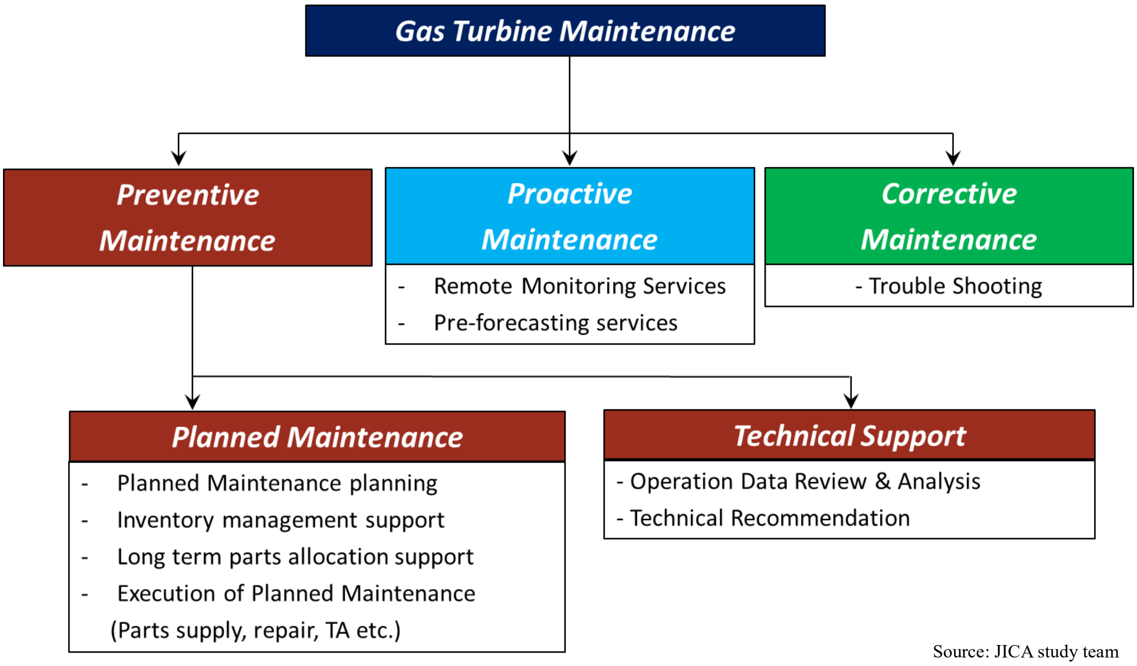
Fig. 5-13 Screenshot of Spare Parts Quantity Control Window

5.4.5 Component Management System

Information on the quantity, life and compatibility of parts stored at each power plant is often not available. As a proposal, we will set up a parts warehouse in Yangon city, introduce a management system, and centrally and collectively manage it. We recommend formulating an effective parts procurement and utilization plan.

5.5 LTSA

A maintenance plan management system is not established and criteria for periodical inspections are not defined. Periodical inspection records are inadequate. The problem is that cheap parts from third party vendors are used due to the small budget allocated to O&M, which resulted in damage and/or outage due to O&M failure in some plants. If an appropriate budget is allocated to the power O&M sector and a structured cycle of preventive maintenance, proactive maintenance and corrective maintenance is performed, electric power will be stably provided and sound operation will reduce fuel cost.



Source: JICA study team

Fig. 5-14 Outline of Gas Turbine Maintenance

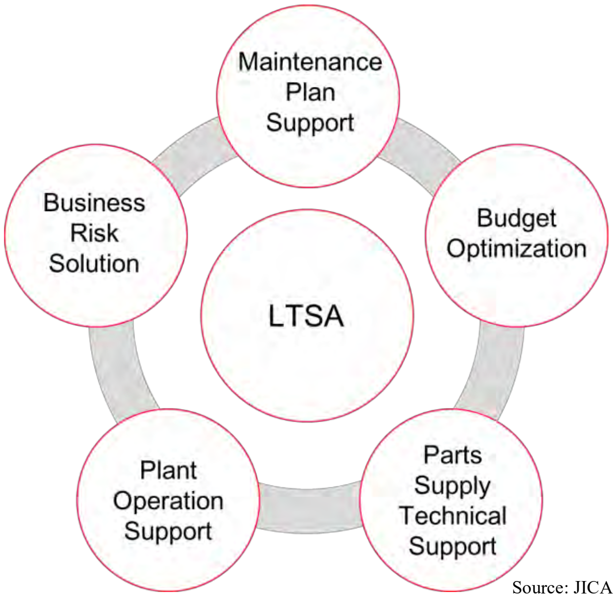
Parts supply and technical support by Long Term Service Agreement (LTSA) will be effective for the proposed improvements.

MHPS provides solutions that enable operators to achieve top-in-class levels of power plant availability and in turn helps secure the reliability of the overall grid.

In designing our LTSA-based solutions, they focus on optimizing plant operations while minimizing maintenance costs, taking responsibility for planning maintenance programs, spare parts supply, dispatch of technical advisors, remote monitoring, etc.

- Support short/long-term maintenance to minimize plant downtime and optimize operation/maintenance costs
- Optimization of the LTSA scope and spreading of maintenance costs over time to minimize EPGE's operating costs
- Supply of replacement parts and technical support from highly experienced engineers
- Utilization of remote monitoring, operating data diagnosis systems, etc. to assist with general plant optimization, including for fuel change-overs, operating load changes, maintenance interval extensions, etc.
- Provision of business risk minimization solutions, such as to counter decreased demand, unexpected plant outages and fluctuations in currency exchange rates, etc.

There are several content variations of Long-Term Service Agreements (LSTA). Various value offerings can be considered based upon EPGE needs, such as a method to agree on a unit price for service and parts and order each time, or a method to comprehensively covering a service package in a lump sum. Although it depends on the financial balance, etc., it is difficult to say what kind of content to apply, but generally it is initially a comprehensive LTSA for users who do not have a lot of maintenance experience and knowledge. The user will then change to a unit price agreement basis in accordance with the improvement in skill over time.



Source: JICA study team

Fig. 5-15 Example of LTSA Comprehensive Service Package

5.6 Rehabilitation & Equipment Installation

5.6.1 Short-Term Recommendation

Rehabilitation is expected for power plants where equipment maintenance is not properly performed. Thermal power plants age. Some of them are scheduled for rehabilitation work. The table below shows the current situation.

Table 5-21 Current Plant Situation & Rehabilitation Plan

Thermal Power Plant Condition Summary (as of Dec. 2018)

Plant	Model	Unit	GT	GEN	GT AUX	HRSG	ST	ST AUX
Ywama	701D	1	Stopped			NA		
		2	Under Operation (with load limit)			NA		
	H-25	1	Stopped					
	Fr.5	1	Stopped			NA		
		2	Under Operation			NA		
Thaketa	Fr.5	1	Under Operation			Stopped		
		2	Stopped					
		3	Under Operation					
Hlwaga	Fr.6	1	Under Operation			Under Operation		
		2	Under Operation					
		3	Stopped					
Ahlone	Fr.6	1	Under Operation			Stopped		
		2	Under Operation					
		3	Under Operation					
Thilawa	H-25	1	Under Operation			NA		
		2	Under Operation			NA		

Existence or Nonexistence of Rehabilitation Plan (as of Dec. 2018)

Plant	Model	Unit	GT	GEN	GT AUX	HRSG	ST	ST AUX
Ywama	701D	1	None	None	None	NA		
		2	None	None	None	NA		
	H-25	1	None	None	None	None	None	None
	Fr.5	1	None	None	None	NA		
		2	None	None	None	NA		
Thaketa	Fr.5	1	Existent	Existent	Existent	None	None	None
		2	Existent	Existent	Existent	None		
		3	Existent	Existent	Existent	None		
Hlwaga	Fr.6	1	None	None	None	None	None	None
		2	Existent	Existent	Existent	Existent		
		3	Existent	Existent	Existent	Existent		
Ahlone	Fr.6	1	None	None	None	None	None	None
		2	None	None	None	None		
		3	None	None	None	None		
Thilawa	H-25	1	None	None	None	NA		
		2	None	None	None	NA		

Source: JICA study team

Table 5-22 Scope of Rehabilitation and Outline

Rehabilitation Proposal Planning Draft (as of Dec. 2018)

Plant	Model	Unit	GT	GEN	GT AUX	HRSG	ST	ST AUX
Ywama	701D	1	- Overhaul Maintenance of GT & GEN - Countermeasure of Inlet Air Filter Chocking - Rehabilitation of Plant Auxially (e.x.;Lube Oil Cooler)			NA		
		2	- Overhaul Maintenance of GT (replacement of Hot Gas Path Parts) - Overhaul Maintenance of GEN (Countermeasure of BRG Metal Temp. High) - Countermeasure of Inlet Air Filter Chocking - Rehabilitation of Plant Auxially (e.x.;Lube Oil Cooler)			NA		
	H-25	1	- Overhaul Maintenance of GT & Comprehensive Rotor Inspection - Maintenance of GEN After Long-Term Storage - Maintenance of Condensor/HRSG/Cooling Tower After Long-Term Storage - Maintenance of ST After Long-Term Storage					
	Fr.5	1	- Overhaul Maintenance of GT & Comprehensive Rotor Inspection - Rehabilitation of Inlet Air Filter			NA		
Thaketa	Fr.5	1	Planned by EPGE			- Maintenance of ST (Repair & Assembly) - Overhaul Maintenance of Steam Turbine GEN - Rehabilitation of Cooling Tower (Replacement) - Rehabilitation of Inlet Air Filter - Maintenance of HRSG		
		2						
		3						
Hlwaga	Fr.6	1	Planned by EPGE (Third Party contracted by EPGE for rehabilitation, operation, and maintenance)					
		2						
		3						
Ahlone	Fr.6	1	- Countermeasure to #1 BRG High Vibration			HRSG Tube Replacement	- Countermeasure for Steam Turbine	
		2						
		3						
Thilawa	H-25	1	- The long-term maintenance planning is required, because GT operated even if recommended inspectin interval was exceeded.			NA		
		2				NA		

Source: JICA study team

We will prepare a specific rehabilitation plan for each plant, discuss the plans in detail with EPGE, and make a mid- and long-term plan that meets EPGE needs. The detailed scope of work will be confirmed with EPGE.

Ywama (701D 2GT)

(1) Outline of Plant

Compressor surging occurred in the #1 GT in February 2018. During the second investigation in December 2018, recovery construction was performed by a third party. It was said that the damaged compressor would only be cleaned and repaired to the extent required to restore operation. Since the compressor is still damaged, early rehabilitation (GT overhaul inspection + compressor parts replacement) is required. The root cause of compressor surging is presumed to be inlet air filter choking.

Since a high bearing temperature occurs on the generator side of the #2 GT, the power plant faces a problem in that load cannot be increased. Though four years have passed since relocation (2014), compressor inspection was performed only once. We think a major inspection needs to be performed.

(2) Proposal for Improvement

We propose the following actions against the above mentioned issues.

a. Major inspection of gas turbine and generator

GT #1 : Major inspection and action against compressor damage

GT #2 : Major inspection and replacement of parts depending on situation

Major inspection, cause investigation and repair to remedy the high bearing temperature of the generator.

b. Modification of inlet air filter

Continuous monitoring of differential pressure and addition of alarm, if the inlet air filter is heavily deteriorated and elements are replaced

c. Modification of auxiliaries

LO cooler renewal construction since the LO high temperature trip occurs due to trouble in the LO cooler

Ywama (H25 1-on-1 CCGT)

(1) Outline of Plant

The plant started commercial operation in 2004 and stopped due to trouble several years later. Rehabilitation was performed in March 2013 and commercial operation was resumed as a combined cycle plant, but stopped due to heavy damage to gas turbine blades in April 2014, which has remained to the present.

HRSG, steam turbine and control devices are not damaged but are not in operation because the turbine has not been started. They have been stopped for nearly 5 years and need maintenance. It is said that EPGE internally has a plan to remove it in a few years.

(2) Proposal for Improvement

To start the plant, we think that the gas turbine needs to be replaced. (It will be not acceptable to only repair (replace) of the turbine blades since rust has formed inside of the rotor.)

To replace the gas turbine,

① Re-design the combustion nozzle. (The current combustion nozzle is designed based of fuel properties from 2004. Fuel properties (calorie) are considerably lower now.)

② Install a bypass stack on the exhaust duct.

We think this will enable the plant to generate electricity using only gas turbine.

As an improvement proposal for the steam turbine,

a. Improve the cooling water quality (*). (Coagulant is added to settle impurities.)
b. Introduce a condenser ball cleaning device.

This will prevent any marked decrease in performance.

(*) The water contains metallic elements including calcium. They generate films and solid materials on the lining of condenser tubes. Films and solid materials reduce the heat transfer coefficient and vacuum degree in the condenser, and lead to marked performance degradation.

As described above, we need to check EPGE's operation plan to provide an appropriate proposal.

<u>Ywama (Fr5 2-on-1 CHP)</u>

<u>(1) Outline of Plant</u>

A flame loss trip occurred on the #1 unit in August 2018. Disassembly inspection was performed and damage was found in the compressor. A spare rotor was delivered for restoration; however the unit is not being operated due to large vibrations. (As of December 10, 2018)

The history of the replaced spare rotor is unclear. It was repaired by Corrtech, a company in India, and stored for more than 3 years. See Fig. 5-16.

Fig. 5-16 Spare Rotor That Was Installed After Compressor Damage

<u>(2) Proposal for Improvement</u>

We think the plant needs 2 kinds of improvements: preventive measures for the compressor accident and a solution for the shaft vibrations.

a. Though detail investigation is required, it is presumed that the IGV was closed due to an abnormality in the solenoid valve and high cycle fatigue occurred on the compressor row 2 vanes, which eventually caused damage in the compressor.

Maintenance may not have been performed on the solenoid valve. It is important to plan and implement periodic maintenance (or replacement). Recurrence prevention measures are: ① a trip to prevent HCF (High Cycle Fatigue) though an alarm is activated when the IGV closes, and ② introduction of the MHPS-TOMONI® and related guidance to warn operators.

b. Mass unbalance is presumed the cause of the shaft vibration. Firstly, field balance is checked using CABS (Computer Aided Balancing System). If it is not effective, the rotor is lifted and balancing is performed in a shop that has LSB (Low Speed Balancing).

Thaketa (Fr5 3-on-1 CCGT)

(1) Outline of Plant

The plant is to undergo GT renewal construction, but has no plan to operate as a CCGT since there are some issues with the ST. We do not recommend rehabilitation construction because capacity increases only by 35MW if the plant restarted as CCGT, because the plant is operated at high demand and renewal construction for the cooling tower is considered to be necessary due to the heavily damaged concrete of the cooling tower.

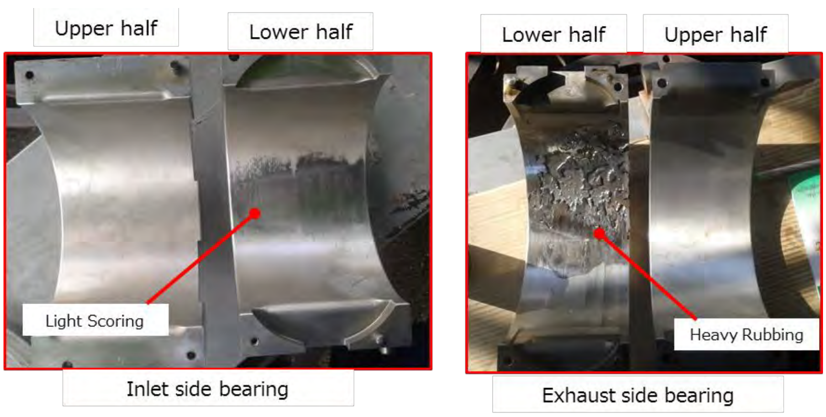
Ahlone (Fr6 3-on-1 CCGT)

(1) Outline of Plant

The plant is an Fr6 3-on-1 CCGT. Three units are operated as a simple cycle due to a tube leak in the HRSG. Shaft vibration in the #1 and #3 units exceeds the alarm value. Their parts were replaced during HGPI in 2018 and 2016, respectively, but vibrations are still high. (A new rotor was delivered for the #3 unit.) A past periodic inspection report showed heavy contact on the bearing surface for both units (Fig. 5-17). This is presumed to lead to the shaft vibration. The cause of the heavy contact on the bearing surface is presumed to be:

a. Lube oil shortage
b. Poor lube oil quality
c. Misalignment of the rotor.

Detail investigation is required to find the cause.



Source: JICA study team

Fig. 5-17 Bearing Damage as of November 2018

Table 5-23 Change in Vibrations Before and After #1 Inspection

	Inlet side [mm/s]		Exhaust side [mm/s]	
Sensors	1A	1B	3A	3B
Pre-outage (Sept 2018)	12.75	12.34	0.01	0.33
Post-outage (Dec 2018)	14.25	13.63	4.24	5.28

Source: JICA study team

Vibration values increased despite the replacement of parts.

(2) Proposal for Improvement

The following proposals are considered as improvements for the heavy contact on the bearing surface.

a. Lube oil shortage

If a lube oil shortage occurs due to a mistake in system installation or failure in the lube oil pump, a T/A will be dispatched to check the system and instruct the correct installation method.

b. Poor lube oil quality

If lube oil is poor quality and contains fine particles and dust, a static oil purifier is considered as a way to remove them. There is a vender that supplies it amongst MHPS's partners. The vender has experience with power generation plants in Japan and overseas.

c. Misalignment

If rotor misalignment causes contact between the bearing surface and rotor journal, we think that a TA needs to be dispatched to check the alignment.

Thilawa (H-25 2GT)

(1) Outline of Plant

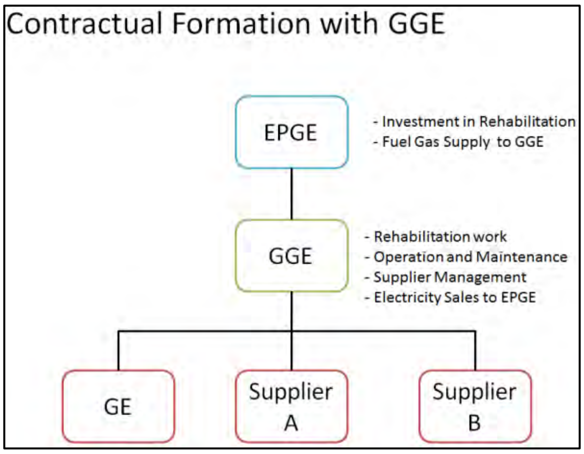
The plant started commercial operation in 2016 and has the latest GT, therefore we do not think GT rehabilitation is necessary.

5.6.2 Medium- & Long-Term Recommendations

As described in the proposals for improvement for machines and facilities where damage is found, the JICA study team thinks that the most important thing for Myanmar is to provide a "place" to establish an optimal O&M system considering the mid- and long-term development of the electric power sector in addition to just sales of maintenance equipment and one-time training.

As a proposal for O&M development from a mid- and long-term view point, our idea is to establish a Joint Special Purpose Company between the public and private sectors of Japan and Myanmar as a "place" to jointly plan and implement appropriate O&M business schemes.

The idea is based on the Rehabilitation Operation Maintenance Management (ROMM) project for the Hlawga power plant (Fr6:3-on-1), a 10-year O&M contract including rehabilitation with Golden Green Energy (GGE). We think that the innovative points of the contract are to obtain business ownership of existing facilities, receive payment from EPGE on a Cent/kWh basis, and perform all O&M work except fuel procurement. We heard that EPGE staff at the Hlawga plant will be replaced with GGE staff when the contract is executed. However, our idea is to jointly perform the ROMM by collaborating with EPGE's existing staff with on-the job training in order to achieve O&M growth for the future of Myanmar. This concept should be investigated as to whether it will be really workable or bankable or not in Myanmar by carrying out a feasibility study from several aspects in more detail.

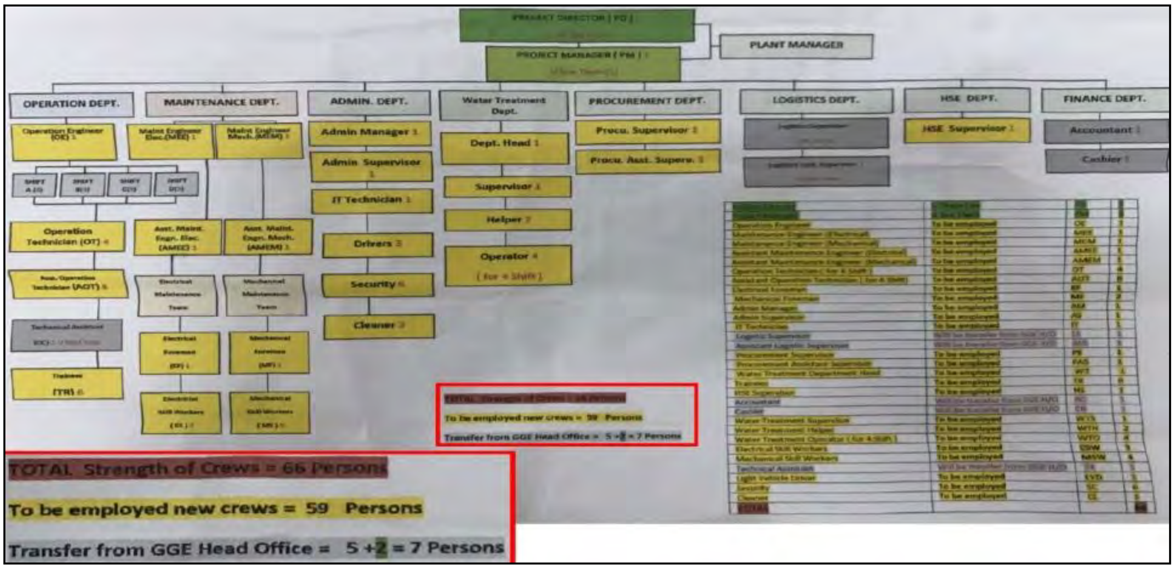


Source: Provided by Plant Manager

Fig. 5-18 Project Scheme

Source: Website

Fig. 5-19 Signing Ceremony



Source: Provided by Hlawga Plant Manager

Fig. 5-20 Project Formation After ROMM Contract Is Executed
(With the exception of a few, EPGE staff at the Hlawga plant will be replaced with GGE staff.)

5.6.3 Countermeasures Against Splash in the Yeywa Switchyard

The problem in the Yeywa switchyard is the increase in the possibility of grounding fault due to the large amount of algae adhering to the insulators. Adhesion to insulators in Japan is mainly salt and dust. KANSAI is taking priority measures to ensure the safe and stable supply of outdoor substations in seaside areas where there is a large amount of salt adhesion. Although the Yeywa power station is operated as a base power source and it is necessary to provide a stable supply, the Yeywa switchyard is located in an environment with a large amount of algae adhesion. Therefore, the Yeywa switchyard has high risk of grounding fault, so countermeasures should be given priority.

(1) Switchgears, etc.

Circuit breakers, disconnectors, lattice steel structures, and electric wires are defined as "switchgears, etc." Countermeasures for switchgears, etc. will be considered as follows.

1. High-place insulator cleaning by human power
2. Installation of GIS
3. Installation of insulator cleaning device.

At the Yeywa switchyard, there is the highest risk of grounding fault at the high-place insulators attached to the lattice steel structure. There is a problem with the location of the high-place insulators and the scheduled outage needed to clean the insulators manually. In first place, the switchyard is located where it may be rapidly dirtied. Discharge from the spillway is carried out in the rainy season when there is much inflow to the dam. At the same time as dirt adheres to the insulator during the rainy season, it is washed away with rain. Therefore, it is considered that no grounding fault has occurred so far. Algae breeds rapidly influenced by sunlight and nutrients. After discharge from the spillway, if there is a little rain and sunlight, algae will grow rapidly, which can cause a grounding fault. Next, when cleaning insulators in high places, a wide range of outage for the insulator cleaning work will be necessary. The work for circuit breakers and disconnectors need to be conducted in turns and divided into several areas in order to minimize the outage area of the switchyard. Because the wires cross vertically and horizontally in the switchyard, when cleaning the insulators in high places, a wide range of outage for the work needs to be considered. In addition, the scheduled outage period is influenced by the amount of work. Considering its role as a base power source, the annual scheduled outage should be shortened.

(2) Transformer

In addition to manually cleaning insulators, which is the current countermeasure, the installation of pollution prevention equipment (building or wall) and the installation of an insulator cleaning device will be considered. In 2011, a steel wall was installed around the upstream side transformer to protect the transformer against dirt. After the installation of steel walls, although the transformer was less dirtied than other facilities on the upstream side of the switchyard, it was quite dirty. This is because the spray reaches the transformer by wind. The transformer risks overheating due to reduced cooling capacity, if a lot of algae attaches to the radiator. And, the insulation oil may leak from the body of the transformer and radiator, if the rain water causes them to rust. The part covered by the wall is not an adequate measure against the adherence of algae. From the above, it is effective to install a building that covers the whole as dirt prevention.

Suggestion for improvement

(1) Proposal contents

a. Suggestion improvement for switchgears, etc.

(a). GIS installation work

A GIS (Gas Insulated Switchgear) is a gas-insulated switchgear housed in a cubicle. Circuit breakers, earthing switches, disconnectors, lightning arresters, and instrument transformers are integrated in a GIS. The appearance of a GIS is shown in Fig. 5-21.

Fig. 5-21 GIS (Gas Insulated Switchgear)

(i) Salient Features

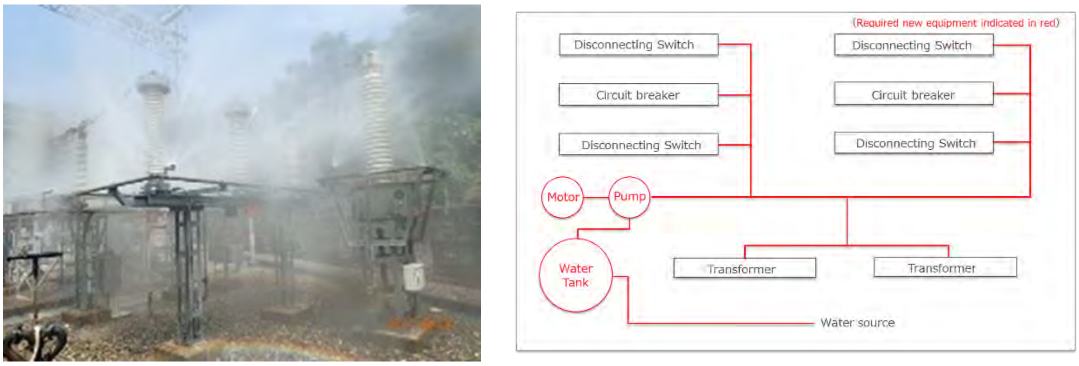
- The installation area can be reduced to about 1/10 to 1/5.
- Easy maintenance
  - The energized parts are sealed and not affected by situation surrounding the GIS.
  - The method of maintenance and inspection can be simplified because of the compact size.

(ii) Operating experience

- In Japan, a GIS is adopted as a measure against salt pollution and to reduce.
- Used in the other power stations in Myanmar.

(b) Installation work of insulator cleaning device

The insulator cleaning device removes dirt from insulators by injecting high pressure water without a scheduled outage. It is necessary to add tanks, pumps and piping to the existing facilities. The appearance of the insulator cleaning device and the equipment configuration are shown in Fig. 5-22.



Source: JICA study team

Fig. 5-22 Insulator Cleaning Device

(a) Salient Features

● Automatic cleaning can be performed periodically.

・The labor load can be reduced.

・ There is no need to work in high places.

・ Insulator cleaning can be done without scheduling an outage.

● Fresh water is necessary for washing the insulators.

(b) Operating experience

● In Japan, it is adopted in coastal areas as a measure against insulation degradation due to salt damage.

●The equipment has never been installed for high-place insulators and control panels.

b. Transformer

(a) Installation of dirt prevention equipment

A building needs to be installed to cover the entire transformer. When installing it, it is necessary to secure a distance from the energized charging parts of the transformer and an inspection space, and consider sufficient transportation dimensions when replacing the unit.

(i)Features

●The transformer is sealed so as not to be dirtied.

(ii)Operating experience

●Buildings for preventing equipment from being covered with dirt are not adopted in Japan, because there is no similar environment.

(iii)Installation cost

●Building price is shown in Table 5-24.

Table 5-24 Building Price

Equipment		Price (MUSD)	Breakdown
Number of units	Specification		
Building×1 (Width:20m,Depth:14m,Height:14 m)※ 1	Steel frame	0.4	Equipment price : 0.3 Installation cost : 0.1

Condition: Transformer dimensions (Width: 8,500 mm, Depth: 4,500 mm, Height: 6,730 mm)

Separation distance: 6,840 mm

(Calculated according to Japan's "Technical Standard of Electrical Facilities, Article 22 (230 kV)")

(Note1) The building size indicates the minimum separation distance.

(Note2) The building size can be reduced if there is no exposure of energized parts.

Source: JICA study team

(b) Installation work of insulator cleaning device

(i) For features, refer to "a. Suggested improvements for switchgears, etc. (b) Insulator cleaning device installation work".

(ii) For operating experience, refer to "a. Suggested improvements for switchgears, etc. (b) Insulator cleaning device installation work".

(iii) Installation cost

●The insulator cleaning device price is shown in Table 5-25.

Table 5-25 Insulator Cleaning Device (Mounted on Transformer) Price

Equipment		Price (MUSD)	Breakdown
Number of units	Voltage		
Insulator cleaning device ×1 (Including pump tank piping)	154k (Transfer mounting)	0. 4	Equipment price : 0.3 Installation cost : 0.1

Source: JICA study team

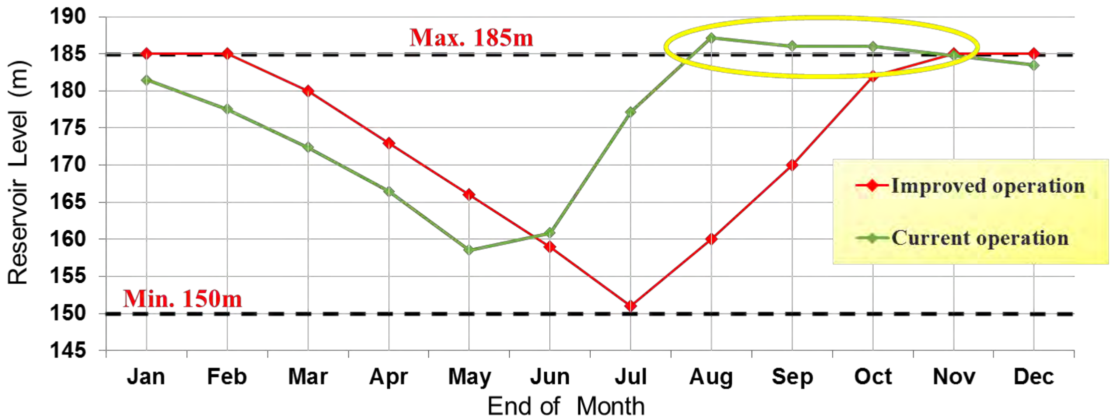
(2) Summary of proposal

As the result of this survey, the above improvement measures can be considered but it is necessary to consider the examination of details including of the cost merit in order to select the best countermeasure.

5.7 Hydropower Plant Operation

5.7.1 Simulation of the Improvement of Reservoir Operation

Reservoir operation can be improved by applying reservoir operation rules. The water levels in the case of current reservoir operation and improved reservoir operation in line with the reservoir operation rules are summarized in Fig. 5-23. Each plot indicates the water level at the end of each month. The green line in Fig. 5-23 indicates the average water level of each month from 2008 to 2018. The red line in Fig. 5-23 indicates the water level of each month assuming that there are no restrictions placed on the water level or output of the hydropower plant.



Source: JICA study team

Fig. 5-23 Improved Reservoir Operation

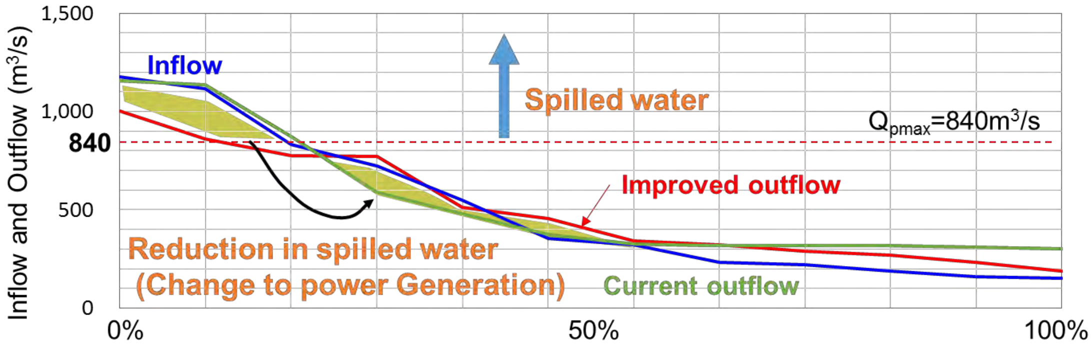
Under the current operation practices, the water level reaches the Full Tank Level (FTL.) of EL 185 m in elevation in November. More water can be discharged for electricity generation than the inflow water by using the stored water in the reservoir. Therefore, the water level gradually falls from December to May. The reservoir water level rises to the FTL of EL 185 m during three months from June to August in which the water inflow is larger than the water discharge. The water level usually becomes lowest at the end of May, however the average water level at the end of May is EL 158 m, 8 m higher than the Minimum Operation Level (MOL) of EL 150 m. This means that the stored water in the reservoir cannot be utilized for power generation. Additionally, the water level rises up sharply and reaches the FTL at the end of August, remaining at that level until the end of November. Due to the rainy season in September and October, frequent flooding in excess of the maximum plant discharge results in the discharge of water from the spillway gate, which does not contribute to power generation (spilled water). Hydropower plants with reservoirs have the advantage of being able to generate sufficient electricity even in the dry season by utilizing the water stored during the rainy season. Utilizing the stored water thoroughly is beneficial to the project. In the rainy season, utilizing a large amount of inflow with minimum spilled water is more preferable. Improvement in reservoir operation is proposed below.

Under the improved reservoir operation practices, the water level of the reservoir is managed to drop to EL 151 m, one meter higher than the MOL of EL 150 m, at the end of July. Compared to the current reservoir operation, electricity generation increases significantly in the dry season especially from March to June. In the rainy season, the speed of the water level rise is slower than under the current reservoir operation practices, and the water level is managed to reach the FTL of EL 185 m at the end of November. The water level is kept lower compared to the current operation practices to ensure room to store water in the case of floods in which the inflow is more than maximum plant discharge in order to reduce the spilled water. The water level is kept to EL 185 m (FTL) from December to the end of February. During those three months, the water discharged for power generation is managed to be the same as the inflow water. It is not probable for the inflow to exceed the maximum plant discharge during the three months in the rainy season, and there is little risk of spilled water. Full utilization of the stored water in the dry season and the minimum spill water will result in a significant increase in power generation.

Reservoir operation rules will be set to improve reservoir operation. Target water levels are set for each month. Considering the average monthly inflow and spilled water, if applicable, the amount available for power generation can be estimated each month. The water level, head, discharge amount, and tailrace water level calculated based on the discharge amount, and the head loss are taken into account for the estimation of the total amount of power generation.
From November to June, the water will be discharged during the peak time from 06:00 to 24:00 midnight. From July to October, the available water increases and water can be discharged all day.

5.7.2 **Effect by Improvement in Reservoir Operation**

An yearly duration curve is shown in Fig. 5-24**.** The blue line, green line, and red line in the figure indicate the inflow, outflow based on the current reservoir operation (“Current outflow”), and outflow based on the improved reservoir operation (“Improved outflow”), respectively.

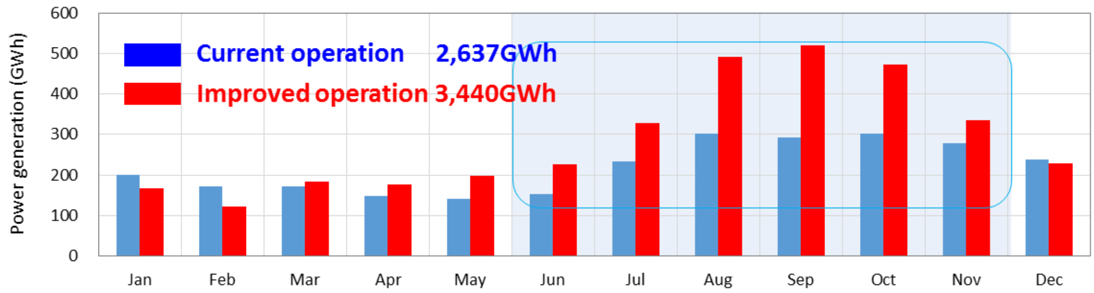


Source: JICA study team

Fig. 5-24 Improved Duration Curve

Outflow below the maximum plant discharge (Qmax) of 840 m^3/s can be discharged from the power plant and effectively utilized for the power generation. Outflow above the maximum plant discharge (Qmax) of 840 m^3/s means that the amount exceeding 840 m^3/s becomes spilled water, which cannot be utilized for power generation. The amount of the Current outflow is almost the same as the inflow amount in the case that the inflow amount is more than a Qmax of 840 m^3/s. On the other hand, the amount of Improved outflow is significantly smaller compared to the amount of the Current outflow in the case that the inflow amount is more than a Qmax of 840 m^3/s, and the Improved outflow increases significantly compared to the Current outflow in the case that the inflow amount is below a Qmax of 840m^3/s. As shown in Fig. 5-24 the outflow above a Qmax of 840 m^3/s is reduced resulting in a reduction of spilled water. Instead, outflow increases below a Qmax of 840 m^3/s, resulting in an increase in power generation. The utilization rate for river flow is improved from 70% under the current reservoir operation practices to 76% under the improved reservoir operation practices. The spilled water in the rainy season decreases, while the discharge for the power generation increases.

Fig. 5-25 shows a comparison of the total power generation between the current operation and improved operation. The blue bars and red bars indicate power generation based on the current operation practices calculated from hydrological data for 1995 to 2016, and the improved operation practices, respectively.

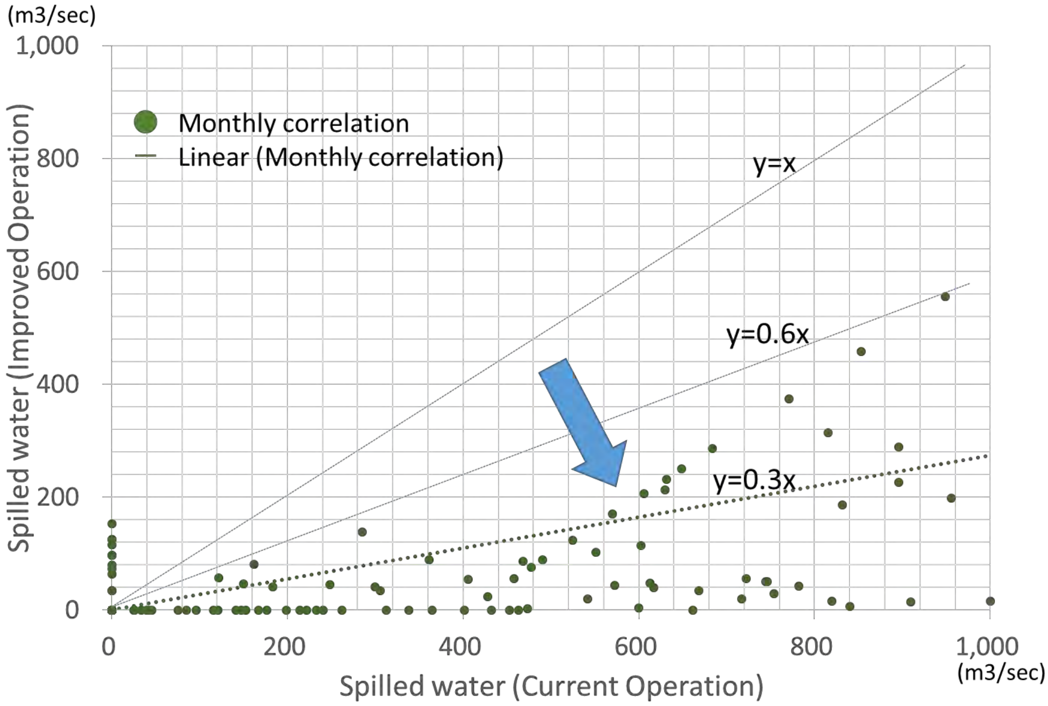


Source: JICA study team

Fig. 5-25 Improved Power Generation (GWh)

Though the maximum plant discharge of the Yeywa power plant is large, the inflow amount in the rainy season frequently exceeds the maximum plant discharge. Therefore, keeping the water at the FTL results in a large amount of spilled water that does not contribute power generation. Although the high water level is beneficial because of the larger head, the disadvantage of the spilled water has a greater impact. Therefore, keeping the water level lower than that under the current operation practices in the rainy season results in a reduction of spilled water and thus increases the total amount of power generation. Improving the reservoir operation increases electric power generation from the current average annual power generation of 2,637 GWh to 3,440 GWh, which means an increase in power generation of around 30%. Under the improved operation practices, the discharged water is reduced and managed to be the same as the inflow amount from December to February, therefore power generation from December to February also decreases accordingly. However, power generation in the remaining nine months from March to November will increase due to the reduction in spilled water and more effective utilization of the stored water.

The reduction in spilled water has another benefit in addition to the increase in power generation. A ski jump type of spillway is adopted for the Yeywa power plant. At the diving point of the spilled water, there are a lot of droplets and mist that may have an impact on the switchyard located downstream of the power house. The reduction in spilled water may result in a reduction in the adverse impact on the switchyard.
Fig. 5-26 shows the effect of the reduction due to the improvement in reservoir operation. The horizontal axis and vertical axis indicate the amount of spilled water under the current operation practices and the improved operation practices, respectively. In the case that the reservoir operation is not improved, the plots would be on the line of y = x. In the case that total amount of the spilled water is reduced by 40% and 70%, the plots should be on the lines of y=0.6x and y=0.3x respectively.



Source: JICA study team

Fig. 5-26 Improvement in Spilled Water

In many cases, the spilled water becomes zero, and the spilled water is reduced by at least 40% (all plots are located below the line of y=0.6x). The reduction in spilled water can be expected to be 70% on average, which is considered to mitigate the impact on the switchyard. Spilled water cannot be completely avoided in the case of a big flood when the reservoir water level is high. Therefore, countermeasures against the droplets or mist by the diving of the spilled water from the ski jump spillway must be considered.

5.7.3 Further Improvement of Yeywa Reservoir Operation by Appropriate Inflow Forecasting System

It is necessary to operate the reservoir systematically under reservoir operation rules using past hydrological data, in order to improve the reservoir operation as described in 5.7.1.

Reservoir operation can be improved further if the inflow amount is estimated far enough in advance to respond to fluctuations in inflow volume.

In the current reservoir operation of the Yeywa power plant, the inflow cannot be predicted, so the water level cannot be lowered sufficiently, and the facility capacity cannot be used effectively. In the improvement operation proposed this time, it is necessary to lower the water level to EL 151m, one meter higher than the MOL of EL 150m, in July. In order to realize this operation, it is essential to accurately predict the inflow to the dam.

In general, the inflow amount can be predicted from the inflow amount at the dam site and rainfall in entire catchment area.

The accuracy of the inflow amount prediction can be improved by acquiring a sufficient number of real-time rainfall data and inflow data in the catchment area.

Currently, the Yeywa power plant has a water level gauge installed at the intake gate, and the water level can be confirmed all the time.

However, the inflow amount cannot be calculated automatically by visually checking the water level.

Also, a rainfall gauge is installed only at the dam site, and it is inadequate for inflow prediction.

Additionally, five rainfall gauging stations are installed in the catchment area of the Yeywa power plant, however real-time data cannot be acquired.

In the case of a Japanese dam with 600 km^2 of catchment area, at least three rainfall gauging stations are required to predict the inflow amount.

In the case of dams with a catchment area of over 4,000 km^2, the real-time data from more than 10 rainfall gauging stations are acquired in general.

The catchment area of the Yeywa power plant is large at 28,206 km^2.

It is necessary to install more than 20 rainfall stations in order to predict inflow from rainfall as accurately as in Japan. It is not realistic to install and manage such a number of rainfall gauging stations, considering installation and maintenance costs for the stations.

Inflow prediction based on satellite rainfall data instead of the rainfall gauging stations may show good cost-performance. An outline of an inflow forecasting system by satellite rainfall data and systemization are given in next subsection.

5.7.4 Dam Inflow Prediction Method with Satellite Data

Recently, remarkable technology for observing ground precipitation using a sensor mounted on a satellite has been developed. JAXA (Japan Aerospace Exploration Agency) provides global precipitation distribution (GSMaP: Global Satellite Mapping of Precipitation) created by synthesizing precipitation data estimated by multiple satellites to the public on the internet in real-time (https://sharaku.eorc.jaxa.jp/GSMaP/). A screenshot of the GSMaP website is shown in Fig.5-27. Spatial resolution of the GSMaP is 0.1° (approx. 10 km) and time resolution is 30 minutes. These specifications sufficiently satisfy the resolution required to grasp basin averaged rainfall needed to accurately predict the inflow into the Yeywa dam.

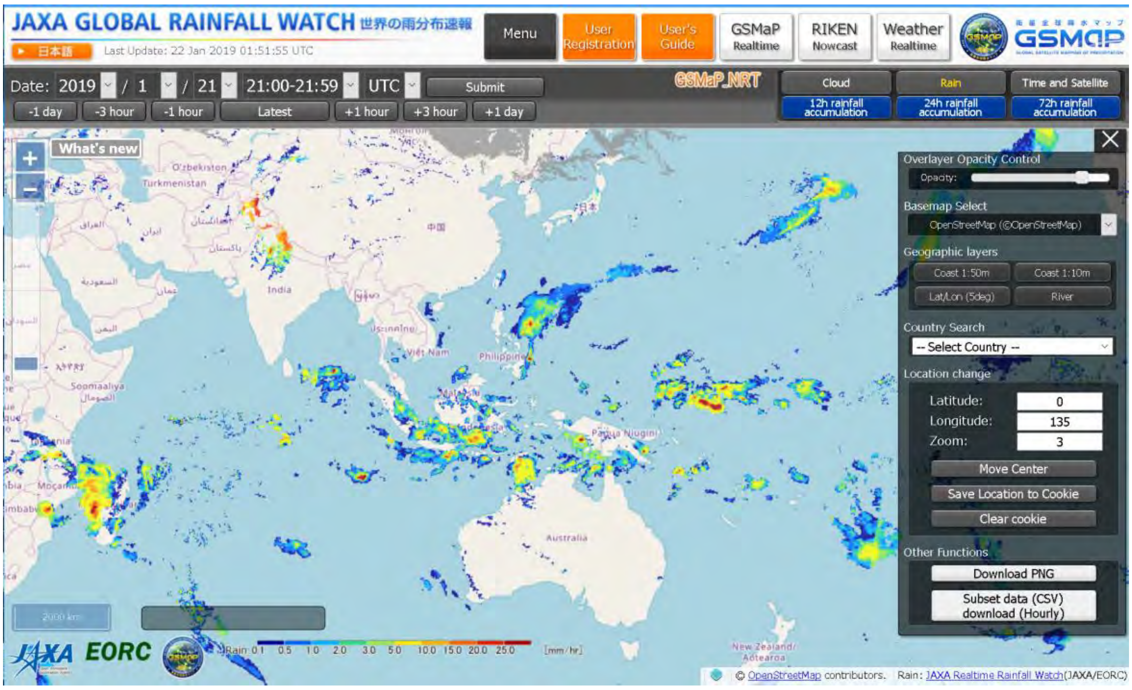


Fig. 5-27 Screenshot of GSMaP Website

(Source : https://sharaku.eorc.jaxa.jp/GSMaP/)

In order to accurately predict the inflow into the Yeywa dam up to several days ahead, it is necessary to grasp the basin averaged rainfall in the dam basin area over several days, in addition to grasping the actual basin averaged rainfall in the dam basin. In order to predict the basin averaged rainfall in the dam basin area up to several days ahead, rainfall prediction by meteorological numerical simulation model is effective. In recent years, weather forecasting technology has developed rapidly and, coupled with the development of computer technology, it is possible to make rainfall predictions in real-time by utilizing a local weather model.

The WRF (Weather Research and Forecasting) meteorological simulation model developed mainly by the National Center for Atmospheric Research (NCAR) of the United States is the world's most popular meteorological model. WRF is open source and available for free. In the meteorological simulation model, the atmosphere is divided into three-dimensional lattices, physical quantities such as atmospheric pressure, temperature, humidity, wind direction and wind speed are defined for each lattice, and physical laws (physical equations, mass preservation law, etc.) are numerically integrated to predict the future physical quantity in each lattice. A conceptual diagram of the calculations made with the meteorological simulation model is shown in Fig. 5-28.

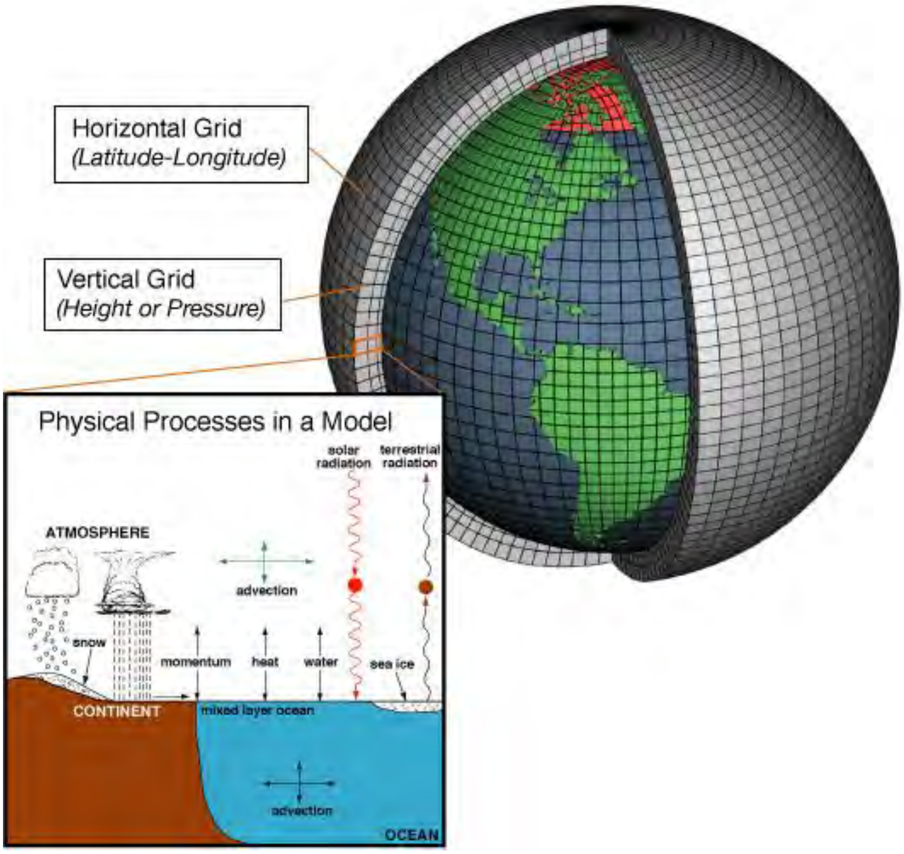
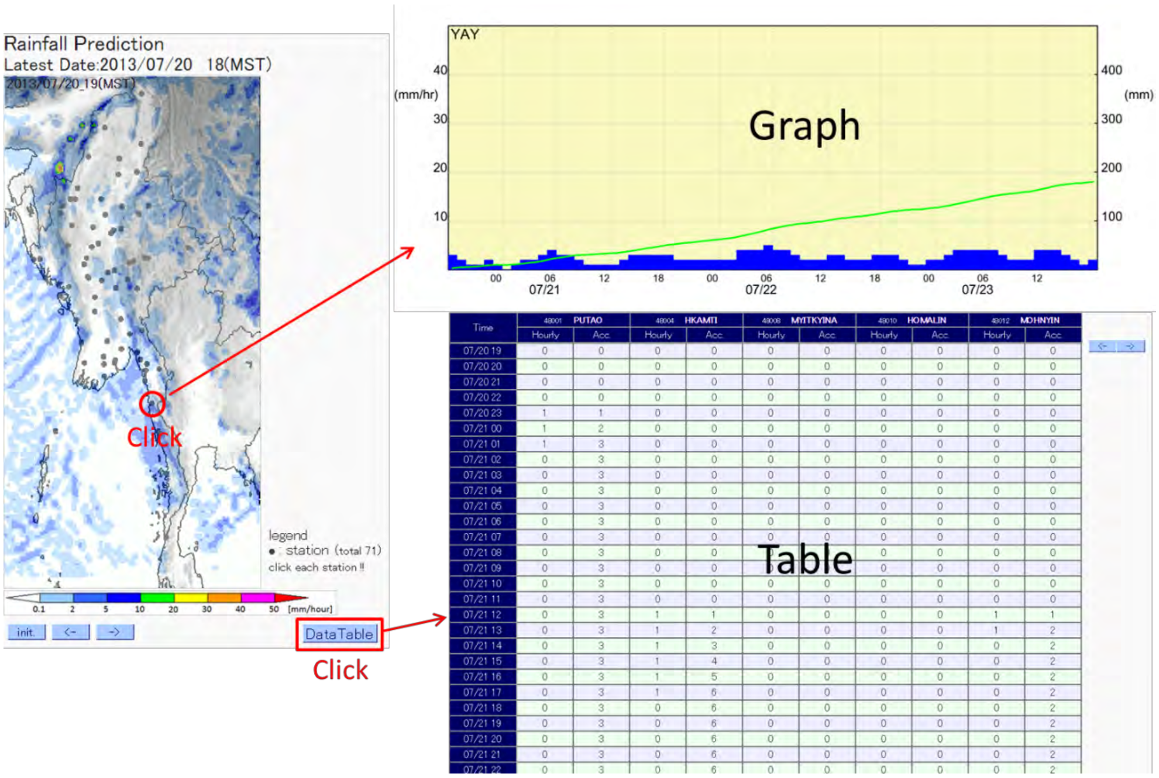


Fig. 5-28 Conceptual Diagram of Calculations Made with Meteorological Simulation Model

（Source : https://en.wikipedia.org/wiki/General_circulation_model#/media/File:AtmosphericModelSchematic.png ）

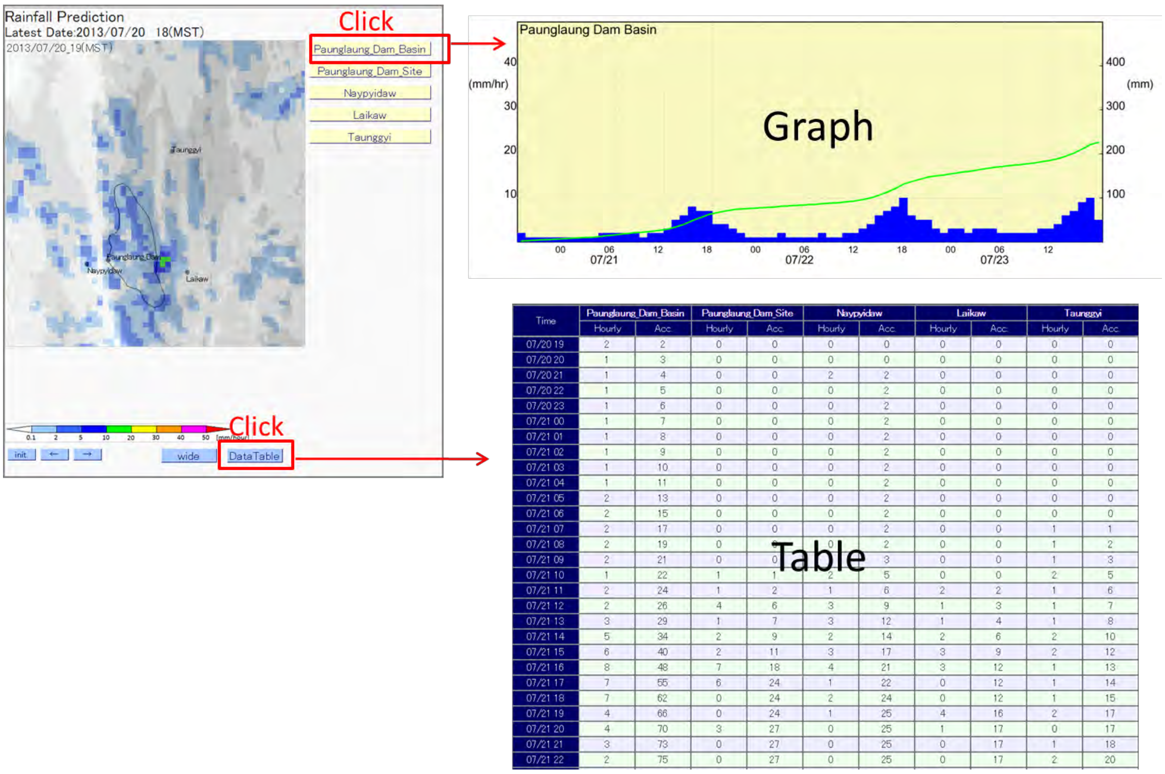
Meteorological Engineering Center, Inc., a group company of KANSAI, operates two rainfall prediction information services for Myanmar utilizing WRF for free. One is covering Myanmar as a whole (http://meci.kir.jp/wld-hydro/myanmar-wide/) and the other is targeting the Paunglaung dam basin (http://meci.kir.jp/wld-hydro/myanmar/). The services are posted on the Internet. Screenshots of rainfall prediction system for Myanmar are shown in Fig. 5-29 and Fig.5-30.

On the above-mentioned free site, the rainfall prediction model has not been customized considering the regional characteristics of Myanmar, so there is a possibility that it may not be adequately accurate. By customizing the model for the Yeywa dam basin, accuracy improvement is expected. We propose to construct a rainfall prediction system using WRF for the Yeywa dam basin. The Yeywa dam catchment area is included in the field of rainfall prediction information for all of Myanmar. By comparing past system forecast data and observed rainfall data, we can grasp the accuracy of the current free service and aim to realize further improvement in accuracy by customizing it for the Yeywa dam basin.



Source: JICA study team

Fig. 5-29 Screenshots of Rainfall Prediction System for Myanmar



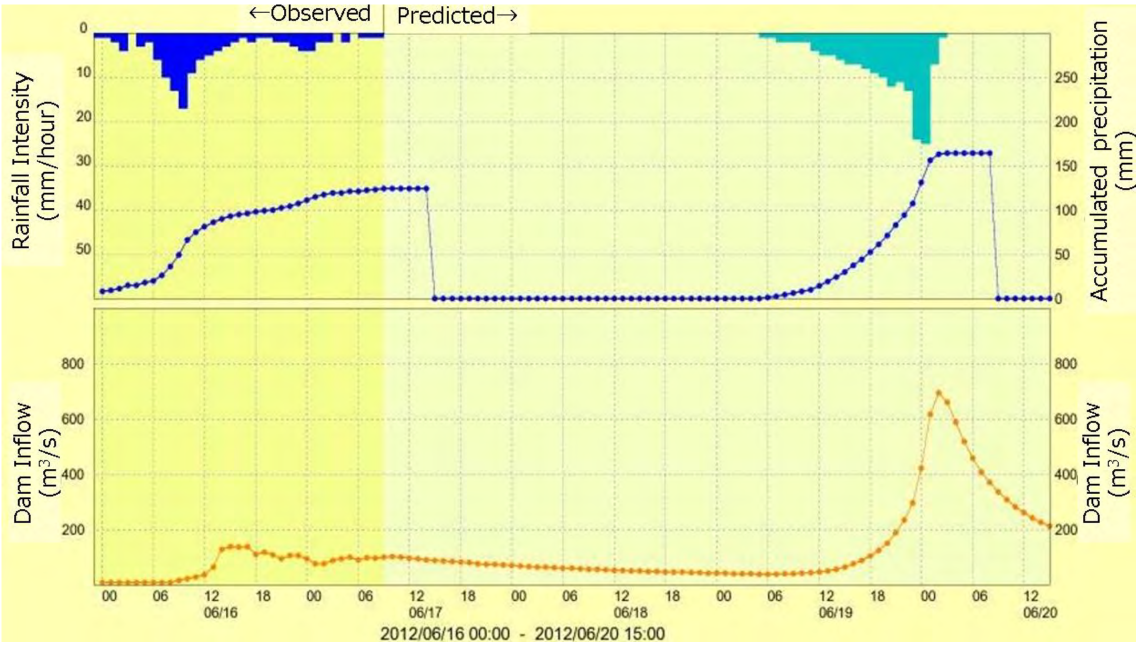
Time	Paunglaung_Dam_Basin		Paunglaung_Dam_Site		Naypyidaw		Laikaw		Taunggyi	
	Hourly	Acc.	Hourly	Acc.	Hourly	Acc.	Hourly	Acc.	Hourly	Acc.
07/20 19	2	2	0	0	0	0	0	0	0	0
07/20 20	1	3	0	0	0	0	0	0	0	0
07/20 21	1	4	0	0	2	2	0	0	0	0
07/20 22	1	5	0	0	0	2	0	0	0	0
07/20 23	1	6	0	0	0	2	0	0	0	0
07/21 00	1	7	0	0	0	2	0	0	0	0
07/21 01	1	8	0	0	0	2	0	0	0	0
07/21 02	1	9	0	0	0	2	0	0	0	0
07/21 03	1	10	0	0	0	2	0	0	0	0
07/21 04	1	11	0	0	0	2	0	0	0	0
07/21 05	2	13	0	0	0	2	0	0	0	0
07/21 06	2	15	0	0	0	2	0	0	0	0
07/21 07	2	17	0	0	0	2	0	0	1	1
07/21 08	2	19	0	0	0	2	0	0	1	2
07/21 09	2	21	0	0	2	3	0	0	1	3
07/21 10	1	22	1	1	2	5	0	0	2	5
07/21 11	2	24	1	2	1	6	2	2	1	6
07/21 12	2	26	4	6	3	9	1	3	1	7
07/21 13	3	29	1	7	3	12	1	4	1	8
07/21 14	5	34	2	9	2	14	2	6	2	10
07/21 15	6	40	2	11	3	17	3	9	2	12
07/21 16	8	48	7	18	4	21	3	12	1	13
07/21 17	7	55	6	24	1	22	0	12	1	14
07/21 18	7	62	0	24	2	24	0	12	1	15
07/21 19	4	66	0	24	1	25	4	16	2	17
07/21 20	4	70	3	27	0	25	1	17	0	17
07/21 21	3	73	0	27	0	25	0	17	1	18
07/21 22	2	75	0	27	0	25	0	17	2	20

Source: JICA study team

Fig. 5-30 Screenshots of Rainfall Prediction System for Paunglaung Dam Basin Area

In a dam managed by KANSAI in Japan, we analyzed relationships between the amount of rain in the dam basin and the amount of dam inflow, and constructed an outflow analysis model that outputs the amount of dam flow using rainfall in the dam basin as input data. Observed rainfall in the dam basin and prediction of rainfall up to several days ahead are used as input for the model to predict the amount of inflow into the dam and the predicted inflow data is utilized for safe and efficient operation of the dam.

A screenshot of the rainfall and runoff prediction system for a dam basin in Japan is shown in Fig. 5-31.

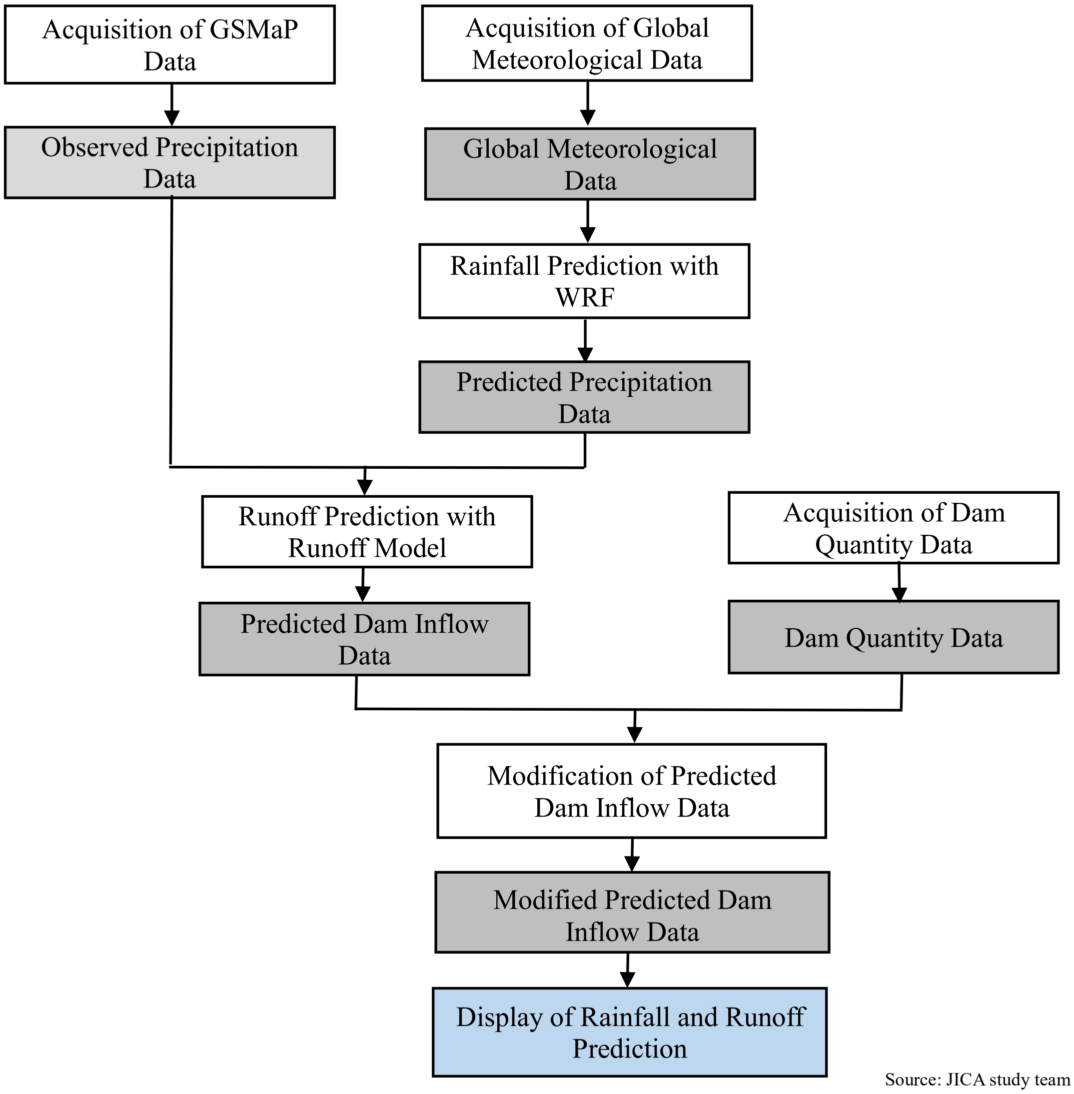


Source: JICA study team

Fig. 5-31 Screenshot of Rainfall and Runoff Prediction System for a Dam Basin in Japan

By constructing an outflow analysis model in the Yeywa Dam basin as well, the actual basin rainfall grasped by the satellite rainfall and the predicted basin rainfall predicted by WRF are input, and the dam inflow amount as shown in Fig. 5-31 is calculated in real-time, therefore it is possible to realize a system that predicts water inflow into the system.

The flow of the real-time dam inflow prediction system is shown in Fig. 5-32.



Source: JICA study team

Fig. 5-32 Flow of Real-Time Dam Inflow Prediction System

5.7.5 Establishment of Rainfall and Inflow Prediction System

A flowchart for the establishment of a rainfall and inflow prediction system and a rough cost estimate for the system are shown here following.

Table 5-26 and Table 5-27 show the flowchart for establishing the rainfall and inflow prediction system and rough cost estimate, respectively.

It should be noted that the work procedure described in the flowchart and cost should be modified according to the specifications and conditions of the facilities of the Yeywa dam and the needs of customers or operators.

Table 5-26 Flowchart for the Establishment of Rainfall and Inflow Prediction

１． **Understanding the current situation**
Confirm the current operation of actual time series data acquisition, internet accessibility and the specifications and conditions of the facilities of the Yeywa dam. In addition, conduct interviews with customers to understand their needs.

↓

２． **Data collection and management**
Collect inflow, rainfall and topographic data to develop a prediction model.

↓

３． **Design of prediction model**
Develop a basin rainfall estimation model, rainfall prediction model and runoff analysis model.

↓

４． **Development of a real-time processing system**
Develop a database of monitoring data accumulated for the prediction of precipitation and dam inflow for real-time use.

↓

５． **Development of a calculation system**
Develop a calculation system for real-time prediction of rainfall and dam inflow.

↓

６． **Development of a display system**
Develop a display system that shows calculated results to users in an easy-to-understand way.

↓

７． **Installation of rainfall and inflow prediction system**

Source: JICA study team

Table 5-27 Rough Cost Estimate for Establishment of Rainfall and Inflow Prediction System

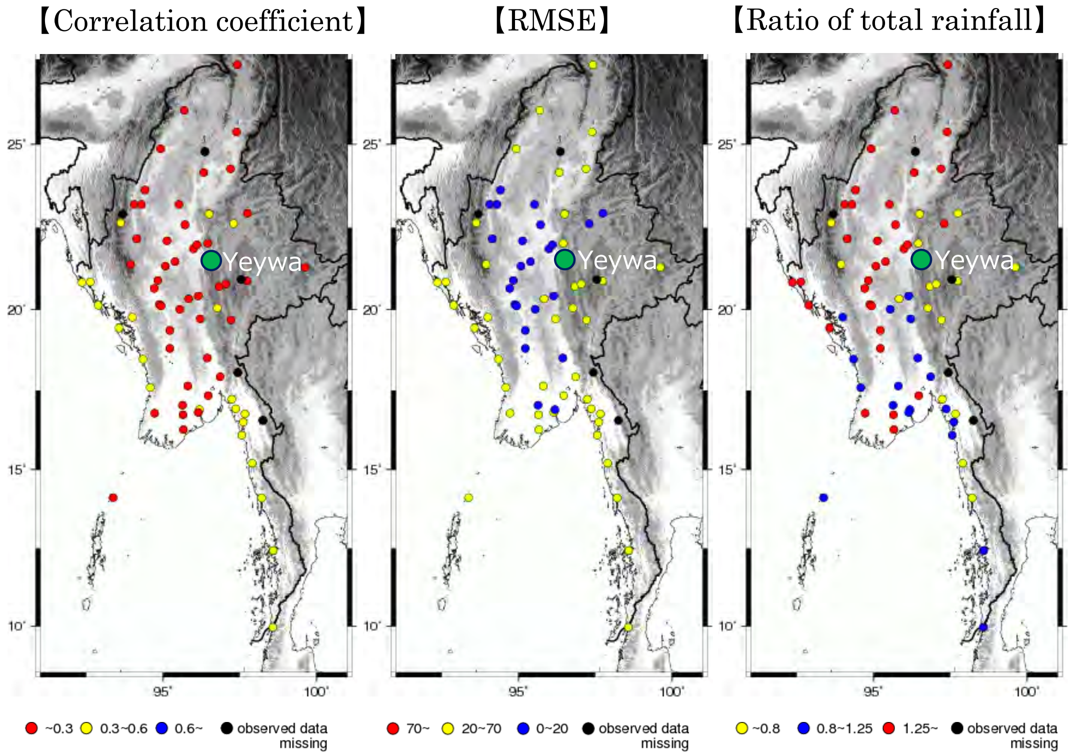
Item	Rough cost	Explanation
Understanding the current situation	2,000,000 JPY	Field survey, etc.
Data collection and management	4,000,000 JPY	Preparation of terrain data for analysis, etc.
Design of prediction model	4,000,000 JPY	Design and examination of each simulation model.
Development of real-time processing system	10,000,000 JPY	Creation of databases.
Development of a calculation system	20,000,000 JPY	Development of calculation equipment.
Development of a display system	5,000,000 JPY	Programming for functions to display results.
Installation of rainfall and inflow prediction	5,000,000 JPY	Connecting to the Yeywa dam.
Total	50,000,000 JPY	

Source: JICA study team

5.7.6 **Accuracy Verification of Satellite Rainfall Prediction**

To confirm the accuracy of the rainfall prediction by meteorological model (WRF) targeting Myanmar rain fall data monitored at the rainfall gauge on the ground and rainfall prediction three days before are compared. The correlation coefficient between the monitored rain fall data and the rainfall prediction three days before is 0.3 or less. RMSE* is 20 or more. The accuracy is judged not to be satisfactory, because the regional characteristics are not taken into account. Therefore, the characteristics of the Yeywa basin should be incorporated in the prediction system to improve accuracy.

*RMSE: Root Mean Square Error represents the standard deviation of the differences between predicted values and observed values. Lower values of RMSE indicate greater accuracy in prediction. In the case of Japanese rainfall prediction, values of RMSE are required to be 10 or less.



Source: JICA study team

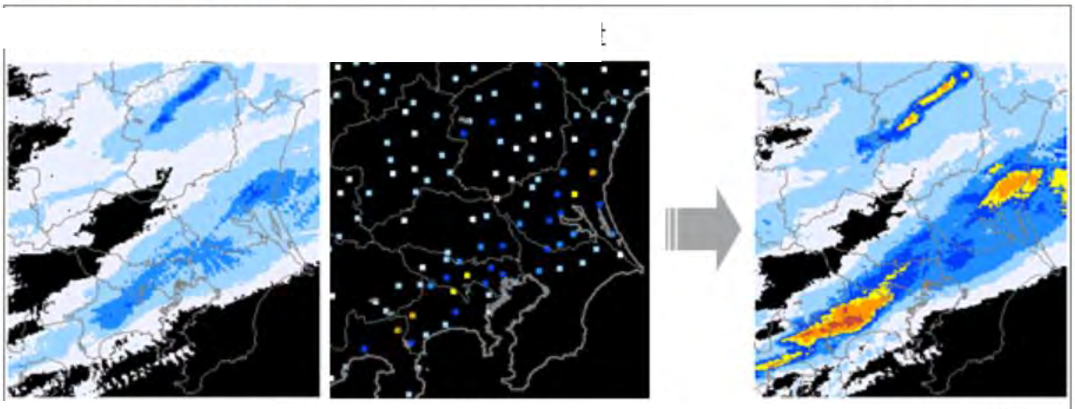
Fig. 5-33 Example of Accuracy Verification of Rainfall Prediction Targeting Myanmar (2014.6.1～2014.10.31)

A method for creating highly accurate rainfall maps has been developed by combining satellite rainfall data with rain gauges on the ground.

Accurate rainfall data can be obtained from the rain fall gauges on the ground, which do not, however, cover the whole area. On the other hand, the satellite rainfall data, which is not as accurate as the rain fall gauges on the ground, has the advantage of covering the whole area. Therefore, a rain fall map covering the whole area can be obtained by correcting satellite rainfall data with rain fall gauges on the ground.

Though the targeting area is not Myanmar, Meteorological Engineering Center, Inc., a group company of KANSAI, compared the accuracy of the results calculated only with the satellite rainfall data and the results calculated with satellite rainfall data corrected by the ground observation data. The accuracy of the rainfall distribution with the corrected satellite rainfall has been significantly improved compared with the rain fall distribution by satellite rain fall data only on condition that the rain fall gauges set every 5,000 km^2.

Considering that the catchment area of the Yeywa power plant is 28,206 km^2, 20 rainfall gauges are required to obtain the accurate rain fall distribution. In the case that the satellite data with the correction of ground rain fall data is adopted, six rain fall gauges are required on the ground at a minimum, therefore the number of the rain fall gauges can be reduced.



Source: JICA study team

Fig. 5-34 Development of Highly Accurate and Spatially Distributed Rainfall Data by Combining Spatially Distributed Rainfall Information and Ground Rain Gauges

In conclusion, to improve the accuracy, utilizing rainfall observation on the ground is quite effective. Therefore, installing at least six rain fall gauges within the Yeywa dam basin area is recommended to implement the precipitation prediction.

5.7.7 Proposal of Rainfall Gauging Stations on the Ground

A rainfall gauge, which is the only gauging station inside the Yeywa basin and gets the rain fall data once a day, is installed at the Yeywa dam site. The local staffs have to go to the rainfall gauging station and collect stored rainfall data to acquire the rain fall data and there is no transmitting system to obtain the data. Therefore, in the current rainfall observation, it is impossible to acquire the real-time data observed from a rainfall gauge.

Introducing the SESAME System to automatically measure rainfall data is recommended to collect real-time rain fall data. The SESAME System was developed by Midori Engineering Laboratory Co. Ltd, a Japanese company. The SESAME System automatically transmits rainfall data to a server through the existing mobile data networks. For transmitting the rain fall data from a large catchment area like Yeywa, this system is very effective.

Table 5-28 Rough Cost Estimate and Specifications of SESAME System Including Rain Fall Gauge

Item	Cost	Remarks
SESAME system	600,000 JPY	SESAMEII-02d
Rainfall gauge	80,000 JPY	Tipping bucket type rain gauge
Installation	100,000 JPY	Personnel expenses, etc.
Data transmission	36,000 JPY/year	Permanent cost after installation （3,000 JPY/month）
Total	816,000 JPY	

Item	SESAMEII-02d
Specifications	SESAME system main unit connected with the rain fall gauges. The SESAME system collects the rainfall data from the rain fall gauges installed in the field, transmits it to the rainfall and inflow prediction system through the mobile data network automatically. ・Measurement interval ：1 to 60 minutes ・Transmission interval ：5 minutes to 24 hours 

Source: JICA study team

The possibility of installing the SESAME system depends on the conditions including accessibility to the sites, permission by the authorities, and availability of the mobile communication network, etc.
There are several towns located upstream of the Yeywa dam, and accessibility is considered to be good. Availability of the mobile communication network should be confirmed. In case that a mobile communication network is not available, a satellite communication system can be utilized.

Source: Prepared by JICA study team based on Google Earth

Fig. 5-35 Catchment Area of Yeywa Dam and Location of City

Additionally, this real time data observation system can reduce the risk of data deficit, and time and cost for data collection.

5.7.8 Proposal of Support for Improving Dam Reservoir Operation

(1) Invitation to Japan

It is proposed to invite core members from the control centers and power plants in Myanmar to Japan and to provide training on the operation technology of hydropower plants in Japan (especially efforts to increase annual generated electricity).

The contents for training in the operation of hydropower plants are on Table 5-29.

Table 5-29 Contents of Invitation to Japan

Seminar on hydropower plant operation technology
・Introduction of hydropower plant operation technology in Japan (Integrated operation of hydropower plants, Inflow prediction technology) ・Tour of hydro power plant in Japan ・Proposal for improvement of annual reservoir operation of Yeywa dam Planned period : 5 days Assumed targets are core members of the EPGE and NCC (National Control Center). Source: JICA study team

(2) OJT and Seminars for Improvement of Dam Operation in Myanmar.

It is proposed to provide On-the-job-Training ("OJT") and seminars for the improvement of dam operation in Myanmar.

Japanese engineers skilled in dam operation would be assigned to provide the OJT and hold the seminars in order to enhance the motivation of effective operation and to improve the skills of local staff. In addition, operation manuals will be prepared. Continuous OJT and seminars are required for local staff to acquire enough skill to improve dam operation. Therefore, the OJT and seminars are to be provided for three to five years.

Table 5-30 Contents of OJT and Seminars in Myanmar

OJT and Seminars
OJT : Technical training on the efficient planning of power generation and dam operation is given to staff from Myanmar by skilled Japanese engineers. After introducing the rainfall and inflow prediction system, technical trainings are provided by skilled Japanese engineers to operate the dam effectively by accurate inflow estimation with the prediction system. Planned period：1 month × 4 times (3 to 5 years) Assumed targets are the employees of the NCC and Yeywa power plant. Seminar: Hold a seminar about necessity of an annual operation plan and improvement in dam operation. Planned period：1 day / year (3 to 5 years) Assumed targets are core members of the EPGE and NCC.

Source: JICA study team

(3) Proposal of OJT for the Rainfall and Inflow Prediction System

In the initial stage, there may be gaps between the actual inflow and predicted inflow due to the shortage of inflow data. As the data are accumulated, the prediction model can be modified and improved to reduce the gap between the actual inflow and the predicted inflow. Well-trained engineers are required to improve the model. Therefore, it is necessary to send Japanese engineers and perform OJT in the initial stage in which the model improvements are to be carried out. Additionally, OJT conducted by well-skilled engineers for the rain fall gauge installation and maintenance is necessary.

Table 5-31 Proposed OJT Program

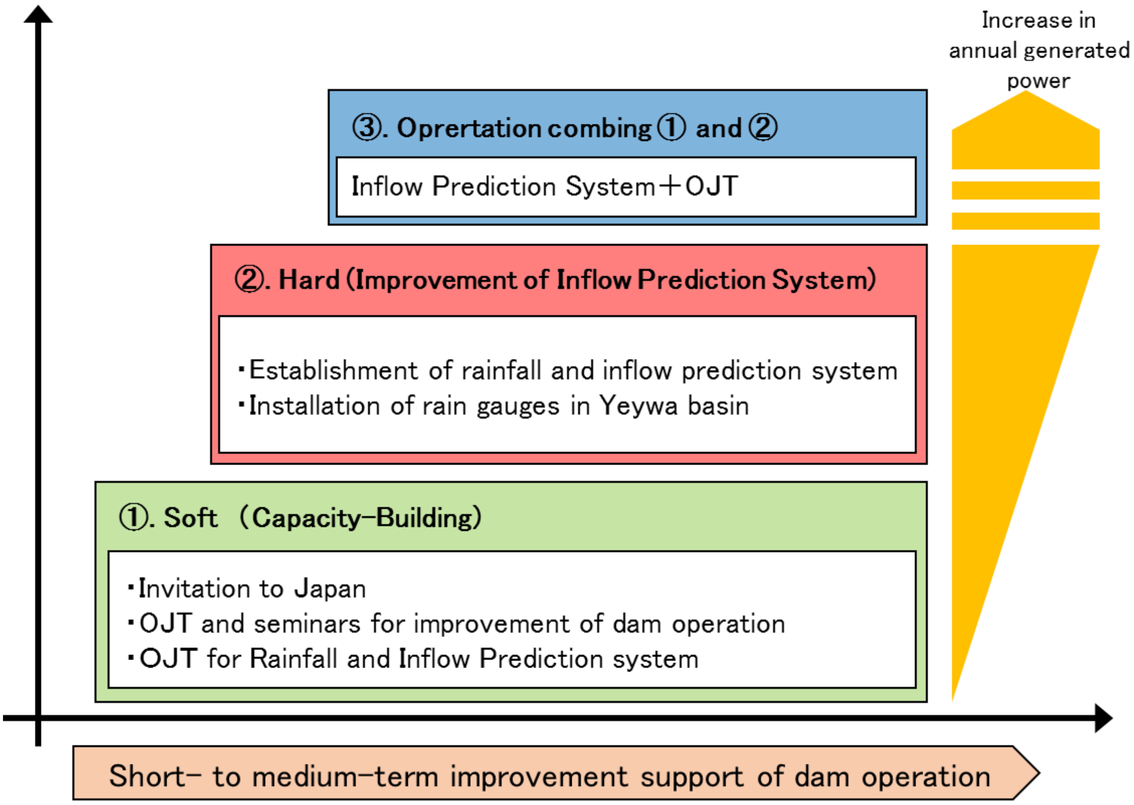
1. Rainfall and inflow prediction system	1-1. Training for the precipitation and inflow prediction system Planned period: 2 days Review of rainfall and inflow prediction system structure and user guidance by skilled Japanese engineers - Review of system structure (Lecture) - User guidance (Lecture and Practical training) 1-2. Improvement of model Planned period: 5 days Lecture about validation of precipitation and inflow system and model improvement by skilled Japanese engineers Assumed targets are employees of the NCC (National Control Center) and Yeywa power plant.
2. Rainfall gauge and SESAME system	2-1.Off-site training in installation and maintenance Planned period：2 days In order to transfer the knowledge and technologies for the maintenance of the SESAME System and rain gauges, technical training is given to staff from Myanmar by skilled Japanese engineers. - Review of system structure (Lecture) - Installation training (Lecture and Practical training) 2-2. OJT (On-site) training in installation and maintenance. Planned period： 7 days To deepen the understanding of the contents learned in the training in 2-1, OJT (On-site training) is carried out by skilled Japanese engineers at the actual installation site. - Skilled Japanese engineers point out and correct errors in the equipment installed by the local staffs. - After equipment installation, equipment wiring connections are checked by the skilled Japanese engineers. Assumed targets are the employees of the Yeywa power plant.

Source: JICA study team

Table 5-32 Implementation Schedule of Rainfall and Inflow Prediction System and Rain Gauge

Item	1				2				3～			
①Rainfall and inflow prediction system												
1.Understanding the current situation	■											
2.Data acquisition and management	■											
3.Design prediction model		■										
4.Development of a real-time processing system			■	■								
5.Development of a calculation system					■	■						
6.Development of a system for displaying results							■					
7.Installation of rainfall and inflow prediction system								■				
8.OJT									■			
9.Development of rainfall and inflow prediction system									■	■	■	■
②Rainfall gauge												
1.Determination of the location to install the prodcut	■											
2.Production of the product		■	■	■								
3.Installation of the product					■	■						
4.OJT					■							
5.Observation							■	■	■	■	■	■

Source: JICA study team



Source: JICA study team

Fig. 5-36 Method of Support for Improving Dam Reservoir Operation

5.8 System Operation

The grid operation system in Myanmar is managed by three organizations: NCC and GCC in the capital Nay Pyi Taw and LDC in Yangon. The roles of each organization are as follows.

GCC is an organization under EPGE, and performs backup such as reporting the possible output of each power plant to NCC taking into consideration the regular inspection period of the power plant.

Table 5-33 Roles of Organizations

Organization	Location	Role	Communication Method	Remarks
LDC (Load Dispatch Center)	Yangon	Frequency Control	Telephone	
GCC (Generation Control Center)	Nay Pyi Taw	Assist for NCC (Check availability, maintenance, etc.)	Telephone	They would like to install a monitory system.
NCC (National Control Center)	Nay Pyi Taw	Generation Planning	Siemens System (HI System)	Since 2015, they have obtained generation information from feeders, but they do not know the performance by units.

Source: JICA study team

In Japan, in order to economically operate the system as a whole, data such as the power generation cost of each power plant are managed, and the dispatching load based on merit order is implemented. Even in Myanmar, EPGE wants to make the best use of low cost hydropower plants, but it is in a difficult situation due to the various limitations described below.

(1) Transmission capacity limitation

(2) Dam storage capacity limitation, seasonal rainfall

(3) Penalty for deviation from the minimum operating guarantee to IPP

(4) Spinning reserve

Therefore, in order to improve the power business in Myanmar, in addition to the improvement in the O&M of thermal power and hydropower facilities, an improvement in the operation method of the power system, that is "System Optimization", is important.

The following shows a daily generation curve in the dry season, as confirmed by interviews with DPTSC.

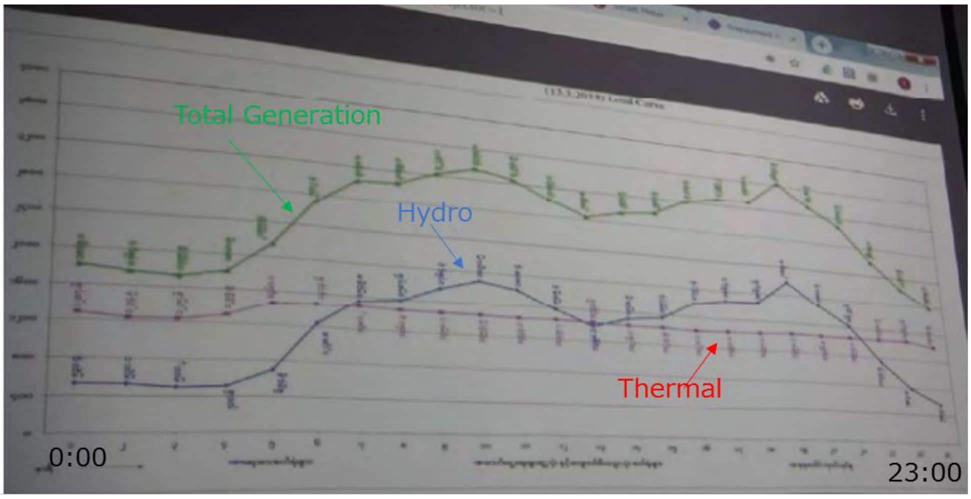


Fig. 5-37 Daily Generation Curve

Table 5-34 Generation Pattern

	IPP		EPGE	
	Hydro(5unit)	Thermal(10unit)	Hydro	Thermal
Dry Season	MAX Load	100% Load	MAX Load	100% Load
Wet Season	100% Load	80% Load	100% Load	50% Load

Source: JICA study team

The operating methods of thermal power and hydropower plants are different in the rainy season and the dry season, and are basically operated as follows.

Dry season: Because the dam storage capacity and inflow are not enough, thermal power is operated at 100% output, and the demand fluctuation is adjusted by hydropower.

Rainy season: Because the amount of water is sufficient, hydropower is 100% loaded and the thermal power reduces its output (approximately 50%).

As for IPP (thermal power), output is reduced within the range of the minimum availability guarantee.

Regarding the operating priority of thermal power, power plants owned by EPGE are determined based on the thermal efficiency calculated from the amount of power generation and gas consumption per month, and the IPP is determined from the thermal efficiency of the contract.

However, the efficiency during partial loading and the loss caused by starting and stopping are not particularly considered. These detailed studies require accurate data from each power plant. But, at the time of the site survey of each power plant, we found maintenance of generation and gas flow meter were not carried out properly, the value may not be measured accurately, and these data have not been accumulated. For this reason, detailed thermal efficiency (rated load, partial load, starting loss, etc.) of each unit cannot be grasped.

Therefore, proper maintenance of each instrument and digitization to enable remote monitoring and data storage would lead to the optimization of operation.

In addition, regarding hydropower, although it is considered that transmission line loss from the power generation area to the Yangon area, which is the main demand area, is considered, detailed calculations have not been performed.

As described above, system optimization has not been achieved due to the lack of accurate thermal efficiency data from each power plant and inadequate training in operation (such as priority calculation method).

Therefore, while managing the KPI proposed in the improvement of the power plant maintenance operation method, we would like to propose that skills for system operation be improved by technical support for DPTSC and lead to overall improvement of the power business in Myanmar.

Chapter 6 Utilization of Japanese Technologies (Especially Technologies Possessed by SMEs)

In this chapter, the JICA study team introduces the general services and technologies (especially the technologies possessed by SMEs) that is used for the equipment that helps to improve the maintainability of power plant equipment in Japan. Among them, the JICA study team proposes specific services that can be expected to solve power plant problems in Myanmar based on interviews with SMEs and the demonstration of some services in the site survey.

6.1 Introduction of Japanese Technology

(1) Portable Measuring Instrument

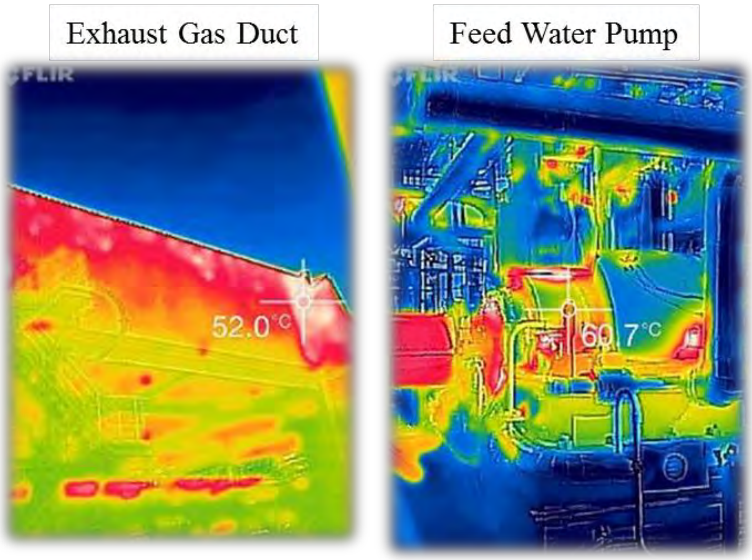
Many Japanese portable measuring instruments are expensive but high-performance and easy to use. Improvement of capacity factor is expected through the early detection and the prevention of troubles by utilizing them effectively in the daily management of power plants.

Examples of application in power plants are described below.

1) Portable Thermal Camera

A portable thermal camera makes it possible to visually confirm gas leaks, steam leaks, and abnormal signs of auxiliary machinery such as rotating equipment through thermal imaging of the temperature distribution. If the above-mentioned defects can be found at an early stage, it is possible to avoid an increase in fuel cost due to degraded efficiency caused by gas and steam leaks. It is also possible to find abnormal signs of auxiliary machinery, which may lead to an unplanned outages . Therefore, a portable thermal camera will contribute to economic profit. It can also be used for trend monitoring in abnormal situations of the main equipment by periodically photographing it. Moreover, it is possible to share accurate information of the situation amongst operators and maintenance personnel, by taking photos at a sudden fault and using them for explaining the site situation. Therefore, a portable thermal camera will help improve safety by preventing secondary disasters.

Two example applications of a portable thermal camera are shown below.



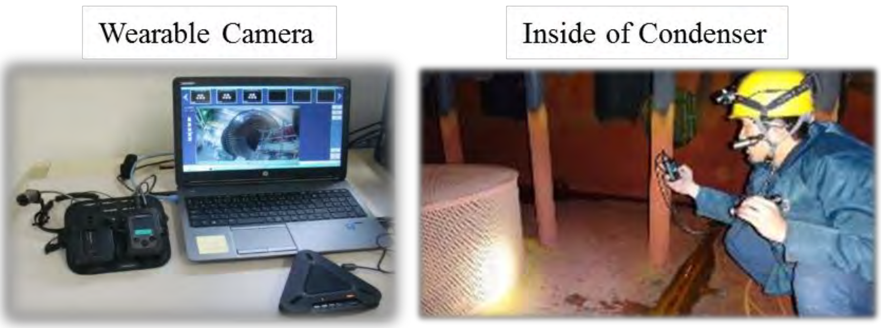
Source: JICA study team

Fig. 6-1 Example Applications of a Portable Thermal Camera

In the site survey, gas and steam leaks, and overheated equipment were found on an operating GT and HRSG. In addition, exhaust gas leaks that were causing a reduction in the efficiency of the power plant were found in the lower part of the HRSG casing and in the bypass damper. Moreover, staff may come in contact with overheated parts because of the exhaust gas leaks and get injured. Therefore, inspection with a portable thermal camera would be effective as a means of economical and safe operation of the power plant.

2) Wearable Camera

Conventionally, it was necessary to work in twos or more, depending on the ability of workers, when checking the operation conditions of equipment and operating equipment in the field. By adding visual information such as images, the work can be done promptly and accurately. Therefore, work efficiency and safety performance can be improved. Moreover, it is possible to utilize this device as an training tool for workers who have never done certain operations by recording the images related to operation of equipment that is rarely operated.



Source: JICA study team

Fig. 6-2 Wearable Camera

At thermal power plants, staff engaged in O&M have limited opportunities for training. The lack of technical capability resultantly causes equipment damage, loss of power output and a decrease in efficiency. Utilizing a wearable camera will help improve work quality because experienced workers can remotely assist other workers. In addition, it is also possible to record video, which can help improve O&M capability by analyzing the cause of trouble, devising recurrence prevention measures, and horizontally deploying those measures to other power plants.

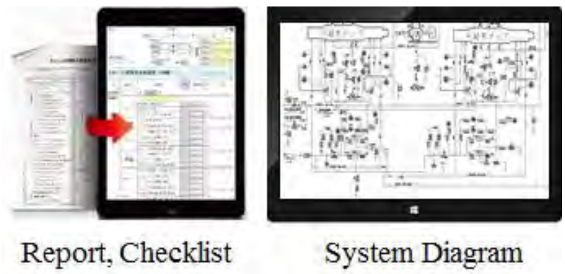
3) Tablet Devices

Utilizing tablet devices improves work efficiency and enables more sophisticated works. Examples of tablet utilization at power plants are shown below.

(a) It is possible to prepare forms without returning to the office by directly entering the inspection results from the tablet.

(b) It is unnecessary to carry paper diagrams around because the tablet device enables users to electronically confirm the related diagrams. Moreover, if other system diagrams are newly required on site, it is unnecessary to return to the office.

(c) Tablets lead to the early detection of abnormal conditions at the power plant because it is possible to understand the operation state of the power plant during patrol inspections.



Source: JICA study team

Fig. 6-3 Examples of Utilization of Tablet Devices

Operational data are recorded by hand during daily inspections and operations, and it is necessary to type the data in an Excel spreadsheet. Additionally, recorded data is also not utilized for trend monitoring, etc. Looking at the current situation, it will be effective to digitize the records of patrol inspections and tests by using tablets, smartphones, and/or smart pen/notebooks for data recording. This improves work efficiency, shares the information promptly by digitization, and prevents typing errors by automating data input. Moreover, it will also be possible to upgrade facility operation because digitized data can be utilized for trend monitoring.

(2) Smart Valve

A smart valve is a next-generation valve that can collect data such as the friction force in valve actuators, supply air pressure, air flow rate, etc. during operation of the power plant by mounting sensors on a control valve. In addition to having self-diagnostic functions, by utilizing the collected data, the following applications are possible.

a. Optimization of the maintenance cycle by understanding symptoms of abnormality and deterioration of the valve from a change in the frictional force
b. Prediction of the deterioration / wear of parts and detection of the deterioration of the function of the equipment such as trouble in a pressure reducing valve and leakage from air piping
c. Reduction in the time required to adjust the valve position by simplifying the valve adjustment method
d. Labor-savings by automatically creating test records

In general, a control valve (pneumatic type) used at a power plant has parts that wear and deteriorate over time in both of the valve main body and driving system. Also, it is necessary to overhaul the valve periodically in order to confirm the deterioration state. On the other hand, if the wear and deterioration of the control valve is understood by using the above-mentioned smart valve, it is possible to shift from time-based maintenance (TBM) to condition-based maintenance (CBM). Also, unlike a pneumatic positioner, an electric positioner has few parts that wear and deteriorate, and its accuracy is reliable because instrument error is less likely over time.

Installing the smart valve to the small power plants and simple cycle GTs with a small number of control valves will be low cost-performance because of high initial cost for renewing the positioner, building the system, etc. On the other hand, installing the smart valve to large power plants with a large number of control valves is feasible because of high cost-performance.

Fig. 6-4 Product Photos of Smart Valves

(Source: https://www.koso.co.jp/products/accessory/smartpositioner/KGP5000.html)

(3) Anti-Loosening Screw

Screws used for rotating equipment and valves at power plants are exposed to vibrations and stresses, so there is a risk of loosening with conventional screws. Loose screws may cause damage to major equipment, steam leaks, gas leaks, and so on. In the worst case, they may result in personal injury and unplanned outages of power plants.

On the other hand, it is possible to prevent troubles in the main equipment due to loosening because these screws do not loosen. As a result, they will contribute to an improvement in the capacity factor of power plants. They are also expected to reduce the labor associated with checking and re-tightening loose screws.

At the thermal power plants in Myanmar, trouble caused by loose screws was not confirmed. However, trouble of the sort is highly possible because equipment of a power plant is often exposed to vibrations for a long period of time. Moreover, because loose screws cannot be confirmed during operation, the problem is learned only after trouble occurs in many cases. Therefore, these products are effective for avoiding equipment damage caused by loose screws due to vibrations.

As above mentioned, trouble caused by loose screws was not confirmed. So, EPGE may not have recognized the Anti-Loosening Screw and its importance. The JICA study team recommends that the effectiveness of products be explained to EPGE for introduction to power plants.

A product photo of some anti-loosening screws is shown below.

Fig. 6-5 Product Photo of Anti-Loosening Screws

(Source: https://www.hardlock.co.jp/wp-content/uploads/pdf/HLN_Applications.pdf)

(4) Rotary Equipment Diagnostic System

It is possible to detect anomalous conditions of motors and rotating equipment by measuring the motor current signal during operation using a clamp-on meter at the distribution board. Therefore, it is possible to change how equipment, such as an underwater pump, that requires a disassembly inspection in order to check the state of deterioration, is managed from TBM to CBM. In addition, predictive maintenance such as early detection of anomalous conditions of motors and rotating equipment by electric signal analysis is also possible because the current signal measured on a wireless network can be remotely monitored.

Power plants in Myanmar have a lot of equipment that is managed by breakdown maintenance because of budget shortfalls and the lack of knowledge related to maintenance methods. Breakdown maintenance often requires long-term repairs when defects are found. This system makes it possible to find abnormal situations concerning equipment. So, we can repair equipment before serious damages occurs. As a result, it will contribute to a reduction in maintenance costs and to the improvement in the operation rate of equipment.

However, in order to maximize the effects of the introduction of this system, it is necessary to shake up the method of managing equipment at the power plants in Myanmar. For this reason, support in the form of O&M technology is necessary for data utilization of this system, for example, how to deal with abnormal signs and prepare equipment management manuals, are recommended.

A configuration example of a rotary equipment diagnostic system is described below.

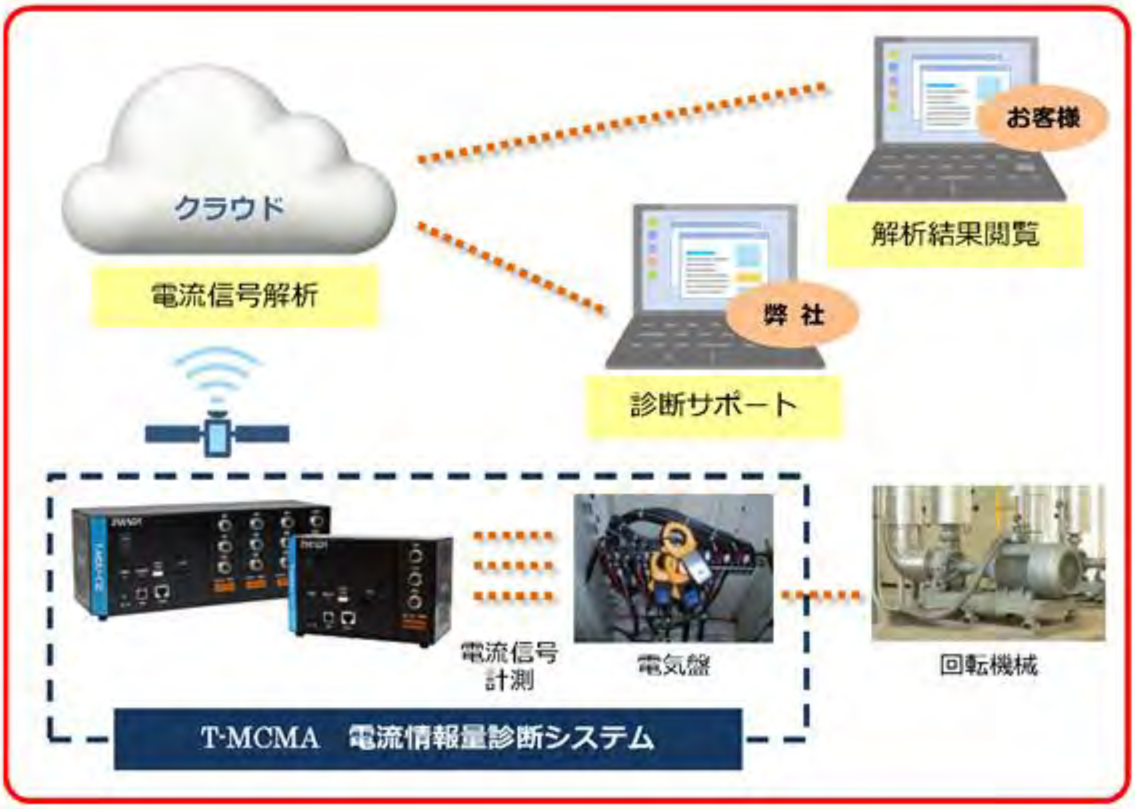


Fig. 6-6 Configuration Example of a Rotary Equipment Diagnostic System

(Source: https://www.atpress.ne.jp/news/175772)

(5) Vibration Sensor / Vibration Analysis System

At power plants, equipment that is greatly affected by failures, such as GTs, STs, generators, etc. has permanently embedded sensors that can measure shaft vibrations and phases, and is monitored continuously by utilizing an analysis system. On the other hand, with regard to BOP, vibration sensors are not permanently installed for cost reasons, so they are periodically measured and managed by a portable vibrometer.

However, in recent years, thanks to technological advances, compact, lightweight and easily retrofittable wireless vibration sensors with built-in batteries have been developed. Therefore, it is possible to prevent trouble by monitoring for abnormal symptoms and analyzing the vibrations when an abnormality occurs, by using this vibration sensor together with an analysis system.

Examples of a portable vibration sensor and vibration analysis system are shown below.

Fig. 6-7 Portable Vibration Sensor

(Source: https://www.shinkawaelectric.com/products/sensor/zark.html)

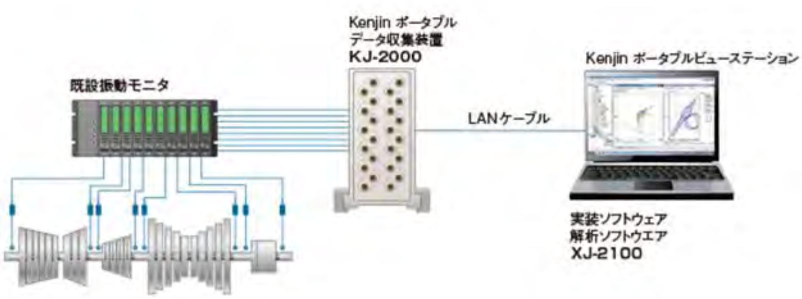


Fig. 6-8 Configuration Diagram of Vibration Analysis System

(Source: https://www.shinkawaelectric.com/products/analysis_diagnostics/kenjin.html)

Some private companies conduct training programs in Japan and overseas with instruction imparted by specialists in vibration diagnostics, as regular training related to certification as a "Machinery Condition Analyst (Vibration)" in accordance with ISO18436-2.

As a result of vibration measurements of the auxiliaries in the first site survey, the vibrations of some equipment were found to exceed the JIS control value. In addition, there were no records of overhaul or maintenance, and it was not possible to identify the cause of the vibrations. However, adopting this system enables monitoring for abnormal symptoms and cause analysis if abnormal vibrations occur, and as a result, it is possible to avoid long-term unplanned shutdown of the power plant due to the serious trouble in equipment.

However, in order to maximize the effects of introducing this product, it is necessary for power plant staff to be able to monitor abnormal signs and analyze the cause of them. Therefore, support in the form of O&M technology that is necessary for the introduction is recommended.

(6) IoT Device (Instrument)

In Japan, various types of low-cost IoT instruments using general-purpose technology have been developed for collecting and recording data automatically from the viewpoint of improving of labor productivity by reducing work time. The products confirmed in the domestic survey are shown below.

Products having wireless functions in conventional transmitters etc. are on the market. Many products allow not only monitoring functions but also large-scale data collection.

As another IoT device undergoing field testing, there is a product that enables remote monitoring by linking the device with a monitoring system after installing a tag label on the glass surface of the indicator at the site. In addition, it is possible to link equipment specification documents, drawings and instruction manuals with information on the tag label. Therefore, improvement in work efficiency will be expected because workers can confirm the above information by using mobile devices in the field.

A configuration example of a facility maintenance management system using radio frequency identifier (RFID) labels is shown below.

Fig. 6-9 Configuration Example of a Facility Maintenance Management System

(Source: https://www.jmfrri.gr.jp/content/files/Open/2017/20170210_IoT-usecase-SME/34_kobata_Gauge.pdf)

An effort has been made to improve the efficiency of business operations by automating data collection using ultra-small sensors that can measure electric current, electric power, angle and frequency with instruments, etc.

Also, a system that automatically inputs process values read from a picture of the field indicator as data has been developed.

As mentioned above, in Myanmar, power plant staff manually record the process value of the local instrument during operator surveillance. Adopting this system will improve work productivity because it is possible to shorten the time required to collect records and prepare reports.

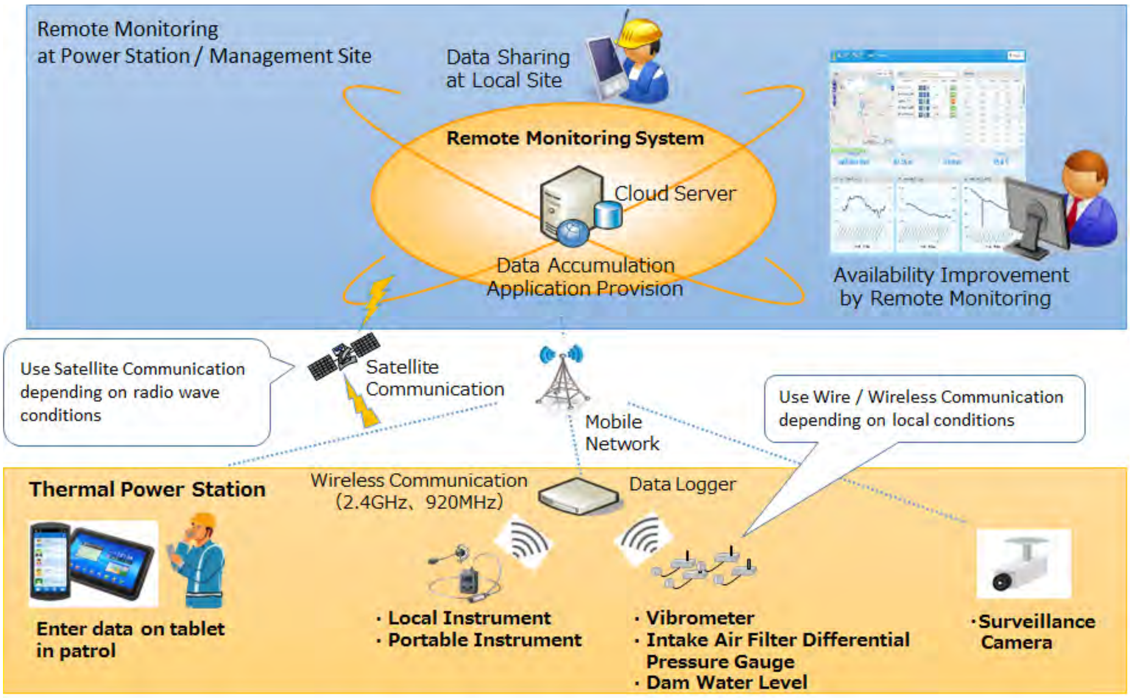
A lot of Japanese IoT devices comply with LPWA (Low Power, Wide Area) communication standards. Since communication regulations in Myanmar and in Japan have some difference, a lot of ready-made products cannot be used in Myanmar. As a result, it will be difficult to develop low-priced services at the moment.

(7) Real-Time Field Data Collection System

At power plants, a system for collecting data in real-time is installed for process values necessary for controlling the operation of the main equipment and the plant. However, the process values of less important BOP equipment often has to be confirmed in the field.

In recent years, with advances in information and communication technology, it is possible to build a system cheaply to collect field data. Therefore, maintenance management can be optimized with data analysis and visualization at low initial cost by building a system that enables data accumulation and analysis on the Internet cloud utilizing general-purpose technologies.

A configuration example of this system is shown below.



Source: JICA study team

Fig. 6-10 Configuration Example of a Real-Time Field Data Collection System

Myanmar's power plants have not installed a system that can sufficiently monitor the accessory equipment of GTs and BOPs. As of recent, the remote monitoring system described above can be constructed inexpensively and easily. And, the system can contribute to the early detection of trouble and the optimization of maintenance. However, the effect is limited because the maintenance cost to be reduced is low. Therefore, when installing the system, it is recommended to sufficiently consider cost-effectiveness such as the improvement of work efficiency and the reduction effect it will have on maintenance cost.

(8) Pat!naLock®-Σ

Equipment handling high temperature and high pressure steam, water, exhaust gas, etc. at a thermal power plant is exposed to a severely corrosive environment. In such an environment, it is necessary to perform periodic maintenance on corrosion and wall thickness reduction of ducts and piping, so the improvement of corrosion resistance has been a problem from the viewpoint of cost reduction. Pat!naLock®-Σ is a corrosion prevention system of new concept that reversely prevents corrosion by turning iron surfaces back into oxide, which is the original natural form (causing rust in other words). The corrosive factor in the environment and the iron in the base metal react with the active ingredients in Pat!naLock, so that a rust layer of high corrosion resistance is formed. It might be possible to extend the life of the equipment without using expensive steel materials such as stainless steel by coating this acid-resistant reactive paint in places highly vulnerable to corrosion and newly installed boiler tubes, from which great cost-savings can be expected.

The mechanism for forming the acid-resistant anti-corrosive layer with Pat!naLock®-Σ is shown below.

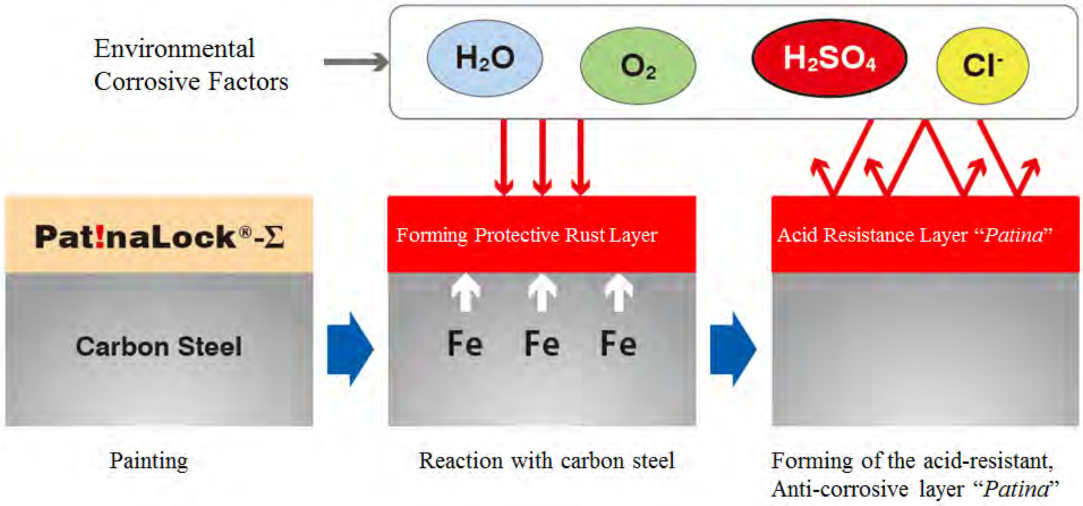


Fig. 6-11 Mechanism for Forming an Acid-Resistant Anti-Corrosive Layer with Pat!naLock®-Σ

(Source: Prepared by the JICA study team based on https://www.mhps.com/jp/news/pdf/20171127.pdf,)

The fuel gas supplied to the thermal power plants in Myanmar contains sulphur constituents. Therefore, the HRSG in which exhaust gas flows will be exposed to a severely acidic corrosive environment.

Applying Pat!naLock®-Σ to areas subject to severe corrosion such as the HRSG economizer tubes will reduce the amount of corrosion in the equipment and help improve the capacity factor.

Many of the power plants in Myanmar have operated a long time since COD. In addition, power plant staff don't have adequate O&M skills. So, equipment deterioration is expected to be severe. Therefore, it is recommended to evaluate the cost-effectiveness before introducing this product.

(9) Water Treatment System

At a power plant, the water treatment equipment is installed for various purposes. For example with regard to water supply, water treatment systems such as a pretreatment system and a demineralizer are installed as necessary in order to prevent trouble caused by poor water quality such as corrosion and scale adhesion in the boiler system and turbine system. And, the water quality specified by industrial standards (JIS) concerning water supply is maintained. With regard to wastewater, wastewater treatment equipment that is necessary to comply with strict emission standards stipulated by laws, regulations and agreements is installed.

Against this background, Japanese manufacturers of water treatment equipment have supplied reliable equipment that can meet the above-mentioned industrial standards (JIS) for water supply and strict effluent standards for many years to electric power companies. Also, desalination equipment is recognized worldwide, and water supply and wastewater equipment are also the world's highest level in terms of the performance of membranes and resins. Advanced automatic operation technology enables efficient O&M, and improves the quality of feed water and effluent, which is important to power plant operation. Therefore, installing Japanese water treatment systems leads to long-term stable operation.

An example of a general water treatment system is shown below.

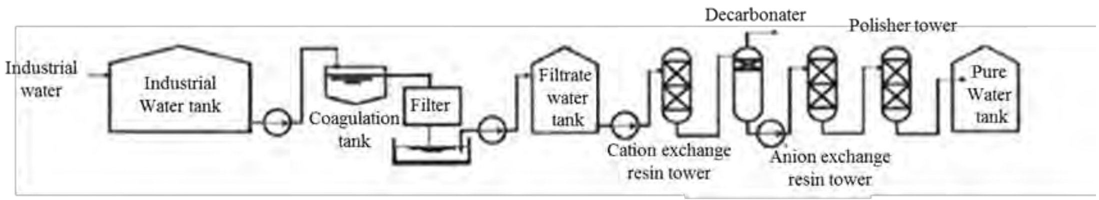


Fig. 6-12 Schematic Diagram of Water Treatment System
(Source: MHI technical report Vol.50 No.3 (2013))

Water treatment equipment for the water supply to power plants was severely deteriorated, and it had been bypassed in some power plants. This seems to be because equipment was not maintained appropriately due to the lack of O&M skills. Poor quality of power plant supply water leads to a decrease in power plant efficiency due to scale sticking to the turbine blades. Therefore, the JICA study team recommends that introduction of this equipment be considered.
Wastewater treatment equipment has not been installed at many power plants in Myanmar. In addition, water containing chemicals was drained without being properly treated. The quality of the wastewater is likely to exceed general international standards, so there are concerns about the impact on local residents, animals and plants. From the above, it is desirable to satisfy the wastewater standards by introducing wastewater treatment equipment to the power plants in Myanmar. Also, it is desirable to provide guidance on appropriate O&M methods so that the standards can be satisfied over the long term.

(10) Inlet Air Cooling System

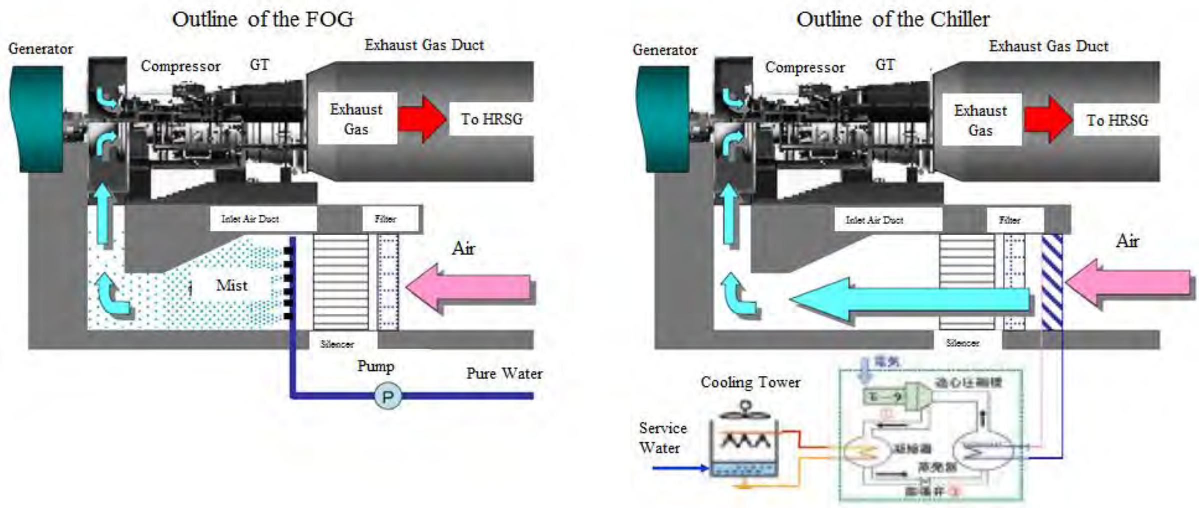
An inlet air cooling system restores power output by cooling the intake air in order to suppress the decrease in the maximum power output due to an increase in the intake air temperature of the GT during periods of high air temperature such as summer.

Inlet air cooling systems are generally divided into chiller types and water spray types. The characteristics and schematic diagrams of each type of intake air cooling system are shown below.

Table 6-1 Characteristics of Intake Air Cooling Systems

Inlet air cooling type	Output recovery	Power consumption of auxiliary equipment	Pressure loss of intake air	Installation cost
Water spray type	Low	Low	Low	Medium
Chiller type	Medium	Medium	Medium	High

Source: JICA study team



Source: JICA study team

Fig. 6-13 Schematic Diagrams of Intake Air Cooling Systems

There are products of high performance and excellent price that are easily mounted. In Myanmar, suppressing the decrease in power output can be expected by installing this system because of the high air temperature throughout the year.

An intake air cooling system requires water treated by a water treatment system. Many existing power plants do not have water treatment equipment, so additional installation of water treatment equipment is required at the time of introduction of the system. Therefore, the cost-effectiveness of this equipment cannot be expected in application to small GTs. On the other hand, the cost-effectiveness of this equipment can be expected in application to large GTs and to power plants where water treatment equipment is already being used.

(11) Reverse Osmosis (RO) System (Seawater Desalination Equipment)

An RO system desalinates seawater to use it as industrial water or drinking water. Fresh water is obtained by supplying seawater at high pressure to semipermeable membranes (membranes that allow water to pass but trap dissolved salts), which is called the “RO method”. It is possible to secure the necessary water for power plants from seawater, sewage water and other sources of poor water quality by using the RO system. The RO membranes made in Japan are high quality and durable, and can also contribute to energy-savings when installed with high-efficiency energy recovery devices.

A schematic diagram of an RO system is shown below.

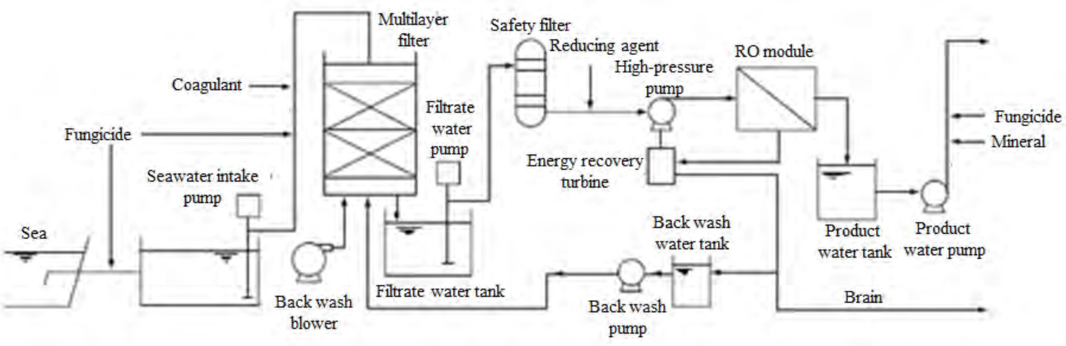


Fig. 6-14 Schematic Diagram of an RO System

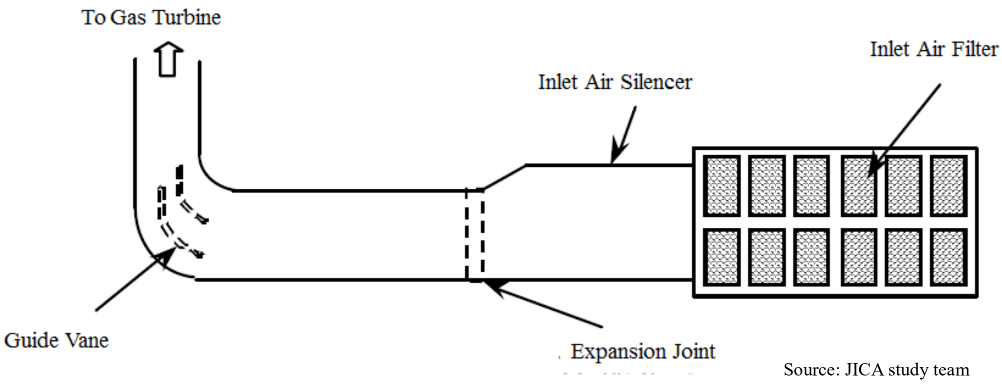
(Source: MHI technical report Vol.39 No.5 (2002-9))

In some case, river water (groundwater) may have water quality close to that of brackish water. In the above case, the use of RO equipment is required in order to satisfy the conditions for receiving water for power plants. However, poor water quality had caused power plant trouble because this equipment was not installed. And, RO equipment installed at the power plants had severe deterioration. Therefore, it is assumed that the RO equipment had not been properly operated and managed due to a lack of O&M skills. The Japanese system can improve durability with high-quality RO membranes. In addition, it can contribute to energy savings by installing high-efficiency energy recovery devices. The JICA study team recommends to teach appropriate O&M methods for long term operation at the time of the system introduction.

(12) Air Intake Filter

In an intake system of a power plant installing GTs, it is important not only to smoothly introduce combustion air, but also to remove foreign matter and dust in the air and to prevent noise. When air containing dust and mist is drawn, it causes wear in the rotor and stator vanes of the air compressor and deterioration in performance because of adhesion of dust and mist to them. And, it causes surging in the worst case. In general, compressor blades wear due to dust of 10 μm or more and get dirty due to dust of 10 μm or less. Therefore, a high efficiency three-stage filter is often adopted as an air intake filter.

A schematic diagram of an air intake system is shown below.



Source: JICA study team

Fig. 6-15 Schematic Diagram of an Air Intake System

Existing power plants in Myanmar are designed to prevent damages to the compressor blades due to foreign matter and dust by installing both a single-stage filter and compressor cleaning system. However, foreign matter and dust entered the air compressor due to the intake filter bypass operation caused by the deterioration of the intake filter medium and the outage of the compressor cleaning system due to defects. As the result, the power plant efficiency has decreased.

The air intake filter products made in Japan are superior in filter medium and have high durability. Therefore, introduction of these products leads to longer maintenance cycles and a high operating rate of the power plant. However, regarding the introduction of this product, it is recommended to evaluate the cost-effectiveness based on the frequency of filter replacement on local operational conditions and the current deterioration status of air compressor blades.

(13) Surveillance Camera

Surveillance cameras are often installed on power plant premises to monitor hazardous materials, reduce labor associated with field confirmation and verify the operating conditions of environmental equipment. In the past, adoption of a monitoring system using expensive analog cameras was the mainstream, but in recent years many systems using inexpensive digital cameras (Web cameras) and cloud services are also adopted.

With digital camera systems, services have been expanded beyond conventional uses for monitoring equipment with moving images, to detecting moving objects and temperature, and providing access control by facial recognition. Some cameras are equipped with communication functions, and it is possible to build a system according to the needs at low cost by making good use of PoE functions, etc.

Examples of digital camera utilization are shown below.

・Monitoring for leaks of hazardous materials (oil, gas, etc.) and accidents
・Confirmation of operating condition of fire-extinguishing equipment during a disaster
・Efficient monitoring of power plant equipment

- Early detection of abnormality by way of moving object detection or temperature detection
- Entry and exiting monitoring to and from the power plant
- Illegal intrusion monitoring
- Efficient operation of hydro power plant by monitoring dam level

At some power plants in Myanmar, surveillance cameras are installed for monitoring substations from a viewpoint of security. Moreover, other power plants needs surveillance cameras for the same reason. There are many kinds of surveillance cameras, and it is possible to provide inexpensive systems and services that meet the needs. Therefore, the installation of surveillance cameras for early detection of equipment abnormalities and improvement of safety will be effective.

6.2 Specific Examples of Utilizing Japanese Technology

The results of comprehensive examination of the devices and services introduced in Section 6.1 are as follows.

Devices and systems above mentioned are evaluated from the viewpoint of needs, maintainability, feasibility, and the possibility of adaptation to Solution A, B and C classified in Chapter 5 is described as a solution category.

Solution A: For remote monitoring
Solution B: For O&M training and daily maintenance inspection
Solution C: Large-scale construction required

Table 6-2 Comprehensive Examination of Devices and Services

Items	Feasibility of introduction in Myanmar	Remarks	Solution
Portable Thermal Camera	High	The cost advantage is low because there are many inexpensive overseas portable products on the market. On the other hand, Japanese devices offer superior performance such as a wide temperature measurement range and high accuracy. The product is made considering ease of use on the user's side, such as the ability to handle measured values as temperature data, which can be expected to be used for confirmation of failure signs.	B
Wearable Camera	High	The cost advantage of Japanese products is low, but the functional advantages are high such as high accuracy. Services linked to VR, etc. have also been developed, and it can be expected to be used in a wide range of ways to improve O&M technologies such as use as educational materials, remote work support and failure factor analysis.	A,B
Tablet Devices	High	Japanese companies have a wide range of services that improve work efficiency and enable more sophisticated work because of digitization of forms and utilization thereof for equipment management. Demonstrations were conducted during a survey in Myanmar, and there were many positive opinions about the introduction of this service. Considering the current O&M situation, etc., service expansion can be expected from the digitization of forms.	A,B
Smart Valve	Medium	Remote monitoring of the valve drive parts, etc. will lead to a reduction in maintenance costs. However, it is difficult to estimate the cost-effectiveness at present because the cost for introduction such as updating of the positioner and system construction is expensive. Installing smart valves at small power plants and simple cycle GTs will offer low cost-performance because of the high initial cost of replacing the positioner, building the system, etc. On the other hand, installing smart valves at large power plants is feasible because of the high cost-performance.	A,C
Anti-Loosening Screw	Medium	The original technology of Japanese companies is used, and it is possible to prevent trouble in major equipment caused by screws loosening due to vibration. In the survey, no failure record due to loose screws was found, but based on the failure record in Japan, accident analysis may have been insufficient. The JICA study team recommends that the effectiveness of products be explained to EPGE to encourage introduction to power plants.	C
Rotary Equipment Diagnostic System	Medium	Using this system makes it possible to grasp abnormal signs. However, in conjunction with the introduction, support for O&M technology necessary for data utilization of this system is recommended.	A,B
Vibration Sensor / Vibration Analysis System	Medium	Vibration analysis enables early detection of abnormalities. However, in conjunction with the introduction, support for O&M technology necessary for data utilization of this system is recommended.	A,B
IoT Device (Instrument)	Medium	In Japan, low-cost IoT instruments using general-purpose technology are circulated on the market. IoT makes it possible to improve reliability by accumulating a huge amount of data and to shorten the work time required to collect data and make out a report. However, it is difficult to deploy Japanese products at the power plants in Myanmar without adjustment due to differences in usable frequency bands.	A,B
Real-time Field Data Collection System	Medium	The system of the main equipment can be expected to develop services together with LTSA by plant manufacturers. Inexpensive services utilizing general-purpose technology have been developed for plant operation management, auxiliary equipment and BOP. Since the cost effectiveness is limited depending on the system scope, it is recommended to evaluate the cost effectiveness when building the system.	A,B
Pat!naLock®-Σ	Medium	The fuel gas supplied to the thermal power plants in Myanmar contains sulphur constituents. And, sulfuric acid corrosion can be prevented by applying this product to the boiler internal piping. Many of the power plants in Myanmar have operated a long time since COD. In addition, power plant staff have inadequate O&M skills. So, equipment deterioration is expected to be severe. Therefore, it is recommended to evaluate the cost-effectiveness before introducing this product.D20	C
Water Treatment System	Medium	As a result of a field survey in Myanmar, water treatment equipment for power plant water supply has been installed, but it was not fully functioning. This seems to be because equipment has not been maintained appropriately due to the lack of O&M technology. The JICA study team recommends that this equipment be introduced. It seems necessary to develop services from proposals that lead to improved operation of this equipment. At existing power plants, there were cases where wastewater treatment equipment was not installed and wastewater was drained without proper treatment. This seems to be due to the delay in the development of environmental laws and regulations. However, legislation is progressing and it is expected that equipment will be introduced in the future. It is thought that services can be developed from proposals tailored to environmental measures. In both cases, it is desirable to provide guidance on appropriate O&M methods so that the standards can be satisfied over the long term.	C
Inlet Air Cooling System	Medium	Although the system can improve the output of thermal power plants, it requires water treated by a water treatment system. Many existing power plants do not have water treatment equipment, so additional installation of water treatment equipment is required at the time of introduction of the system. Therefore, the cost-effectiveness of this equipment cannot be expected in application to small GTs. On the other hand, the cost-effectiveness of this equipment can be expected in application to large GTs and to power plants where water treatment equipment has already been used.	C
Reverse Osmosis (RO) System (Seawater Desalination Equipment)	Medium	As a result of the field survey, in the past, there was trouble caused by the water quality (seawater) of the power plant. RO equipment installed at the power plant had severe deterioration. Therefore, it is assumed that the RO equipment had not been properly operated and managed due to a lack of O&M technology. The Japanese system can improve durability with high-quality RO membranes. In addition, it can contribute to energy savings by installing high-efficiency energy recovery devices. The JICA study team recommends that appropriate O&M methods for long term operation be taught at the time of the system introduction.	C
Air Intake Filter	Medium	Some power plants in the country have increased pressure loss due to deterioration of filter media, and intake filter bypass operation has been implemented. Based on results in Japan, it is assumed that the filter media of Japanese products offers high durability and can be used for a long time. However, it is recommended to evaluate the cost-effectiveness based on the frequency of filter replacement under local operating conditions and the current deterioration status of air compressor blades.	C
Surveillance Camera	High	There are many inexpensive overseas products for cameras, and the superiority of Japanese products is low. On the other hand, with Japanese products, it is possible to build a system that meets needs such as temperature monitoring, motion detection function, security management, and it is expected to develop services that meet the needs of Myanmar.	A

Solution: Application possibilities of each item are shown for Solution A (Digital Package), B (Soft Infrastructure) and C (Hard Infrastructure) described in Chapter 5.

Source: JICA study team

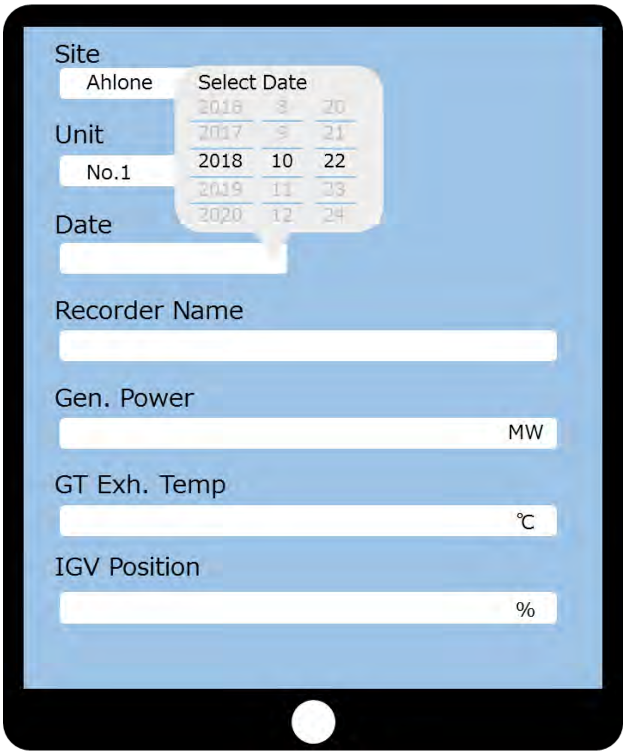
Demonstrations were conducted during the survey with regard to equipment and services that can be prepared and used with comparative ease based on the actual conditions of O&M of power plants in Myanmar and the needs of EPGE and each power plant determined from this survey. The JICA study team proposes concrete usages considering the results of the demonstrations.

As for the remaining equipment and services introduced in Section 6.1, it is difficult to demonstrate them in the investigation period because time is needed to prepare the site and procure the equipment. However, the JICA study team continues to study proposals of more specific services.

(1) Electronic Form Management

Operational data are recorded during daily inspections and operations by hand, then it is necessary to type the data into an Excel spreadsheet at the time of monthly report creation. Additionally, recorded data is also not utilized for trend monitoring, etc. Given the circumstances, the JICA study team judged there is room for improvement in data recording and management method.

As an improvement proposal, it is thought that it would be effective to digitize the records of patrol inspections and tests by using tablets, smartphones, and/or smart pen/notebooks for data recording. This not only improves work efficiency, shares the information by digitization, and prevents typing errors by automating data input, but also creates graphs easily from digitized data. Moreover, it is also possible to upgrade facility operation as a result because digitized data can be utilized for trend monitoring.
In order to confirm applicability in Myanmar, a field demonstration of electronic form management was conducted in the second survey. In this demonstration, the JICA study team used "Microsoft Power Apps" manufactured by Kanden System Solutions Co., Inc. (KS-Sol). In this service, it is possible to automatically create a data recording template by accessing the business application created by KS-Sol from the tablet, inputting datum and uploading it to the cloud. Also, it is possible to upload comments about issues found during patrol inspections and pictures taken with the tablet tool on the cloud. Therefore, it is possible to promptly share information with the EPGE head office and each power plant. In addition, when normal values, limit values, etc. are set on the input screen, it is also possible to instantly judge whether the data is abnormal upon input. In the demonstration, the data was actually input from the tablet. The JICA study team explained how the form was created automatically and the trend monitoring method using the input data.



Source: JICA study team

Fig. 6-16 Input Screen of Tablet (Example)

Time	Gen. Power	GT Exh. Temp	IGV Position	Fuel Gas Flow	Lube Oil Header Temp	No.1 Brg Metal Temp	No.1 Brg Vibration X	No.1 Brg Vibration Y	No.2 Brg Metal Temp	No.2 Brg Vibration X	No.2 Brg Vibration Y	Lube Oil Brg Header Press	Lube Oil Tank Level	Gen Current	Gen Voltage	Gen Freqency
	MW	℃	%	kg/h	℃	℃	μm	μm	℃	μm	μm	Mpa	%	kg/h	kV	Hz
High L		590	84		74	115	105	105	115	105	105	0.26	77	2052		
Normal	31.7											0.172			11	50
Low L					40							0.078				
0:00	0.0	0	0		40	40	0	0	40	0	0	0.26	75	2052	11	50
1:00	10.0	500	70		60	90	80	80	60	80	80	0.26	75	2052	11	50
2:00	30.0	590	84		70	110	80	80	90	80	80	0.26	75	2052	11	50
3:00	31.7	590	84		70	110	80	80	90	80	80	0.26	75	2052	11	50
4:00	31.7	590	84		70	110	80	80	90	80	80	0.26	75	2052	11	50
5:00	31.7	590	84		70	110	80	80	90	80	80	0.26	75	2052	11	50
6:00	31.7	590	84		70	110	80	80	90	80	80	0.26	70	2052	11	50
7:00	31.7	590	84		70	110	80	80	90	80	80	0.26	70	2052	11	50
8:00	31.7	590	84		70	110	80	80	90	80	80	0.26	70	2052	11	50
9:00	31.7	590	84		70	110	80	80	90	80	80	0.26	70	2052	11	50
10:00	31.7	590	84		70	110	80	80	90	80	80	0.26	70	2052	11	50
11:00	31.7	590	84		72	110	80	80	90	80	80	0.26	70	2052	11	50
12:00	31.7	590	84		74	110	80	80	90	100	100	0.26	70	2052	11	50
13:00	31.7	590	84		76	110	80	80	100	100	100	0.26	70	2052	11	50
14:00	31.7	590	84		80	110	80	80	110	101	101	0.26	70	2052	11	50
15:00	31.7	590	84		80	110	80	80	112	102	102	0.26	70	2052	11	50
16:00	31.7	590	84		80	110	80	80	114	104	104	0.26	70	2052	11	50
17:00	31.7	590	84		80	110	80	80	116	106	106	0.26	70	2052	11	50
18:00	31.7	590	84		80	110	80	80	118	108	108	0.26	70	2052	11	50
19:00	31.7	590	84		80	110	80	80	118	108	108	0.26	70	2052	11	50
20:00	31.7	590	84		80	110	80	80	118	108	108	0.26	70	2052	11	50
21:00	31.7	590	84		80	110	80	80	118	108	108	0.26	70	2052	11	50
22:00	31.7	590	84		80	110	80	80	118	110	110	0.26	70	2052	11	50
23:00	31.7	590	84		80	110	80	80	118	110	110	0.26	70	2052	11	50

Source: JICA study team

Fig. 6-17 Output Screen of Form (Example)

(2) Gas Detector

When the JICA study team used the gas detector at the gas receiving station, a large amount of gas leaks in the lid portion of the strainer was confirmed. It is very important in terms of safety and cost to find out gas leaks early and implement measures such as repairs because a large amount of leaked gas amplifies the risk of explosion and the increase in fuel cost.

In the second site survey, the JICA study team used a laser type gas detector (Laser Methane miniSA3C32B-NJ) manufactured by Tokyo Gas Engineering Solutions Corporation as demonstration equipment. An example of using the gas detector is shown below.

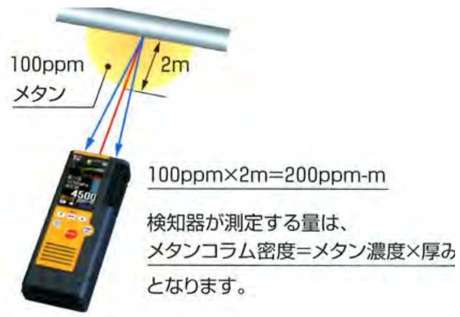


Fig. 6-18 Outline of Laser Type Gas Detector

(Source: https://www.rex-rental.jp/anz/sa3c32b.html)

With this gas detector, it is possible to quickly detect gas leaks and congestion from a remote place by utilizing the characteristics of a methane absorbing infrared laser. Moreover, it does not need calibration and repair in the short-run because this detector does not have parts for causing chemical reactions. Therefore, it is considered to be effective for the power plants in Myanmar where the management system of portable instruments is not established. But, it is difficult to detect gas leaks by laser irradiation to the space because this detector detects the amount of gas by using reflection of laser.

In the second site survey, each staff tried this detector in the field after the JICA study team explained the importance of detecting gas, usage of the gas detector, values displayed on the detector and precautions in use.

(3) Portable Measuring Instruments

In the site survey, many equipment shutdowns due to trouble were confirmed, but root cause analyses of the trouble were not sufficiently conducted. The fact that periodic calibration of the field instruments has not been conducted and the measuring instruments are not sufficiently held is one factor they cannot analyze the cause. As a result, fundamental countermeasures cannot be implemented, and troubles often recur.

Based on such a situation, the JICA study team conducted a demonstration of a thermal camera in the second site survey in order to familiarize the staff with the effectiveness of using portable measuring instruments for the early detection of trouble and cause analysis of trouble.

As demonstration equipment, a thermal imaging camera attachment "FLIR ONE PRO" manufactured by FLIR Systems Japan KK was adopted. The tablet has the functions of a thermal camera by connecting this device to the tablet terminal, so it is possible to easily check the temperature condition of equipment on the screen of the tablet terminal and to photograph the thermal imaging. It can be said that it is easy to introduce this device because there is a high diffusion of smartphones in Myanmar. It is necessary to download a dedicated application to the tablet terminal to use this device. It is possible to detect gas and steam leaks early on and prevent troubles in other equipment due to these leaks by utilizing the thermal camera. Examples of use of the demonstration equipment and photographed images of the thermal camera are shown below.

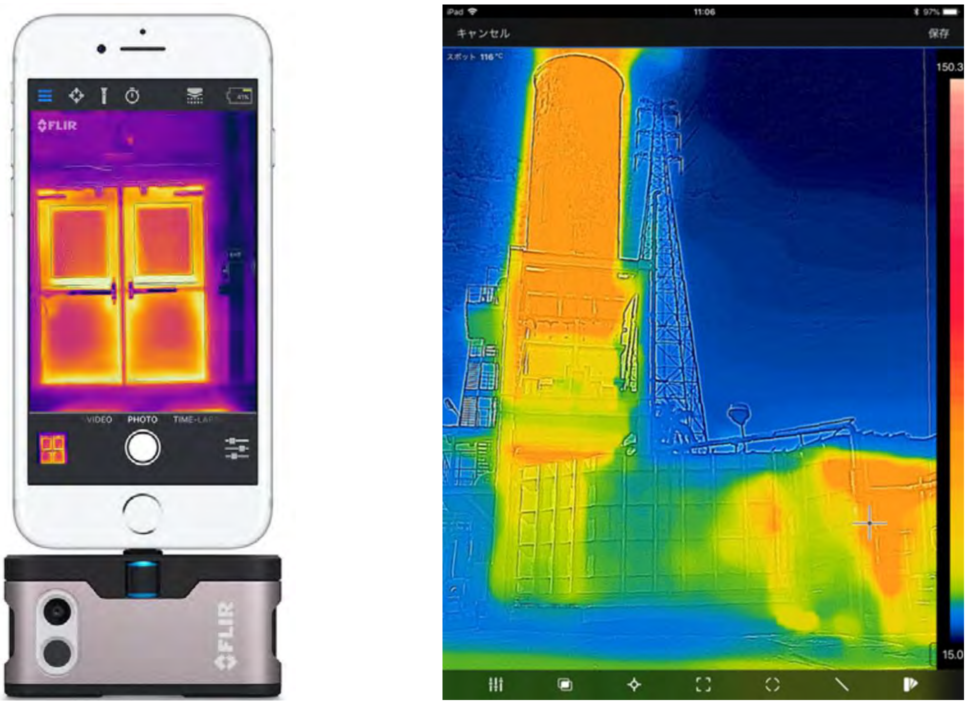


Fig. 6-19 Examples of Use of the Demonstration Equipment and Images of the Thermal Camera

(Source: https://www.apple.com/jp/shop/product/HL5K2J/A/flir-one-for-ios-personal-thermal-imager)

In the second site survey, the local staff confirmed the temperature distribution of equipment in the field by using the demonstration equipment after JICA study team explained the effectiveness of conducting the inspection of the equipment using the thermal camera, usage, usable range, the display value and precautions in use.

(4) Challenges of introducing Japanese services and technologies

As above mentioned, the JICA study team finds that the demonstration devices can be sufficiently effective in terms of improving equipment management capabilities and labor productivity. The power plant staff seemed to be highly interested in AI / IoT devices and were positive about the introduction. Smartphones are spreading in Myanmar, and it is considered that the staffs were positive to introduce devices because the JICA study team demonstrated AI / IoT products associated with smartphones. In particular, at the power plant in Myanmar, there have already been introductions of portable devices made in Japan, etc., and the JICA study team confirmed some power plant staffs hoped the introduction of Japanese products because of the high quality.

On the other hand, one of the challenges of introducing Japanese services and technologies is that there is not yet an environment where the quality of services and technologies can be maintained in Myanmar. In general, it is necessary to calibrate device and replace consumables periodically in order to maintain the quality of devices. However, it is difficult to procure parts and equipment for adjusting devices and to find the person who is familiar with maintenance of devices in Myanmar, so it is difficult to maintain the quality. This situation not only happened in Myanmar but it is also a hurdle to the introduction of Japanese products overseas. Therefore, it can be said that it is relatively easy to introduce services and technologies that do not require maintenance or that can be easily adjusted by the user.

Chapter 7 Improvement of O&M and Possibility of Official Development Assistance by JICA

In this chapter, we describe the method of realizing Solutions A, B, and C, which are the digital, soft and hard O&M infrastructure support package programs proposed in Chapter 5, and the possibility of official development assistance by JICA.

Utilization of Japanese technologies especially the technologies possessed by SMEs described in Chapter 6 is assumed in this package program. The relationship between Japanese technologies and solutions is described in Table 6-2. In addition, how to use facilities and equipment using Japanese technologies and the utilization of Japanese technologies in operation and maintenance will be included in Solution B.

As mentioned in “1.4 Implementation Structure”, the JICA study team and EPGE have agreed to jointly consider the development of O&M. As a result of discussions with EPGE, in order to establish a system that enables EPGE's key personnel to autonomously maintain and operate the power plant even if new generation facilities are built and rapid development is pursued in the future, we propose the following improvements as a support program classified into three categories for the sake of O&M improvement in Myanmar.

The outline of the target (power plant and EPGE head quarter) of the support program and implementation method is as follows.

Table 7-1 Support Program Target and Implementation Method

<table>
<tr><th colspan="2"></th><th>Ahlone</th><th>Hlawga</th><th>Thaketa</th><th>Ywama</th><th>Thilawa</th><th>EPGE HQ</th><th>Assumed Assistance by JICA</th></tr>
<tr><td colspan="8">Solution A Digital O&M Infrastructure</td><td></td></tr>
<tr><td colspan="2">Digital Solution
(including technologies of SMEs)</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>Included in Other Projects</td></tr>
<tr><td colspan="8">Solution B Soft O&M Infrastructure</td><td></td></tr>
<tr><td colspan="2">PDCA O&M Management Support</td><td></td><td></td><td></td><td></td><td></td><td>✓</td><td rowspan="6">Technical Cooperation etc</td></tr>
<tr><td colspan="2">O&M Guideline Preparation Support</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td colspan="2">Asset Optimization Support</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td colspan="2">QMS Manual Preparation Support</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td colspan="2">Operational Support</td><td colspan="5">✓</td><td></td></tr>
<tr><td colspan="2">Training in Japan</td><td colspan="6">✓</td></tr>
<tr><td colspan="8">Solution C Hard O&M Infrastructure</td><td></td></tr>
<tr><td>Short Term</td><td>Overhaul Maintenance
Rehabilitation program</td><td>✓</td><td>Already Planned</td><td>Already Planned</td><td>✓</td><td></td><td></td><td rowspan="2">ODA Loan / Private Sector Investment Finance etc</td></tr>
<tr><td>Mid / Long Term</td><td>Rehabilitation Program
LTSA
O&M Service Program etc</td><td>✓</td><td>Already Planned</td><td>Already Planned</td><td>✓</td><td>✓</td><td></td></tr>
</table>

Source: JICA study team

The summarized contents to be proposed in each Solution this time are as follows.

Although it includes a concept as a part of a new idea, the implementation of this new idea requires more detailed consultation with related parties.

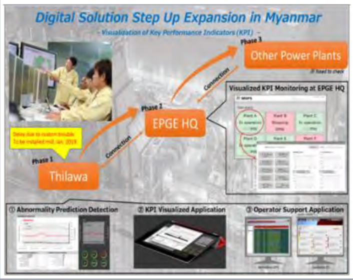
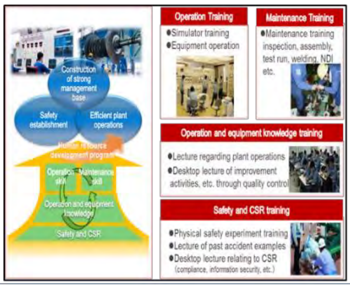
	A. Digital O&M Infrastructure Package	B. Soft O&M Infrastructure Package	C. Hard O&M Infrastructure Package
Customer Value	Support for optimization and efficiency improvement of O&M business with the latest AI/IoT technologies 【A Place to Connect Hard O&M and Soft O&M】	Support for the establishment of O&M guidelines of Electric Power Agency, Development of future engineers at EPGE headquarters 【A Place to Apply O&M Theory】	Development O&M infrastructure at existing power stations, Development of future EPGE field engineers 【A Place to Experience the Practice of O&M】
Direction of proposals to Myanmar and EPGE	**Study introduction of EPGE at headquarters and other power stations using pilot introduction results** 	**Support for the establishment of rules, manuals, and systematic education capacity building, etc.** 	**Support for autonomous O&M through a long-term maintenance contract for existing power plants and a comprehensive O&M subcontracting business including rehabilitation** 
Support Idea	Included in Other Projects	JICA Technical Cooperation	JICA ODA Loan Private Sector Investment Finance etc
Project Size	Millions of USDs	Millions of USDs	Tens of Millions of USDs

Fig. 7-1 Solution Overview

7.1 Solution A [Digital O&M Infrastructure]

(1) Issues

The operation and maintenance methods at EPGE HQ and its power plants are analog, and effective methods using digital data have not been introduced so far. As a result, the JICA study team assumes the below.

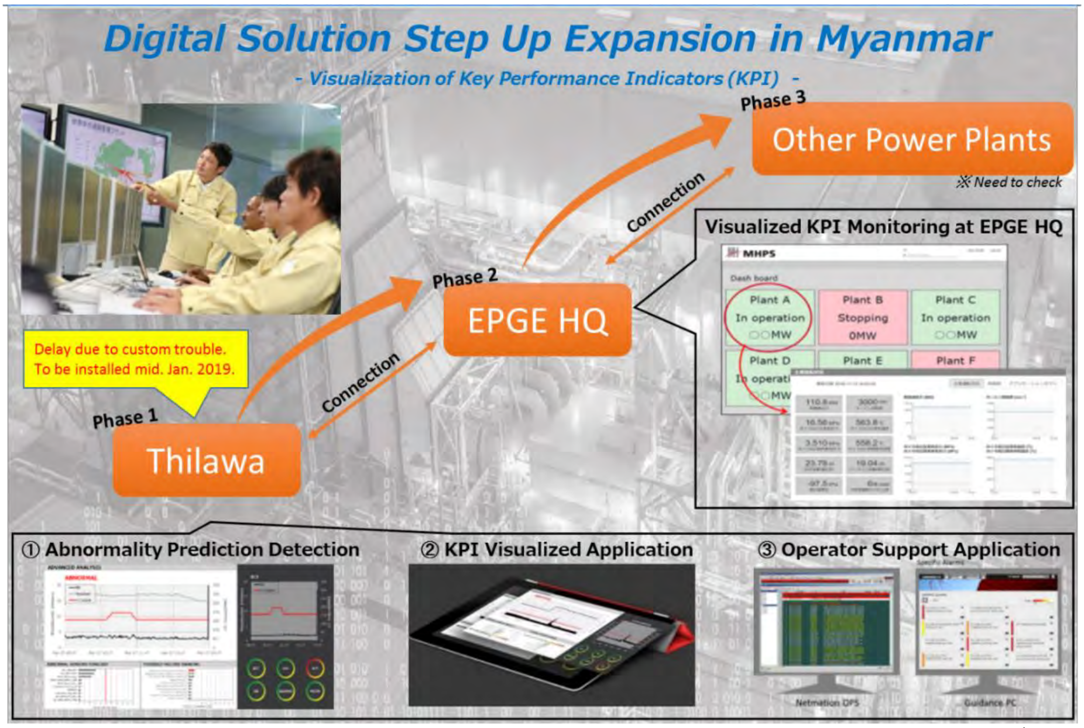
1) O&M data is not accumulated.
2) Improvement is not conducted using past O&M data.
3) Education of knowledge and technique to EPGE staff is not conducted.
4) There is no culture to improve O&M.
5) As a result, similar troubles which EPGE previously experienced occur.

(2) Improvement Proposal

For the platform to accumulate O&M data, the JICA study team introduced pilot equipment, and it was effective. In order to improve the issues, the JICA study team considers that EPGE HQ and its power plants need digital tools that have some of the functions listed below.

[Introduction of O&M improvement support digital tools and plan in Myanmar]

1) Daily Maintenance : KPI recording and monitoring tools anywhere and anytime
2) Regular Maintenance : Prediction and diagnosis tools for abnormal facility conditions
3) Response to abnormal conditions : Operator support tools that enable operators to respond quickly after detecting abnormal conditions



Source: JICA study team

Fig. 7-2 Digital Solution O&M Infrastructure

When considering solutions that have these functions, Japanese SMEs technologies should be well considered in addition to these functions.

(3) Response and request from EPGE

During communications with EPGE executives, they said, "We want you to introduce digital solutions not only at the Thilawa power plant but also EPGE HQ and other plants. Especially, we want to monitor each plant's KPI from anywhere anytime." Therefore, the JICA study team studied whether digital solutions could be introduced at each power plant or not. As a result, there are possibilities to introduce digital solutions though detailed surveys. The JICA study team explained this and EPGE understood it.

(4) Possibility of assistance from JICA

Considering the issues and requests from EPGE, EPGE has strong interest in the digital solutions. There are possibilities to introduce digital tools such as the pilot equipment that the JICA study team introduced in this study, though detailed study is necessary. Considering that the JICA study team confirmed EPGE's needs, there is high possibility of assistance from JICA.

In addition, remote monitoring systems such as the pilot equipment will be more effectively used by introducing Japanese SMEs technology such as portable thermal cameras, wearable cameras and tablets. At the stage of assistance by JICA, detailed surveys are necessary at each power plant because the Japanese SMEs technology to be introduced will vary from plant to plant.

7.2 Solution B [Soft O&M Infrastructure]

(1) Issues

Most of the support to Myanmar has been hard infrastructure. As described in Chapter 5, EPGE needs soft infrastructure support such as O&M methods and education.

(2) Improvement Proposal

In order to resolve the issues, Solution B is necessary. Solution B is largely divided into the following three steps.

First Step : Training Support (in Japan)

Second Step : On-site Operation Support (Dispatch of Engineers)

Third Step : Preparation of Technical Standard, O&M guidelines and manuals, Operation Support

	Training Support	On-site Operation Support	Manual Preparation
Content	Training for O&M of power plant utilizing educational facilities in Japan	Post-training follow-up and practical work support in Myanmar	Support for creating a structure that enables them to carry out efficient and continuous improvement themselves
	・Training in Japan	・Follow-up in Myanmar (Business trip)	・Manual, Regulation Preparation ・System Construction
Goal	・Reform Awareness ・Basic Knowledge, Skill Improvement	・Development into OJT ・Development into Practice	・Further Efficiency Improvement ・Continuous Improvement

Source: JICA study team

Fig. 7-3 Solution B Proposal Items

First of all, as a first step, it is important to reform awareness of the importance of soft infrastructure through training by Japanese invitation.

The second step is to dispatch engineers to a power plant in Myanmar to conduct follow-up and OJT. It is carried out in order to reinforce the awareness reform conducted in the first step, and to promote basic and expertise skills at each power plant.

In the future, it is desirable for EPGE to build a QMS, to further improve its technical capabilities and to operate thermal power efficiently by utilizing a PDCA cycle.

In order to realize the above, the third step is assumed to be support to improve the mechanisms such as regulations, O&M guidelines and manuals that enable EPGE to manage and improve technical skills and quality. As a part of this step, we also plan to support the creation of the grid code and O&M guidelines requested by the EPGE Managing Director, through discussions with EPGE.

Items assumed as Solution B concerning the O&M of thermal power plants and their priorities are as follows.

Table 7-2 Solution B Priority Items

Item	Priority		
	Manual Preparation	Training	System Construction
General Matters Concerning Power Plant O&M	✓	✓	
Human Resource Development System	✓	✓	
Quality Control and Safety Management System	✓	✓	
Procurement Procedures Management		✓	
Document and Record Management	✓	✓	
Quantitative Records	✓	✓	✓
Maintenance Planning and Management	✓	✓	✓
Spare Parts Management	✓	✓	
Accidents Correspondence and Records	✓	✓	✓
Environmental Management			
Access Management			
Equipment Maintenance	✓	✓	

Essential : ✓

Source: JICA study team

(3) Response and request from EPGE

When explaining the importance of training and technical support, which is the soft infrastructure in this survey, we obtained consent from the EPGE Managing Director, and also received a request for advice on the code for the grid that is under construction and cooperation in making O&M guidelines.

In order to use this project, we reported to EPGE the O&M training items for thermal power plants that seem to be necessary from the current conditions in Myanmar described in Chapter 5, and received the following comments.

(1) In Myanmar, economic operation (optimization) of the power plant has not been achieved due to problems such as transmission capacity limitation, Must Run situations due to PPA with IPPs, and securing spinning reserve. Technical support is necessary to select power plant priorities and to optimize system operation.

(2) After examining the actual conditions of DPTSC system operation and understanding that there are various limitations, it is necessary to propose a system operation method and provide technical support that are suitable for Myanmar.

(4) Possibility of assistance from JICA

Solution B is assumed to use country-specific training for technical cooperation.

Based on these comments, we propose a technical cooperation package to improve Myanmar's electricity business as a whole that adds improvement training in hydropower dam operation, O&M of transmission and distribution, and the system optimization described in Chapter 5 to impart training in the O&M of thermal power plants.

The program and schedule are as follows.

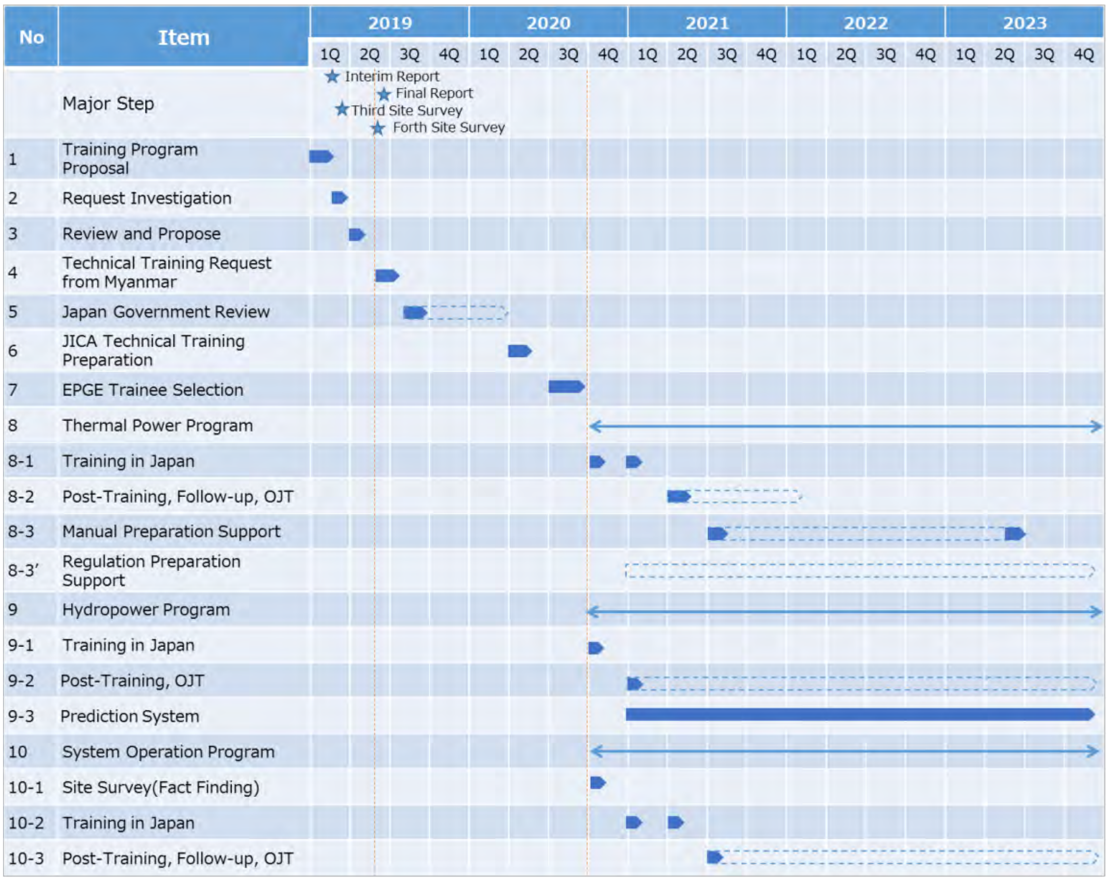
With regard to the support for creating regulations described in 8-3 of the schedule table, it is a long-term technical cooperation project, and it is necessary for not only users but also manufacturers and academic experts to promote the project in unison. Therefore, we consider that it should be negotiated with EPGE, taking into consideration that this content will be a separate technical support project.

With regard to O&M for thermal power and hydropower plants, site surveys are being conducted within this survey, and the necessary training items will be selected based on the results. However, as for the system operation program, the site surveys did not go far enough. Therefore, it is necessary to consider the training items after examining the actual situation.

Table 7-3 Training Items for Technical Cooperation Program

Engineering Training
・Method for developing thermal power plant engineers ・Maintenance technology of CCGT power generation (GT・ST・HRSG・electricity・control system) ・Equipment diagnosis technology (non-destructive inspection・remaining life evaluation) ・Quality management of thermal power plant (TQM) and efficiency management ・Instruction of preparation for action plan ・Factory tour of thermal power plant and manufacturer ・Instruction of utilization method for IoT・AI
Technician Training
・Quality management・safety management (physical training) ・Equipment inspection maintenance technology (piping・valve・electric motor・welding・electric equipment・control equipment, etc.) ・Equipment diagnosis technology (non-destructive inspection・remaining life evaluation) ・Instruction of preparation for action plan ・Factory tour of thermal power plant and manufacturer ・Instruction of utilization method for IoT・AI
Hydropower Training
・Method of reservoir operation in hydroelectric power plant ・Method for predicting dam inflow using weather forecasting system ・Factory tour of hydropower plant
System Operation Training
・Demand forecasting method ・Stability, frequency control method ・Tour of dispatching center

Source: JICA study team



Source: JICA study team

Fig. 7-4 Assumed Schedule of the Proposed Program

7.3 Solution C [Hard O&M Infrastructure]

(1) Issues

The JICA study team proposed Solution A and B respectively from soft and hard viewpoint. The JICA study team confirmed that some plants could not operate due to facility damage. Such damage was caused by EPGE not maintaining or replacing important parts regularly.

Once facilities are in trouble, EPGE used to replace such facilities with new ones. However, new facilities are in trouble soon because such replacement is not conducted from the long term view point of O&M improvement.

(2) Improvement Proposal

As a short term improvement proposal, it is necessary to rehabilitate facilities which that are already in trouble. Therefore, improvement proposals at for each power plant such as Hlawga, Ywama, Thilawa, Ahlone, Thaketa areis required.

On the other hand, as a middle and long term improvement proposal, it is necessary to make EPGE to aware of the importance of O&M improvement. Such a culture will resolve the decrease of in availability and increase of in fuel costs caused by degradation. In order to develop the O&M strategy, EPGE's policy is important. Some O&M contract schemes are summarized below from the EPGE's point of view.

		Scheme adopted by EPGE at present	Proposed scheme to EPGE	
		Contract Scheme① Parts Supply Repair Technical Advisory	Contract Scheme② LTSA	Contract Shceme③ O&M Service Project
Features of Contract	Scope	Parts/Instructors (Narrow Scope)	Maintenance Only	O&M (Wide Scope)
	Order / Payment	Every time Order / Payment (Complicated)	One time Order (Simple)	One time Order (Simple)
	Budget Management	Difficult to Set Cash Flow (Risk of Cost Fluctuation)	Simple Budget Management (Cost is Leveled)	Simple Budget Management (Cost is Leveled)
	Risk	Big Risk for EPGE (General for National Company)	←→	Small Risk for EPGE (General for IPP)
Applicable	EPGE's Ability	O&M Planning by itself (No need for Support)	Need for Maintenance Support	Need for O&M Support
	Characteristics of Target Power Plants	Less Troubles No Need for Advanced Operation	←→	Many Troubles Need for Advanced Operation

Fig. 7-5 Feature of O&M Services by Each Contract Schemes

Until now, EPGE has taken the contract form of ordering parts and instructors dispatched whenever a problem caused by O&M is discovered, as shown in the contract scheme ①above. There were the below problems.

[Issues in the conventional contract scheme ①]

- Orders for parts / instructors were considered after a problem was discovered, and it took time for the EPGE internal process, such as obtaining an emergency budget. As a result, it could not be recovered immediately.
- There is no contract unit rate agreed with O&M providers in the medium to long term, so it is necessary to bid each time, and it takes time to conclude the contract.
- It is difficult to apply for budgets related to O&M because it is required to do so in the annual budget application period.
- The planned O&M could not be implemented, and EPGE staff could not be trained because problems were handled on the spot.
- Originally, it is customary in other countries to experience long-term maintenance contracts such as the above contract schemes ② and ③, acquire a certain amount of O&M skills, and then aim for the above contract scheme ①.

In order to resolve these issues, long-term contracts for maintenance and operations are concluded for a certain period of time, such as the contract scheme ② in the diagram above, the long-term maintenance comprehensive contract, and the contract scheme ③ O&M service business long-term contract.

After completing this process, a foundation for independent and autonomous O&M would be established, and EPGE should develop its foundation for O&M business as in ①. From this, the JICA study team believes the following two proposals should be considered.

Proposal (1) “Contract Scheme ① LTSA”

Even power plants that are originally less troublesome and those that do not require advanced operation technology, the speed of equipment degradation will increase if proper maintenance is not performed. For such plants, contract scheme ② is effective.

The Thilawa power station (H-25 x 2 units), which currently has state-of-the-art power generation facilities in Myanmar, has already exceeded the recommended periodic inspection implementation timing. There is no denying the possibility of a long-term outage due to equipment damage, which is a real problem at other power plants.

From this point of view, it is considered beneficial to apply the long-term maintenance comprehensive contract program for existing power plants as one of the hard O&M infrastructure packages.

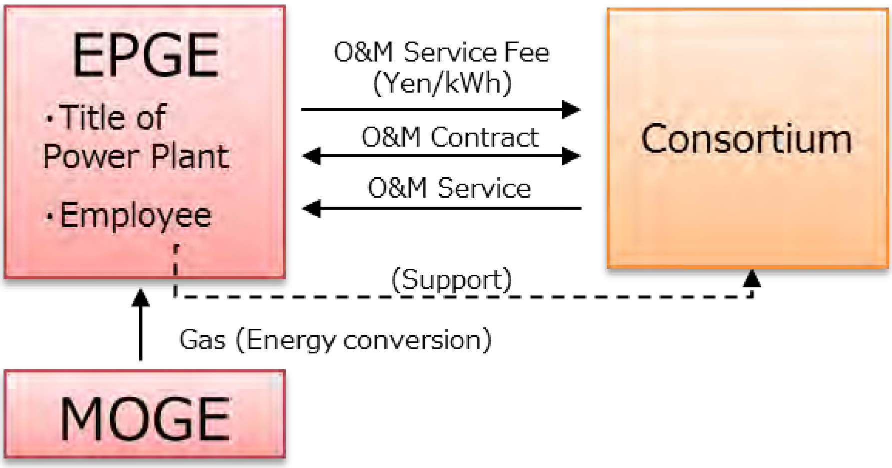
For specific detailed scopes and target power plants, it is necessary to examine a long-term comprehensive maintenance package based on requests and interviews from EPGE.

Proposal (2) “Contract Scheme ② O&M Service Project”

For power plants with many troubles and power plants that require advanced operation technology, through OJT and high-quality O&M services in Japan as in “Contract Scheme ③”, the JICA study team considers that it is most effective to implement human resource development and capacity development. Therefore, it is assumed that human resource development and capacity development from a long-term perspective, such as the O&M service business long-term contract, is the first step in promoting EPGE independence.

As described in Chapter 5, local companies have acquired O&M business rights for power generation facilities owned by EPGE, and payments from EPGE are received at Cent/kWh, and all O&M operations other than fuel procurement are handled collectively.

In order to build an O&M infrastructure, this case study can be customized as a proposal that adds value unique to Japan, and then a proposal that accepts EPGE's O&M service business in the long term can be considered. The image of the scheme is as follows.



Source: JICA study team

Fig. 7-6 Long Term O&M Service Project Structure Idea

In order to implement equipment rehabilitation and advanced O&M, it is desirable that O&M operators and equipment manufacturers cooperate to form a private enterprise alliance. As for the private enterprise alliance, there are the method of establishing a business company and the method of a consortium. Establishing a business company has the advantage that the barriers to entry of private companies can be reduced because the risk to the mother companies can be limited. In the case of a consortium, there is an advantage that early commercialization is possible.

In this scheme, while maintaining good cooperation with EPGE, land use rights and the current affiliation of EPGE's existing staff remain with EPGE, and it takes a form close to a concession format for carrying out O&M projects. This idea has the following advantages.

1) Various improvements can be expected from knowledge of both operation and maintenance.
2) With regard to digital software improvements such as those described in Solution A and Solution B, technology and know-how can be transferred to EPGE staff while actually operating the plant jointly for a certain period of time, and other O&M improvements synergistic effects with measures can be obtained.
3) By providing a "place" for joint execution of O&M with the private sector federation, it is possible to contribute to the development of young engineers in operation and maintenance who are expected to play an active role as future key personnel at EPGE.
4) EPGE can prepare for O&M infrastructure for new thermal power plants in the future.

As proven by other companies, the idea that EPGE directly outsources O&M to private companies may be realized, but more specific due diligence and business feasibility evaluations are necessary to proceed.

(3) Response and request from EPGE

In the course of the survey so far, the JICA study team has explained to EPGE about the long-term maintenance comprehensive O&M package, and very high interest has been shown. The following comment was obtained from the managing director of EPGE.

1) Due to economic sanctions in Myanmar, there have been few examples of O&M being carried out in close cooperation with overseas manufacturers. It is true that there are few EPGE staff who are highly skilled in O&M.
2) On the other hand, there is a method that has been cultivated by the country itself. While Japanese O&M is high level, in order to transplant it to Myanmar, EPGE actually needs to work together at the power plant for a certain period of time. In this sense, there is a great interest in the long-term joint implementation of O&M.
3) EPGE wants to include not only O&M support but also programs to train EPGE staffs.

(4) Possibility of assistance from JICA

Solution C is assumed to use JICA ODA loan or private sector investment financing.

In particular, as described in the June 2019 infrastructure system export strategy, the government of Japan provides support to Myanmar as a package for supporting human resource development and capacity building as well as providing O&M services including parts supply. It is considered important to promote the independence of Myanmar.

There are several schemes for improving hard O&M infrastructure, but the optimal scheme differs depending on power plants. Therefore, it is necessary to select the optimum scheme according to the target power plant at the cooperation implementation stage by JICA.

Chapter 8 Conclusions and Recommendations

8.1 Conclusions

In July 2019, the government of Myanmar raised the electricity tariffs (up to 3 times for households and 80% for business use). Until then, the power generation sector in Myanmar is was in the red (2018 EPGE sales: 1062B Kyat, deficit: 499B Kyat), and the annual O&M budget is was about 0.4 Kyat/kWh (2010) on average for all gas-fired power plants (2015) and very few. The O&M management system in Myanmar is not properly established. Some EPGE staffs explained that financial sanctions as a result of economic sanctions by the United States and others have affected financial and technical acquisitions.

For this reason, education on in O&M technology is not enough, and the output and efficiency of power generation facilities are greatly reduceddeclining. As a result, recovery costs due to fuel costs and equipment damage are high, resulting in a vicious cycle of budget shortages.

In order to solve these problems, not only hardware support, such as rehabilitation, new plant construction and maintenance parts supply, but also software support aimed at mid- to long-term human resource development and system design. In the future, as new power generation facilities are introduced in order, the key staffs of EPGE should be able to run PDCA autonomously so that the power plant can be operated and maintained with continuous improvement.

8.2 Recommendations

We propose implementation of the digital, software and hardware countermeasures mentioned above as follows.

8.2.1 Solution A

In Myanmar, digitization is insufficient (Chapter 5), and there is much room for improvement in business management that integrates the headquarters and the power plant.

(1) Based on the results of the introduction of pilot equipment for examining the feasibility of introducing IoT technology at the Thilawa power plant this time, it should be deployed throughout the EPGE headquarters and other power stations to operate and maintain it efficiently (Chapter 4).

(2) Though EPGE carries out O&M patrols, the records are collected by hand, and the records are not used effectively. The JICA study team recommends a real-time local data collection system and recording data from a tablet device. Such data is useful for reviewing the inspection interval and analyzing the cause of malfunctions (Figure 6.10).

(3) When trouble occurs, the cause is estimated based on experience, without a QC work flow such as investigation of the cause, planning of countermeasures, implementation of countermeasures, and

evaluation of effects. As a result, the true causes are not addressed, and similar troubles often recur (3.4.2). As a cause of performing such countermeasure, it is estimated that analysis based on data cannot be performed because no measurement tool is implemented. Many Japanese SMEs products, including measurement tools, are inexpensive, high quality and original. So, they are considered effective in improving O&M in Myanmar. The JICA study team would like to recommend introducing them by JICA ODA projects (Chapter 6).

8.2.2 Solution B

Education in O&M is necessary for proper power plant management in Myanmar (Chapter 5), and education and technology transfer through training in Japan should be conducted at an early stage.

(1) The JICA study team would like to propose a technical cooperation training package (7.2) that includes not only thermal and hydro power plants O&M education but also grid operation education. Overall optimization of the power generation business can be expected, such as preferential allocation of limited domestic gas to efficient generators and overall optimization while appropriately managing the water level of the dam.

(2) The status of human resource development is not managed and depends on the OJT of senior employees in the workplace, so a database (human resource development management system) that manages the skill level of each staff member and the history of training attendance should be established (5.4.1).

(3) Because important records and design data are lost, power plants, EPGE headquarters, and MOEE should introduce a document management system to efficiently store, search, and retrieve them (5.4.2).

(4) Although the storage status of spare parts is managed in handwritten forms, there are some parts that cannot be used due to reasons such as not meeting specifications or reaching the end of their service-life. Although the spare parts are shared with other power plants using the same model, they are not managed efficiently. A spare parts management system should be introduced to manage specifications, service-life, repair history, etc. so that they can be viewed elsewhere and at EPGE headquarters (5.4.4).

(5) At the Yeywa hydro power plant, the water level of the dam reaches full level in the rainy season and overflows. It is desirable to effectively use the dam by introducing a rainfall / inflow prediction system (5.7).

(6) Since regulations and technical standards, which are stipulated in the electricity law, have not been formulated, it is recommended that they be formulated in accordance with the actual situation in Myanmar (2.1 and 8.2.2).

(7) Rules and manuals are not codified throughout the work at EPGE headquarters and power plants, and many are carried out according to customary or higher-order letters. Rules and manuals should be established and the PDCA cycle should be run to continuously improve quality (7.2).

(8) Although the training center specified by the electricity law is owned at Naypyidaw, the training center for thermal power plants is not well established and it is desirable (2.1).

(9) Technical transfer is carried out only by OJT, therefore power plant staff are not able to receive systematic education. It is necessary to establish an educational system at EPGE and provide efficient training.

8.2.3 **Solution C**

The equipment in Myanmar is not sufficiently maintained (Chapter 5), so the equipment is deteriorated and the output and efficiency are greatly reduced. It is recommended that repairs to troubled equipment be performed in accordance with the planned rehabilitation work.

(1) Equipment improvements through rehabilitation and long-term maintenance contracts may be a means to obtain electricity early and at low cost without significantly affecting the environment (Chapter 7).

8.2.4 **Others**

Although they are not directly related to the O&M of the power plants, the proposals noticed in this survey are as follows.

(1) When the cause of unplanned shutdown of the power plant was investigated, there were many troubles due to factors from the transmission system. This tendency is more conspicuous in power plants with a generator connected to a 33 kV system than in a power plant with a generator connected to a 230 kV transmission line. The 33kV power plant supplies power directly to nearby customers, and it is difficult to stop due to system limitations. It is highly possible that the entire country is not operated economically. It is necessary to improve the system connecting the generators and eliminate bottlenecks (Figure 3-16, Table 3-1).

(2) Although a SCADA system has been introduced, some facilities are not installed, so it is not possible to manage all the facilities from the load dispatch center. It is necessary to proceed with the introduction to the uninstalled facilities.

(3) The only power plant operating governor-free is the Baluchaung hydropower plant. The introduction of IPP with a take or pay clause is in progress. Therefore, there are a limited number of units that can flexibly adjust the load. In order to reduce unplanned outages of power plants due to system factors, it is recommended to formulate a power development plan with an overall view.

Appendices

Appendix 1

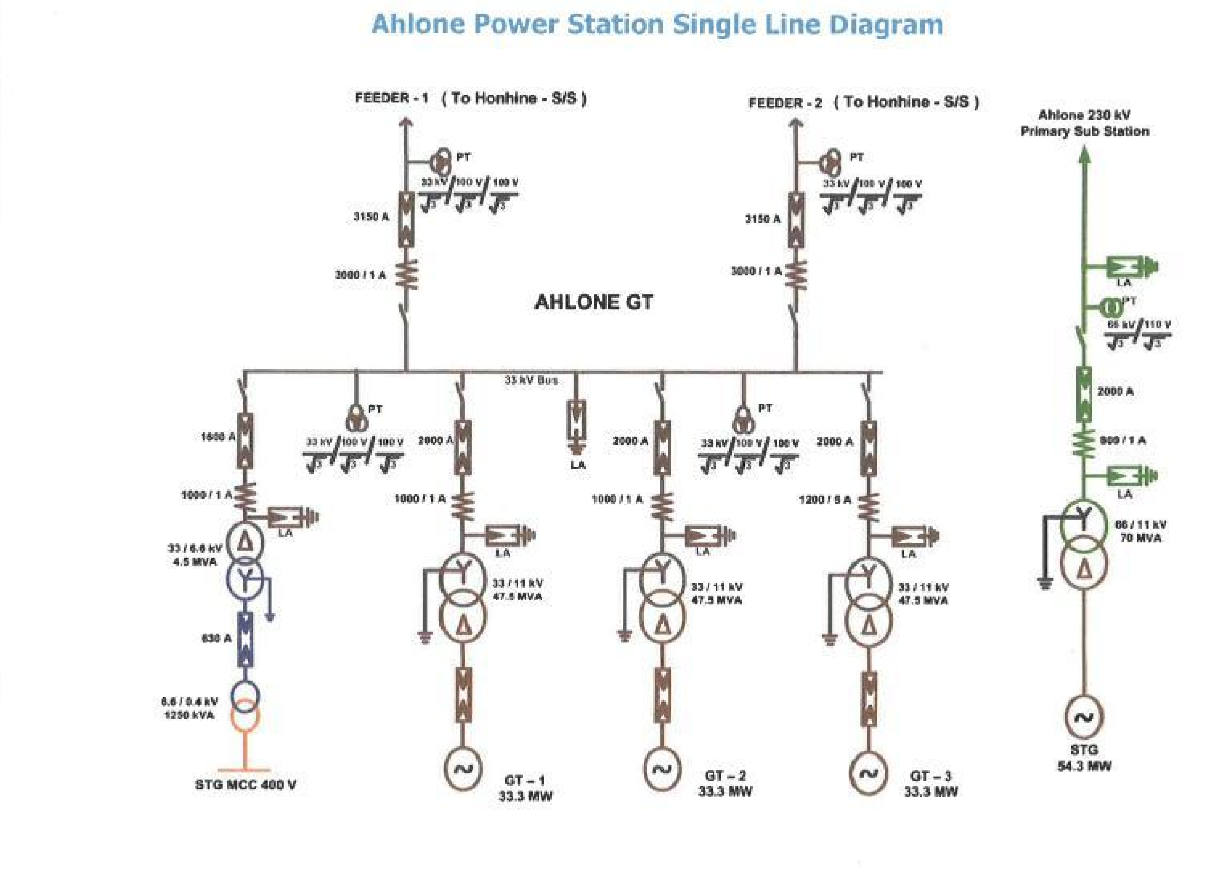
Ahlone Power Station Survey Results

■**Ahlone（First Site Survey：2018.9.4 - 9.6、Second Site Survey：2018.12.11 - 12.13）**

（1）O&M System Survey

a. Outline of Facility

Location (Address)		No.39, Kannar Road, Ahlone Township, Yangon, Myanmar
Configuration		3-3-1 CCGT
EPC	CCGT	Marubeni-Kawasaki (Boiler [Kawasaki], Turbine [ABB])
GT	Model	Frame6 (GE)　PG6541B
	Output	33.3MW
	COD	2.16, 1995　4.11, 1995　5.29, 1995
ST	Model	V-63 (ABB)
	Output	54.3MW
	COD	9.10, 1999
Power Plant Output		154.2MW　(3on1 CCGT)
Fuel		NG（Yadana Gas）
Connection to Transmission Line		Connect to Ahlone S/S（#1,2,3GT:33kV, ST:66kV）



Fig：Ahlone P/S Single Line Diagram

Equipment Specifications

Gas Turbine		
Model：	Frame6　PG6541B（GE）	
	(Air Temperature 15℃, Humidity 60%, Atmosphere Pressure 1013.25hPa)	
	Designed Output　：	38,340 kW
	Designed Heat Rate：	11,460 kJ/kWh
	Designed Heat Consumption：	439,400 MJ/h
	Designed Exhaust Gas Flow：	500.5 t/h
Gas Turbine	Type：	Open Simple Cycle/Single Shaft
	Stage：	3 Stage
	Turbine Inlet Temperature：	1,104℃（Internet）
	Turbine Outlet Temperature：	537℃（Internet）
	Rotating Speed：	5100 rpm
Combustor	Type：	Reverse-Flow / Multiple-can
	Number　：	10
Compressor	Stage：	17
	Outlet Pressure：	12.0 bar（GT-PRO）
Generator	Type：	T190-240　43 MVA－3000 rpm

HRSG	
Number of Unit　：	3
Model　：	Kawasaki-Vogt natural circulation / Horizontal gas flow
GT Fuel：	NG
Steam Flow：	67.3 t/h（per unit）
Steam Pressure：	42.9 ata（SH Outlet, Absolute Pressure）
Steam Temperature：	485 ℃（SH Outlet）
Feed Water Temperature：	54.5 ℃
Bypass Stack：	Available

Steam Turbine		
Steam Turbine	Manufacture：	ABB
	Output：	56.65 MW
	Rotating Speed：	3,000 rpm
	Number of ST：	1
	Rotor Weight：	16,617 kg
	Rotation Direction：	C.　C.　W
	Steam Pressure：	43.16 bara（norm）
	Steam Temperature：	464 ℃（norm）
	Steam Flow：	216 t/h（max）
	Exhaust Steam Pressure（norm）：	0.12 bara
	Exhaust Steam Flow Rate（max）：	216 t/h
Generator	Type：	Three-Phase Synchronous Generator
	Output：	67,875 kVA
	Power Factor：	Leg 0.80
	Frequency：	50 Hz
	Rotating Speed：	3,000 rpm
	Voltage：	11,000 V
	Current：	3,563 A

Condenser

Manufacture：	EDI（Evaans Deakin Engineering)
Type：	Shell & Tube
Steam Flow（norm/max）:	216t/h
Pressure：	0.12（norm）/0.14（max）bara
Temperature：	50（norm）/60（max）℃
Cooling Water Flow Rate：	4,165 kg/s
Cooling Water Inlet Temperature：	42.8℃
Cooling Water Outlet Temperature：	51.8℃
Surface Area：	6,013 m^2
Number of Tubes：	9,786
Length：	7,700 mm
Weight(empty)：	135,000 kg
Weight(full)：	249,450 kg

Wastewater Treatment

Capacity：	120 m^3/day
Type：	2 Stage Reverse Osmosis
Chemical：	Chlorine Treatment（NaOCl）
	Coagulation Treatment（FeCl3)
	Reduction, PH Control（SBS）
	PH Control（H2SO4)
Designed Demineralized Water：	Conductivity 10 μS/cm or less, Silica 0.5 ppm or less

Fuel Gas

1)Fuel Gas (Yadana Gas)

Methane	:	69.8801 mol%
Ethane	:	1.0106 mol%
Propane	:	0.1694 mol%
i-Butane	:	0.0184 mol%
n-Butane	:	0.0279 mol%
i-Pentane	:	0.0065 mol%
n-Pentane	:	0.0037 mol%
Neo-Pentane	:	0.0214 mol%
Hexane and Heavier	:	0.0211 mol%
CO2	:	4.1294 mol%
N2	:	24.727 mol%
H2S	:	0.0021 mol%
H2O	:	0.0011 mol%

2) Gas Delivery Condition

Gas Station	High Temperature：	45℃
	Low Temperature：	22℃
	High Pressure：	35 barg
	Low Pressure：	27 barg
	Max Flow Rate：	54,000 Nm^3/h
GT Inlet	High Temperature：	45℃
	Low Temperature：	20℃
	High Pressure：	30 barg
	Low Pressure：	18 barg
	Max Flow Rate：	18,000 Nm^3/h

b. Layout

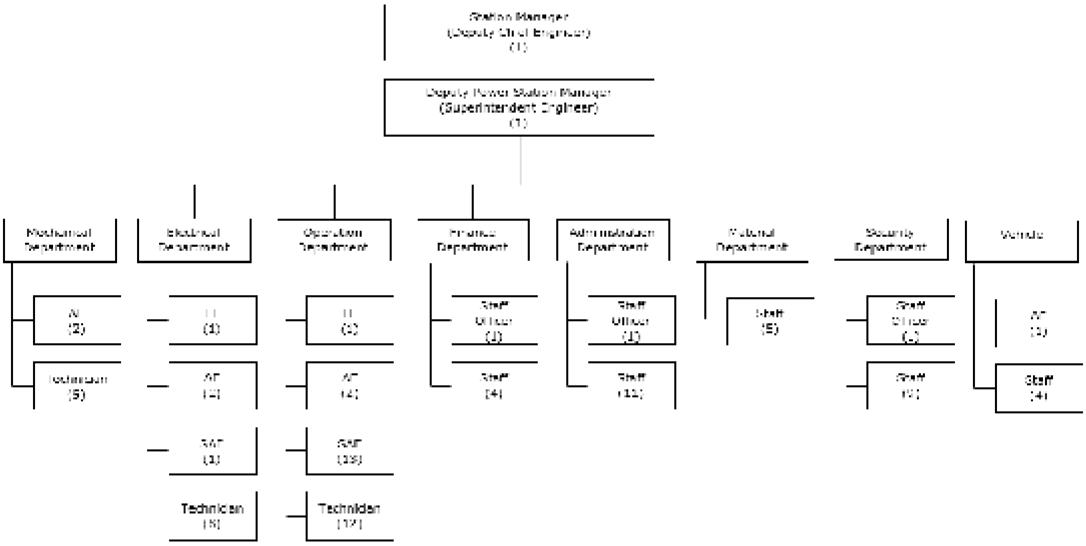
- There is no chemical analysis room at the power station to conduct water quality, lubricant, control oil, or fuel management.
- For water quality, measurement is carried out after cooling the high temperature boiler water for 2 hours at ambient temperature due to a boiler water cooling system failure (pH, electric conductivity).
- Based on the measurement results, the person in charge of chemistry instructs the amount of chemicals to be injected once a day.
- River water contains salt, so now well water is being used with water treatment.

Fig：Ahlone P/S Layout

Installed Instrument Failure

c. Power Station Management and Education System

- The plant is staffed by 90 persons.
- All operators received several days of training by Ethos in 2013-14.
- The Chief Engineer conducted OJT using his educational materials.
- There are no official qualifications or internal qualifications.
- The plant manager judges the skill of the operator in consideration of the experience and resume.



Fig：Ahlone P/S Organization Chart

d. Regulations and Manuals of Power Plant O&M

- Rules are hardly documented.
- Regarding the start / stop procedures and operation control values of the units, the maintenance manuals of the manufacturers are used.

e. Procedure of Part Procurement

- For necessary parts and consumable supplies such as chemicals and lubricants, the procurement department of the power plant submits a request list to EPGE.
- The parts procurement flow is as follows.
- However, since EPGE manages all budgets, approval by EPGE is necessary even if it is 0.3 million MMK or less, which is the amount that can be approved by the plant manager.

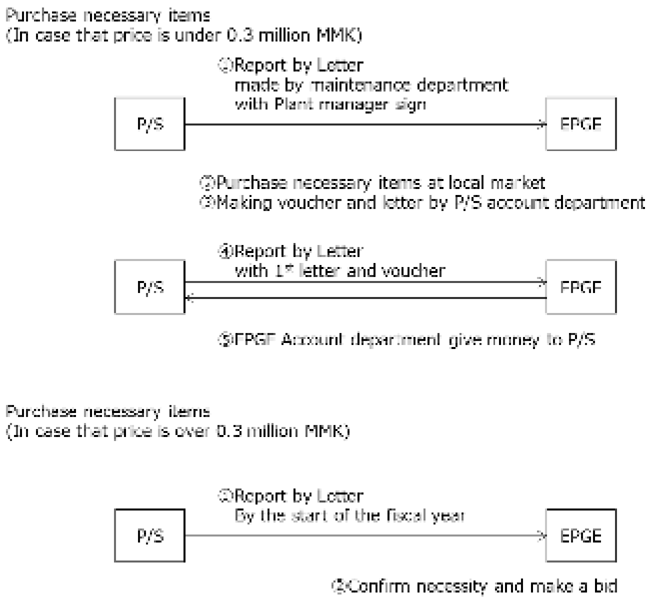


Fig : Flow of Parts Procurement Procedure

(2) Daily Operation

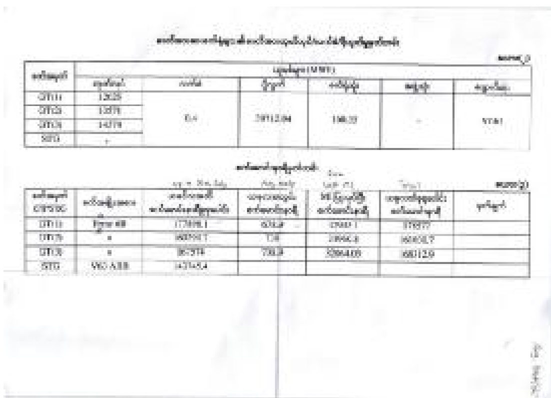
a. Operation System

- 2-shift, 4-team system (Day shift: 8:30 – 17:30, Night shift: 17:30 – 8:30). There are 8 to 10 persons per shift.
- The logbook is used to hand operation over.
- The operator carries out a patrol inspection and records operation data every hour.
- The maintenance workers conduct a patrol inspection twice a day, in the morning and evening.
- Cleaning is carried out on Tuesday and Thursday.

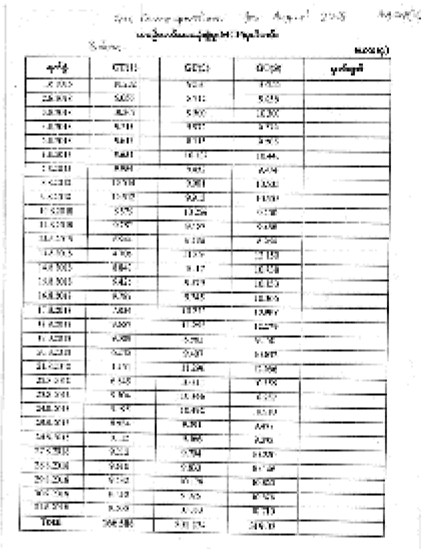
b. Quantitative Records Related to Power Generation

- GT, ST output, fuel gas consumption, etc. are recorded every hour and organized on a daily basis. In addition, output and gas consumption are reported to the Hlawga P/S.
- The output of TTCL's IPP next to the Ahlone P/S is also recorded.
- There is no regulation about how to use operation data, such as graphing, etc., and Excel data conversion and graph projection are not implemented.
- Daily operating records and maintenance records are used only within the Ahlone P/S and not shared with other power plants.
- The daily report, monthly report, and annual report are sent to EPGE.

Quantitative Records



Monthly Report



Gas Consumption Monthly Report

c. Record of the Implementation Status of O&M

- As of March 2018, the ST is turned for 24 hours every Friday.
- Online wing cleaning is being carried out every Saturday.
- The results of the maintenance are recorded in the logbook. (operation record, daily maintenance record)
- When there is a notification of occurrence of trouble from the operator, the maintenance engineer checks the state of the equipment and reports it to the plant manager.
- Reporting is also carried out in documents as well as verbally.
- The engineer decides how to repair trouble.
- Confirmation tests of troubled parts such as motor insulation resistance are carried out by plant staff as necessary.

d. Spare Parts Management

- Spare parts are kept in a warehouse and managed by spare parts list. Stocktaking is carried out once a year. Serial number management has not been implemented.
- The approval of EPGE is necessary to use spare parts.
- The power plant requests EPGE for the type and quantity of parts required for plant operation.
- Two Fr 6 rotors (used, no repair, no rust prevention) and one Fr 5 rotor (used, repaired, no rust prevention) are kept.
- There is parts interchange with the Hlawga P/S.
- The generator rotor (spare rotor →Ahlone#2GT → Hlawga#1GT) is currently stored at the Hlawga P/S.
- HRSG replaced all of the tube bundle in 2005-2007 and used two rows of removed economizer at the Hlawga P/S.

e. Action against Events/Abnormalities and Record Management

- When a problem is found, it is reported to the mechanical department, the electrical department, and the plant manager, and the plant manager instructs the countermeasure. The content of the problem is recorded in the logbook.
- There is no system for managing trouble.
- The inspection cycle of troubled equipment can be changed at the power plant as necessary.
- Confirmations and measures for the same type of equipment that had problems are not conducted .(horizontal deployment)
- Although the cause is considered to be a bearing clearance failure or compressor blade damage, it has not been identified yet.
- Minor issues, such as cooling fans, are decided by plant managers and engineers.
- When it is necessary to stop the GT, EPGE decides the countermeasure based on the contents reported from the power plant to EPGE.
- Except for serious problems of the control system, no inquiries about trouble are made to the

OEM.
- Inquiries to the OEM are made by MD.

f. Environment Management
- Exhaust gas is not monitored or managed.

g. Entry Management
- People entering the power station are checked at the guard room using security cards and log sheet. There is no auto entry management system.

(3) Periodic Maintenance

a. Maintenance Plan Management (Contents, Cycle, Budget, etc.)
- Regular maintenance items are determined by EPGE based on the latest regular maintenance records reported by the power plant.
- In the case of # 3 GT high vibration, EPGE requested the power plant to submit the construction scope.
- EPGE determines the timing of regular inspections taking power demand into account.
- The power plant notifies EPGE of the inspection process and obtains approval from EPGE.

b. Implementation Status, Frequency, and Method of Periodic Maintenance
- EPGE arranges necessary workers according to the request of the power plant. The power plant arranges workers from other power plants if necessary.
- A report will be submitted if the manufacturer participates in the regular inspection, but there is no record when the regular inspection is carried out only with EPGE staff.
- The weekly report reported from the power plant to EPGE is documented.
- Although clearance measurement is carried out, the data is not documented, therefore it is difficult to identify the cause when an accident occurs.
- EPGE procures necessary parts.
- The plant manager and mechanical department manager decide how to repair the removed equipment.
- The Hlawga power station manager decides treatment with VT (Visual Testing).

c. Initiatives for Continuous Improvement
- The power plant owns the necessary tools to implement regular inspection.
- If problems are found during regular inspection, the power plant submit a letter to EPGE, and EPGE contacts the OEM.
- All judgments are finalized by the Managing Director.
- Control unit update (Mark V → Ethos), addition of wing washing equipment, and fuel valve motorization were carried out in the major regular inspection in 2013.
- There is information that #1GT valve hunting occurs at startup. However, details are unknown.

4. Maintenance Record for Gas Turbine , Steam Turbine and HRSG

Sr. No	Machine No.	Date of Commercial Running	Combustion Inspection		Hot gas Path Inspection		Major Inspection	
			Date	Running hours	Date	Running hours	Date	Running hours
1.	Gas Turbine No(1)	19th, Feb, 1995	1st, May,1996	8685	-	-	18th, Dec, 2005	90299
			12th, Jun,1999	36514	-	-	21st, Nov,2010	120773
			15th, Jan,2002	57772	-	-	22nd, Nov,2013	145585 (Control system)
			24th, Jun,2007	100364	-	-	-	-
			31st, May,2009	114850	-	-	-	-
	Total		5 times				3 times	
2.	Gas Turbine No(2)	11th, Apri, 1995	18th, Apri,1996	8633	-	-	11th, Jan,2005	72685
			3rd, Jun,1999	35105	-	-	9th, Sept,2009	106008
			20th, May,2010 (01)	43884	-	-	11th, Aug,2010	107928
			30th, Apri,2011	113987	-	-	3rd, Oct,20(1)3	129071 (Control system)
			28th, Oct,2011	118001	-	-	-	-
	Total		5 times				4 times	

7

4. Maintenance Record for Gas Turbine , Steam Turbine and HRSG

Sr. No	Machine No.	Date of Commercial Running	Combustion Inspection		Hot gas Path Inspection		Major Inspection	
			Date	Running hours	Date	Running hours	Date	Running hours
3.	Gas Turbine No(3)	1st, Jun, 1995	16th,Jun,1996	8837	11th, Jan, 2006	83157	25th, Mar, 2001	45300
			23rd, Jun,1999	34182	-	-	3rd, Mar,2008	92193
			20th, Mar,2004	68461	-	-	1st, Feb,2014	136250 (Control system upgrade)
			11th, Mar,2007	89470	-	-	July 2016 Rotor Replacement (From Hlawga)	-
			21th,Apri,2011	113726	-	-	-	-
	Total		5 times		1 time		3 times	
4.	Steam Turbine	10th,Sept,1999	Sand blasting on Rotor and stator Blades (Date: 22nd , Apr, 2005; Running hrs = 46062 hrs)					
			Replacement of Condenser Tubes (9th , Feb , 2006 ; Running Hours = 50556) (2018. 3 143745.4 hr) control system upgrade 2015. Apr.					
5.	HRSG (1)	Ditto	Replacement of Tube Bundle (all) (Date: 21th , Dec, 2006)					
6.	HRSG (2)	Ditto	Replacement of Tube Bundle (all) (Date: 1st, May, 2005)					
7.	HRSG (3)	Ditto	Replacement of Tube Bundle (all) (Date: 19th , Jan, 2007)					

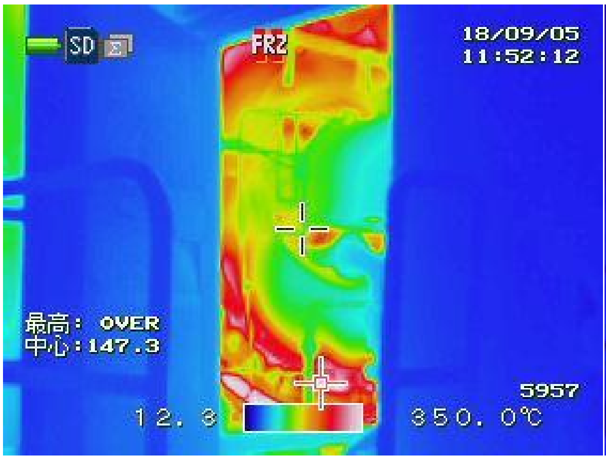
8

Fig : Ahlone P/S Periodic Inspection Results

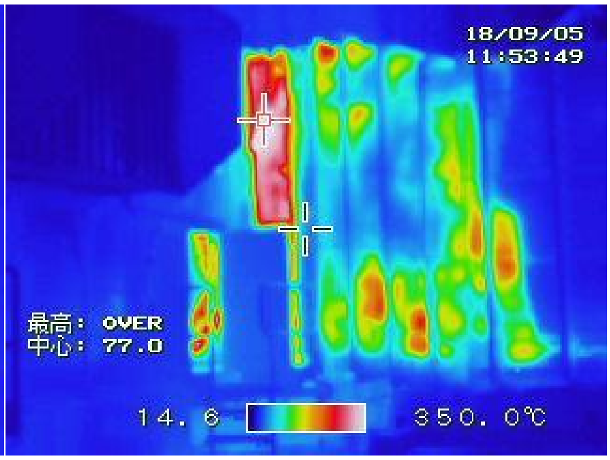
d. Status of Equipment

(a) Damage Status

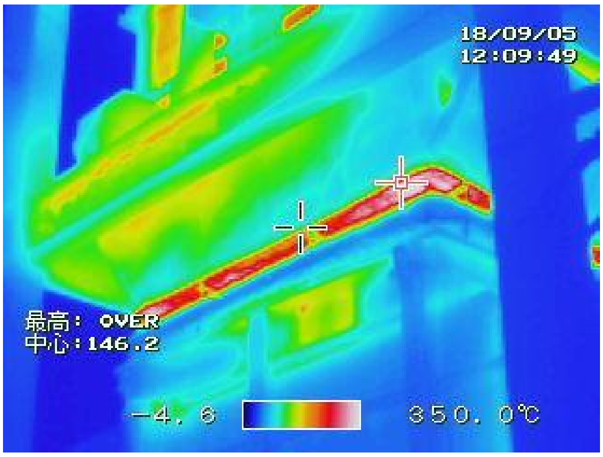
No.	Gas Turbine Common Issues （#1GT, #2GT, #3GT）
1	Exhaust gas leakage
2	GT exhaust gas duct overheating
3	Bypass stack expansion gas leakage
4	Oil leakage around lube oil equipment



GT Common Issue No.1



GT Common Issue No.2



GT Common Issue No.3

GT Common Issue No.4

No.	HRSG Common Issues （#1HRSG, #2HRSG, #3HRSG）
1	Water, steam piping insulation removed
2	Feed water control valve corrosion
3	Blowdown tank exterior board corrosion
4	Spray control valve corrosion
5	Boiler water sampling device malfunction
6	Manhole not closed
7	Inappropriate spare tube storage (outdoor)


HRSG Common Issue No.1


HRSG Common Issue No.2


HRSG Common Issue No.3


HRSG Common Issue No.4

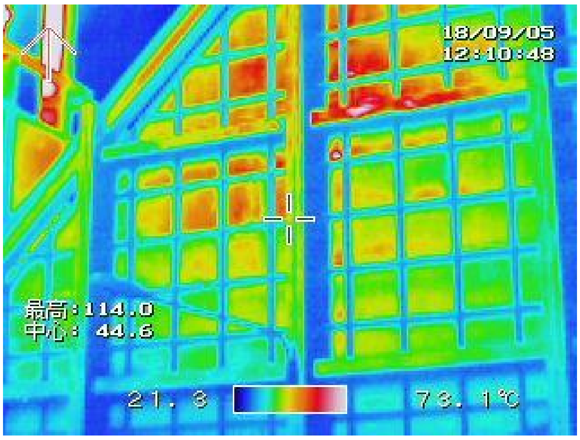

HRSG Common Issue No.5


HRSG Common Issue No.6


HRSG Common Issue No.7

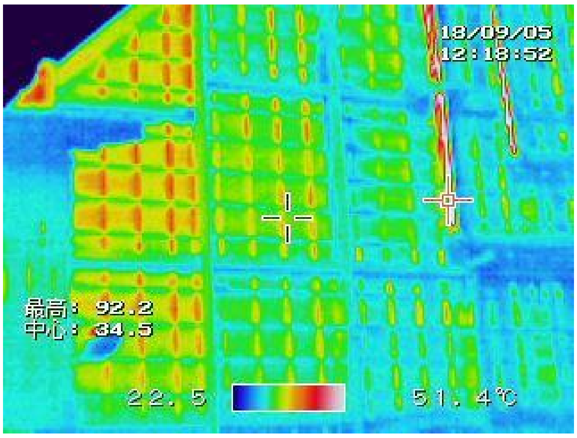
No.	#2GT Issues
1	Exciter side bearing high vibration (horizontal direction)
2	Diverter damper closing defect

#2GT No.1



#2GT No.2

No.	#3GT Issues
1	Diverter damper closing defect



#3GT No.1

No.	#1HRSG Issues
1	Inappropriate storage of removed boiler tube
2	Control cable inappropriately laid around drum
3	Boiler top handrail damaged

#1HRSG No.1

#2HRSG No.2

#1HRSG No.3

No.	#3HRSG Issues
1	Heat insulation material scattered around boiler

#3HRSG No.1

No.	Steam Turbine Issues
1	Turbine top oil leakage

ST No.1

No.	BOP Issues
1	Gas station strainer level gauge lower side flange gas leakage
2	Gas station cyclone separator level gauge lower side flange gas leakage
3	Gas station check valve outlet flange gas leakage

No.	BOP Issues
4	Cooling tower staircase corrosion
5	Cooling tower concrete peeling
6	Cooling tower cable tray deformation
7	Demineralized water tank outlet pump leakage
8	Oil leakage around main oil tank
9	Condenser inspection stand corrosion
10	Condenser vacuum pump system disconnect such as separator
11	Spiderweb in the control center board
12	Control air compressor malfunction


BOP No.1


BOP No.2


BOP No.3


BOP No.4


BOP No.5


BOP No.6


BOP No.7


BOP No.8


BOP No.9


BOP No.10


BOP No.11


BOP No.12

(b) Simple Diagnosis

Ø Water Quality Diagnosis

At demineralized water tank outlet   No abnormality

測定値	現地盤指示	装置仕様
5.91	EE	4.8

pH Measurement

測定値	現地盤指示	装置仕様
1.793	1.19	-

Electric Conductivity (mS/m)

Water Quality Measurement

Ø Vibration Diagnosis

ž Vibration measurements were carried out with the # 1, 2, and 3 GT.

ž There are discrepancies between the installed equipment and the measurement results obtained with portable device at this time.

ž Also, the horizontal direction of the # 2 GT exciter side exceeds the trip value.
Alarm value: 12.7 mm / s   Trip value: 25.4 mm / s

◆Vibration Measurement

Title	Vibration Measurement
Power Station	Ahlone
Object	#1GT
Measurer	Hiraoka (MHPS)
Observer	Ozaki (Kansai)

Equipment Specification

Type	Frame6(GE) PG6541B	Capacity	38,340 kW (15℃)
Roating Speed	5100 rpm (GT) 3000 rpm (GEN)	COD	1995.2
Generation Type	T190-240 43MVA		

Measurement Result

Measurement Date		9.5,2018
Measurement Tool	Type	Portable Vibrometer
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD
#1 Bearing Stand	V	52 μm (13.95 mm/s)
	H	42 μm (11.27 mm/s)
	A	33 μm (8.86 mm/s)
Exciter	V	40 μm (6.28 mm/s)
	H	25 μm (3.93 mm/s)
	A	42 μm (6.60 mm/s)

◆Vibration Measurement

Title	Vibration Measurement
Power Station	Ahlone
Object	#2GT
Measurer	Hiraoka (MHPS)
Observer	Ozaki (Kansai)

Equipment Specification

Type	Frame6(GE) PG6541B	Capacity	38,340 kW (15℃)
Roating Speed	5100 rpm (GT) 3000 rpm (GEN)	COD	1995.4
Generation Type	T190-240 43MVA		

Measurement Result

Measurement Date		9.5,2018
Measurement Tool	Type	Portable Vibrometer
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD
#1 Bearing Stand	V	25 μm (6.71 mm/s)
	H	30 μm (8.05 mm/s)
	A	25 μm (6.71 mm/s)
Exciter	V	90 μm (14.14 mm/s)
	H	170 μm (26.70 mm/s)
	A	52 μm (8.17 mm/s)

◆Vibration Measurement

Title	Vibration Measurement
Power Station	Ahlone
Object	#3GT
Measurer	Hiraoka (MHPS)
Observer	Ozaki (Kansai)

Equipment Specification

Type	Frame6(GE) PG6541B	Capacity	38,340 kW (15℃)
Roating Speed	5100 rpm (GT) 3000 rpm (GEN)	COD	1995.5
Generation Type	T190-240 43MVA		

Measurement Result

Measurement Date		9.5,2018
Measurement Tool	Type	Portable Vibrometer
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD
#1 Bearing Stand	V	35 μm (9.39 mm/s)
	H	15 μm (4.03 mm/s)
	A	27 μm (7.25 mm/s)
Exciter	V	15 μm (2.36 mm/s)
	H	40 μm (6.28 mm/s)
	A	44 μm (6.91 mm/s)

Vibration Measurement

Ø Electric Current Diagnosis

Current measurement was carried out with the No.2 exhaust flame cooling fan of the #3 GT.
No abnormality

◆Motor Current Measurement

Title	Motor Current Measurement
Power Station	Ahlone
Object	#3 GT Exhaust Frame Cooling Fan
Measurer	Sato (Kansai)
Observer	Ozaki (Kansai)

Motor Specification

Type	–	Capacity	30 kW
Number of Poles	2	Serial Number	752163000002
Rotating Speed	2955 rpm	Voltage	400V
Current	52 A	Insulation Type	F
Manufacturer	LEROY SOMER	Made Date	–

Measurement Result

Measurement Date		9.5,2018
Measurement Tool	Type	HIOKI 3285
	Serial Number	80523503
	Calibration Date	2009.8
Phase Current	A	19.0 A
	B	20.5 A
	C	20.6 A

Current Measurement

Ø Insulation Resistance Diagnosis

Insulation resistance measurement was carried out with the B condensate pump.
No abnormality

◆Motor Insulation Resistance Measurement

Title	Insulation Resistance Measurement of Low Voltage Motor
Power Station	Ahlone
Object	B-Condensate Pump
Measurer	Sato (Kansai)
Observer	Ozaki (Kansai)

Motor Specification

Type	Totally-enclosed Fan-cooled	Capacity	110kW
Number of Poles	4	Serial Number	K11R315S4 TWS
Rotating Speed	1480 rpm	Voltage	400V
Current	195A	Insulation Type	–
Manufacturer	VEM motors	Made Date	1998.5

Measurement Result

Measurement Date		9.5,2018
Measurement Tool	Type	Insulation Resistance Measuring Device 500V Type
	Serial Number (Model)	YOKOGAWA MY40-01
	Calibration Date	2017.8
Condition	Weather	Cloudy
	Temperature (℃)	29.7℃
	Humidity (%)	75%
Insulation Resistance	MΩ	8.3 MΩ

Reference Value: more than 1MΩ

Insulation Resistance Measurement

Ø Lube Oil Diagnosis

Steam turbine and gas turbine lube oil were collected and taken back to Japan for analysis.

■Sampling Date : 12/04/2018 Sampler : KANSAI Sato, MHPS Hiraoka
■Analysis Date : Analysis company : Kanden Engineering

Manufacture of Lube Oil : Michang (Korea)-TURBINE OIL VG32

Item	Unit	Reference Value		Analysis Result	Evaluation
		Value	Exhibition		
Acid number	mgKOH/g	≦0.3	JIS K2213	0.07	ü
Kinematic viscosity	mm2/s (40℃)	28.8～35.2	JIS K2213	31.94	ü
Moisture	%	≦0.1	ASTM 4378-01	0.003	ü
Sludge Content	Mg/100ml	≦10	General Reference Value	0.6 (mesh 0.80.8	ü

ü : The analysis results met the reference values and no degradation was observed.

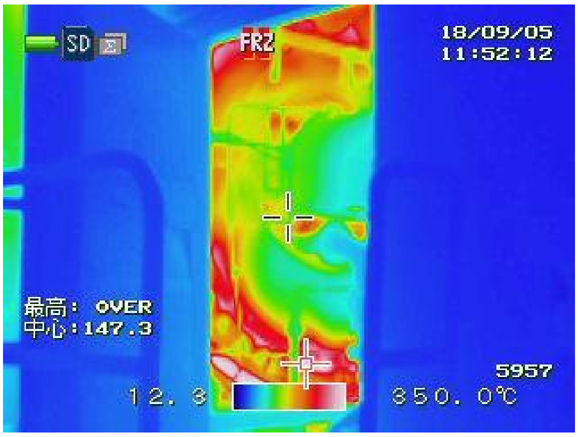
Lube Oil Sampling
Sampling Point : #3GT Pressure Gauge
Connect point

◆Considerations

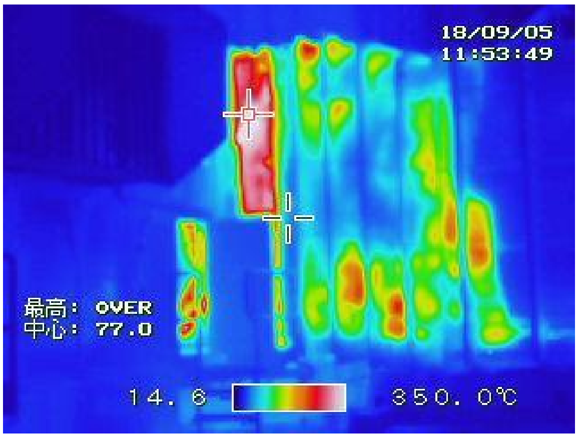
The residual rate could not be analyzed because new oil could not be collected. However, all other items were within the reference values, therefore it was considered that there was no decline in lubricating oil performance.

Ø Leakage Location Diagnosis

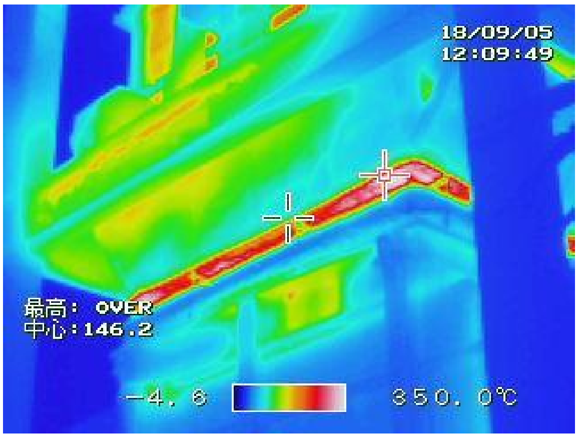
Surveys such as gas leakage, steam leakage, overheating, etc. of equipment (GT, HRSG) during operation were conducted using a thermal camera.
Overheating of the GT exhaust duct and gas leakage of the bypass damper, etc. were found.



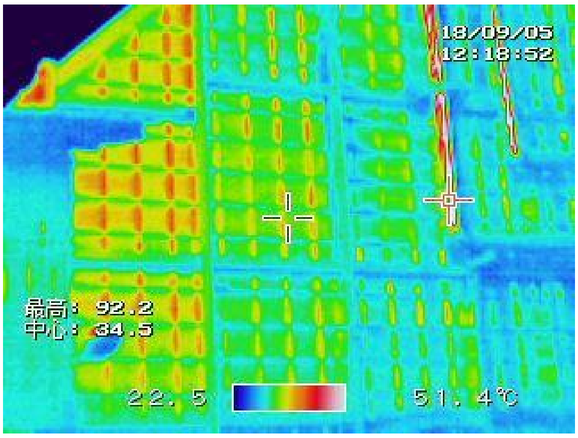
GT Exhaust Seal Gas Leakage（#1, 2, 3 GT）



GT Exhaust Duct Overheating（#1, 2, 3 GT）



Bypass Stack Expansion Joint Gas Leakage（#1, 2, 3 HRSG）



Bypass Damper Gas Leakage（#2, 3 HRSG）

Gas leakage diagnosis of NG station was carried out using a portable gas detector.
Gas leakage at the strainer inlet/outlet flange was found.


Strainer Level Gauge Flange Gas Leakage


Check Valve Outlet Flange Gas Leakage

※Gas leakage concentration of the strainer level gauge flange exceeded the LEL (lower explosion limit).

- Unit Performance Diagnosis

The thermal efficiency of a Combined Cycle Power Plant is theoretically calculated as follows.

$$\eta C = \eta G + (1 - \eta G) * \eta B * \eta S \quad \cdots \text{Equation A}$$

The definition of each variable and the calculation are as follows.

ηC : Thermal Efficiency of CCGT

$$= \frac{3600}{\frac{\text{NG } \mathit{Heating\ Value} \text{ LHV[kJ/kg]} \times \mathit{Total} \text{ NG } \mathit{Flow\ Rate} \text{ [kg/h]}}{\mathit{Total} \text{ GT } \mathit{Output}\text{[kW]} + \text{ST } \mathit{Output}\text{[kW]}}}$$

(*)Equation A does not consider some losses (GT-HRSG duct loss, HRSG-ST steam pipe loss). Therefore, the thermal efficiency of the CCGT calculated by the above equation is likely more accurate than Equation A.

ηG : Thermal Efficiency of Gas Turbine

$$= \frac{3600}{\frac{\text{NG } \mathit{Heating\ Value} \text{ LHV[kJ/kg]} \times \text{NG } \mathit{Flow\ Rate}\text{[kg/h]}}{\text{GT } \mathit{Output}\text{[kW]}}}$$

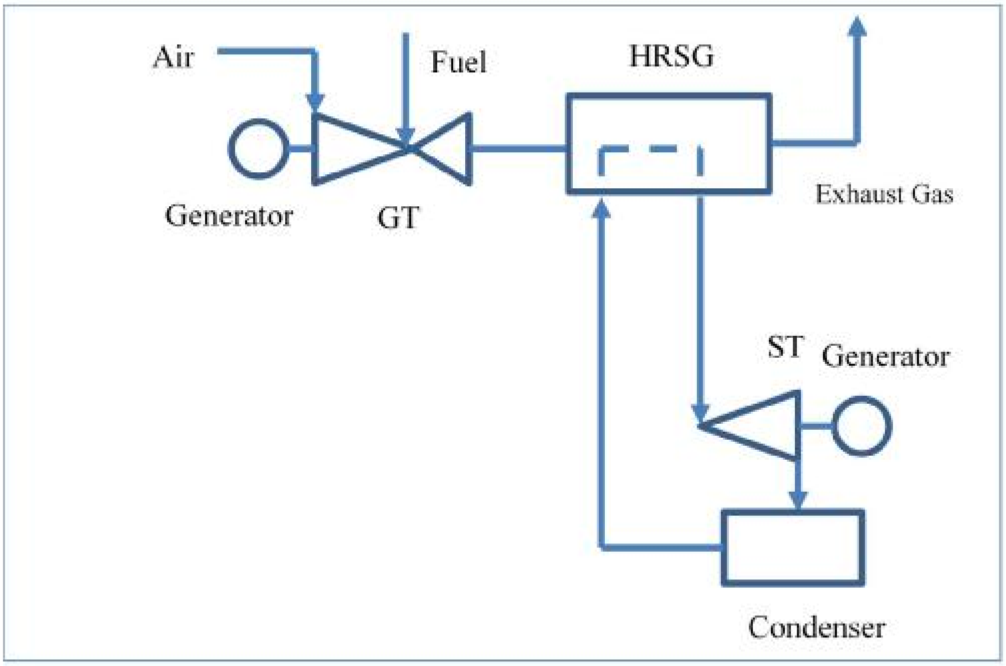
ηB : Thermal Efficiency of Boiler (HRSG)

$$= \left(1 - \frac{\mathit{Heat\ Loss}}{\mathit{Heat\ Input}}\right) \times \mathbf{100}$$

$$= \left(1 - \frac{(\mathit{HRSG\ Outlet}\ h\text{[kJ/kg]} - \mathit{Atmospher}\ h[kJ/kg]) \times \mathit{Exhaust\ Gas\ Flow\ Rate}[kg/h] \times \mathit{Constant\ Pressure\ Specific\ Heat}[kJ/kg \cdot K]}{(\mathit{HRSG\ Inlet}\text{[kJ/kg]} - \mathit{Atmosphere}\ h[kJ/kg]) \times \mathit{Exhaust\ Gas\ Flow\ Rate}[kg/h] \times \mathit{Constant\ Pressure\ Specific\ Heat}[kJ/kg \cdot K]}\right) \times \mathbf{100}$$

ηS : Thermal Efficiency of Steam Turbine

$$= \frac{3600}{\frac{(\text{ST } \mathit{Inlet}\ h\text{[kJ/kg]} - \text{ST } \mathit{Outlet}\ h[kJ/kg]) \times \mathit{SteamFlow\ Rate}[kg/h]}{\text{ST } \mathit{Output}\text{[kW]}}}$$



The result of the site survey is as follows. The condition is LHV, gross basis (output, efficiency, Yadana gas).

※Because it was the rainy season, the plant was under partial load operation and performance evaluation was not possible. (The following shows the values at partial load.)

Item		Design	Measurement Data (2017.1)		Measurement Data (2018.9)		
Operation Mode		Full Load	Partial Load		Partial Load		
		3-3-1	2-2-1		GT only		
Ambient Temperature		30℃	30℃		25℃		
Output	gross	157MW	59MW		68MW		
	net	154MW	-		-		
Efficiency	gross	46.3%	32.3%		22.6%		
	net	45.5%	-		-		
Unit			#2	#3	#1	#2	#3
GT Output		35.0MW/unit	26.7MW	27.0MW	19.9MW	23.1MW	25.0MW
ST Output		51.9MW	16.8MW		-		
GT Efficiency		31.0%	22.9%	23.3%	21.5%	23.1%	23.1%
HRSG Efficiency		74.3%	48.0%	47.5%	-		
ST Efficiency		30.8%	25.0%		-		
Fuel Consumption		43.35t/h	11.19t/h	12.08t/h	11.89t/h	12.83t/h	13.90t/h

(4) Predictive Maintenance

a. Control Status of Records

- Data collected in the central control room is recorded in a log sheet.
- The data collected on site (every hour) are as follows.
  lube oil level, lube oil pressure, cooling water inlet / outlet temperature for GT oil cooler, transformer oil level, transformer oil temperature, fuel gas supply pressure, SRV pressure, GCV pressure, intake air filter differential pressure
- Predictive maintenance is not carried out and no management system has been introduced.

b. Accumulation and Analysis of Operation Data

- When the oil temperature rises, analysis is performed using Excel and a graph..
- Operation data is not shared with other power plants; it is only reported by fax and phone to Hlawga.
- The operation data is kept in a locker in the central control room.
- The Ethos control device can save operation data as CSV data, but it is not utilized.

c. Past Performance of Predictive Maintenance Based on Data Analysis

- The power plant reports the analysis data to EPGE and requests necessary maintenance. For example, in the case of a rise in lube oil temperature, cleaning of the cooler is requested.

d. Remarks

- The GT lube oil cooling water temperature cannot be monitored in the central control room due to a control cable failure.
- In addition, it is requested to make it possible to monitor GT intake filter pressure at the center.
- A function that can automatically create hourly data and daily, monthly, and annual reports is desired.
- The problems currently recognized by the power plant are # 1 GT high vibration, # 1, 2, and 3 HRSG tube leakage, and # 1 GT gas control valve hunting at start-up.

Appendix 2

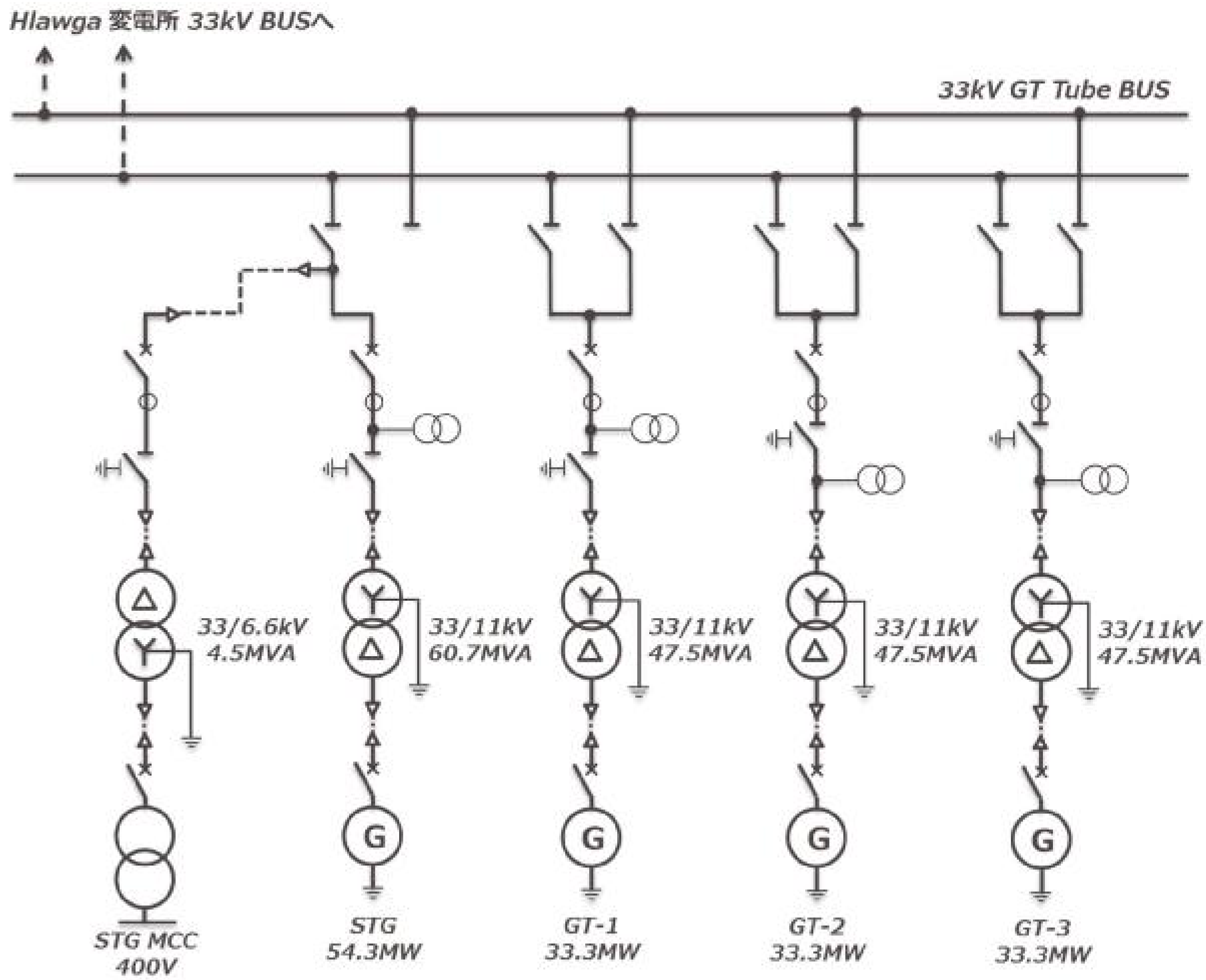
Hlawga Power Station Survey Results

■**Hlawga（First Site Survey：2018.9.1, 9.3　Second Site Survey：2018.12.4, 12.5, 12,13）**

（1）O&M System Survey

a. Outline of Facility

Location (Address)		16 1/2mile, Pyay Road, Mingaladon, Yangon, Myanmar
Configuration		3-3-1 CCGT
EPC		Marubeni-Kawasaki (Boiler [Kawasaki), Turbine [ABB))
GT	Model	Frame6 (GE)　PG6541B
	Output	33.3 MW
	COD	5.11,1995　1.19,1996　2.23,1996
ST	Model	V-63 (ABB)
	Output	54.3 MW
	COD	5.1, 1999
Power Plant Output		154.2 MW　(3on1 CCGT)
Fuel		NG（Yadana Gas　・Zawtika Gas）
Connection to Transmission Line		Connect to Hlawga S/S（33 kV）



Fig：Hlawga P/S Single Line Diagram

Equipment Specifications

Gas Turbine		
Model：	Frame6 PG6541B（GE） (Air Temperature 15℃, Humidity 60%, Atmosphere Pressure 1013.25 hPa)	
	Designed Output：	38,340 kW
	Designed Heat Rate：	11,460 kJ/kWh
	Designed Heat Consumption：	439,400 MJ/h
	Designed Exhaust Gas Flow：	500.5 t/h
Gas Turbine	Type：	Open Simple Cycle/Single Shaft
	Stage：	3 Stage
	Turbine Inlet Temperature：	1,104℃（Internet）
	Turbine Outlet Temperature：	537℃（Internet）
	Rotating Speed：	5100 rpm
Combustor	Type：	Reverse-Flow / Multiple-can
	Number：	10
Compressor	Stages：	17
	Outlet Pressure：	12.0 bar（GT-PRO）
Generator	GEC ALSTHOM Type：	T190-240 43 MVA -1 1 kV – 3000 rpm
	Power Factor：	Lag 0.80

HRSG	
Number of Units ：	3
Model ：	Kawasaki-Vogt natural circulation / Horizontal gas flow
GT Fuel：	NG
Steam Flow：	67.3 t/h（per unit）
Steam Pressure：	42.9 ata（SH Outlet, Absolute Pressure）
Steam Temperature：	485 ℃（SH Outlet）
Feed Water Temperature：	54.5 ℃
Bypass Stack：	Available

Steam Turbine		
Steam Turbine	Manufacture：	ABB
	Output：	56.65 MW
	Rotating Speed：	3,000 rpm
	Number of ST：	1
	Over Speed Trip：	3,300 rpm
	Turning Speed：	50 rpm
	Turbine First Critical Speed：	2.300 rpm
	Rotor Weight：	16,617 kg
	Rotation Direction：	C. C. W
	Steam Pressure：	43.16 bara（norm）
	Steam Temperature：	464 ℃（norm）
	Steam Flow：	216 t/h（max）
	Exhaust Steam Pressure（norm）：	0.12 bara
	Exhaust Steam Flow Rate（max）：	216 t/h
Generator	MEIDENSHA Type：	TIC-AFT Three-Phase Synchronous Generator
	Output：	67,875 kVA
	Power Factor：	Lag 0.80
	Frequency：	50 Hz
	Number of Poles：	2
	Rotating Speed：	3,000 rpm
	Voltage：	11,000 V
	Current：	3,563 A

Main Transformer

GT		ST	
Manufacture：	ALSTHOM	Manufacture：	MEIDEN
Model：	TTHRV	Model：	BORSD-A
Output：	47.5 MVA	Output：	56/70 MVA
Voltage：	33/11 kV	Voltage：	33/11 kV
Cooling Type：	ONAF	Cooling Type：	ONAF/ONAF

Condenser

Manufacture：	EDI（Evaans Deakin Engineering)
Type：	Shell & Tube
Steam Flow（norm/max）：	216 t/h
Pressure ：	0.12（norm）/0.14（max）bara
Temperature：	50（norm）/60（max）℃
Cooling Water Flow Rate：	4,165kg/s
Cooling Water Inlet Temperature：	42.8℃
Cooling Water Outlet Temperature：	51.8℃
Surface Area：	6,013 m^2
Tube Bundles：	2
Tube Size：	25.4×1.47 mm 25.4×0.87 mm
Number of Tubes：	9,786
Length ：	7,700 mm
Weight(empty)：	135,000 kg
Weight(full)：	249,450 kg

Cooling Tower

Capacity：	15,340 m^3/h
Wet-Bulb Temperature：	37.8℃
Outlet Temperature：	42.8℃
Inlet Temperature：	49.8℃
Number of Fan：	4
Structure：	Reinforced Concrete
Fill ：	Cured Polyvinyl Chloride

Wastewater Treatment

Capacity：	120 m^3/day
Type：	2-Stage Reverse Osmosis
Chemical：	Chlorine Treatment（NaOCl） Coagulation Treatment（FeCl3) Reduction, PH Control（SBS） PH Control（H2SO4)
Designed Demineralized Water：	Conductivity 10 μS/cm or less, Silica 0.5 ppm or less

Fuel Gas

1)Fuel Gas	Methane：	69.8801 mol%
（Yadana Gas）	Ethane：	1.0106mol%
	Propane：	0.1694 mol%
	i-Butane：	0.0184 mol%
	n-Butane：	0.0279 mol%
	i-Pentane：	0.0065 mol%
	n-Pentane：	0.0037 mol%
	Neo-Pentane：	0.0214 mol%
	Hexane and Heavier：	0.0211 mol%

CO_2 :	4.1294 mol%
N_2 :	24.727 mol%
H_2S :	0.0021 mol%
H_2O :	0.0011 mol%

（Zawtika Gas）

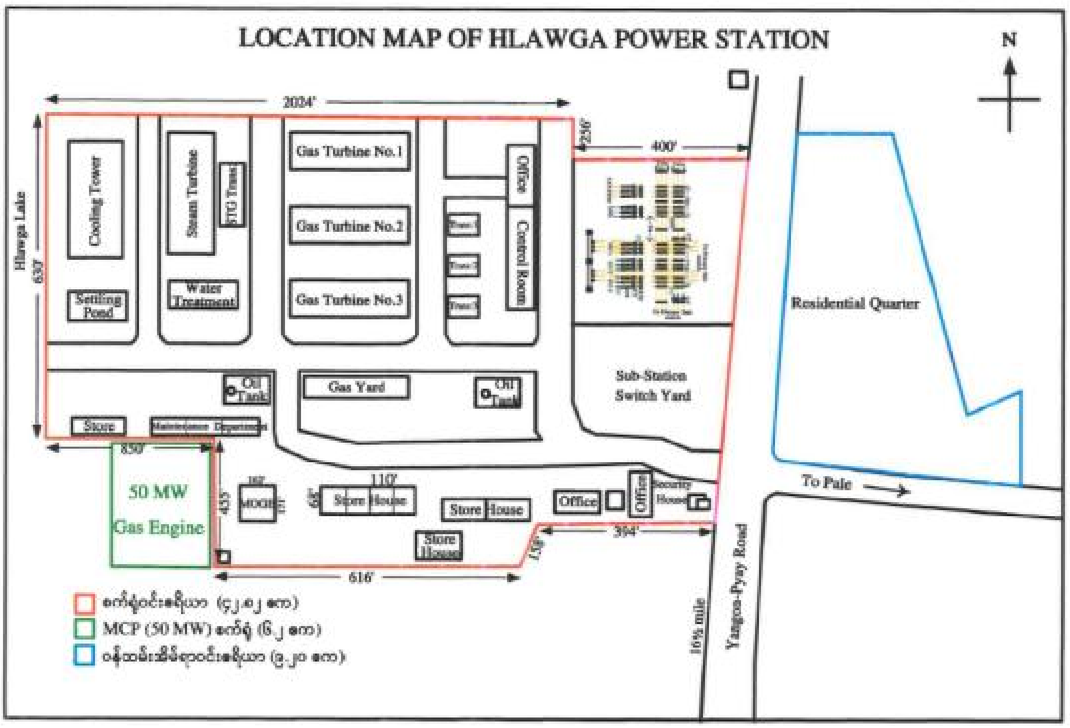
Methane：	91.786 mol%
Ethane：	0.401 mol%
Propane：	0.111 mol%
i-Butane：	0.035 mol%
n-Butane：	0.021 mol%
i-Pentane：	0.01 mol%
n-Pentane：	0.007 mol%
Hexane and Heavier：	0.031 mol%
N_2 :	7.531 mol%

2) Gas Delivery Condition

Gas Station	High Temperature：	45℃
	Low Temperature：	22℃
	High Pressure：	35 barg
	Low Pressure：	27 barg
	Max Flow Rate：	54,000 Nm^3/h
GT Inlet	High Temperature：	45℃
	Low Temperature：	20℃
	High Pressure：	30 barg
	Low Pressure：	18 barg
	Max Flow Rate：	18,000 Nm^3/h

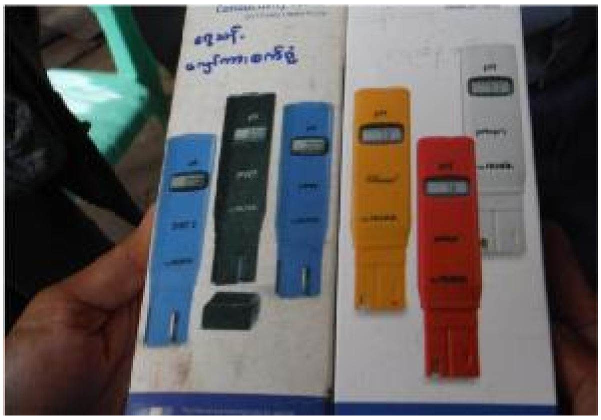
b. Layout

- There is no chemical analysis room at the power station to conduct water quality, lubricant, control oil, or fuel management.
- Lube oil is only checked at the tank level; exchange standards, replacement timing, etc. are not specified.
- For water quality control, water quality is checked by portable analyzer due to malfunction of installed instruments. (PH, electric conductivity)
- However, periodic calibration of instruments has not been implemented.



Fig：Hlawga P/S Layout

Instrument Malfunction



Potable Analyzer

c. Power Station Management and Education System

- The plant is staffed by 100 persons .
- Education of new employees is basically carried out by OJT.
- Several members undergo education at the Pounlong training center.
- The director judges the operation and monitoring skills.

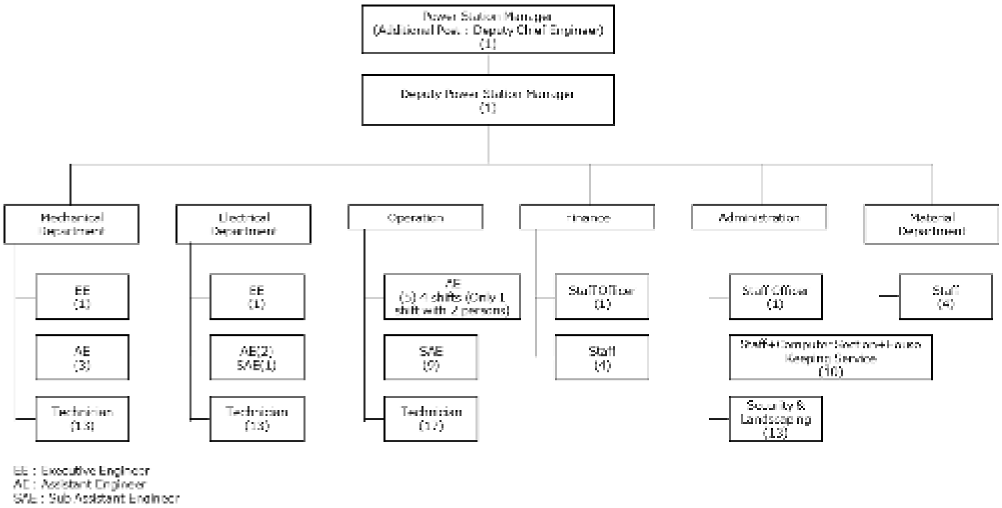


Fig : Organization Chart

・Responsibilities are as follows.

Table : Division of Responsibilities

Division	Section		Kind of Work
Maintenance	Mechanical		Mechanical Equipment Maintenance checking & Filling for water supply, oil supply, vibration iinspection, etc. Repair
	Electrical		Electrical Equipment Maintenance Transformer inspection, S/Y inspection, battery inspection for UPS, battery bank inspection, security lighting, etc. Repair
Operation	Operation	AE(1)	Operation Management
		SAE(2)or(3)	Operation & Monitoring for GT, STG and Boiler
		Technician(4)or(5)	Site Work (BOP) / Site data recording and equipment patrols
Finance			Salaries & Wages Budgets & Drawing limit Pay Roll & Pention
Administration	Office & Other staff		Administrative Management
	Computer Section		Recording and reporting of official data, Recording of equipment data
	House Keeping Service		Housekeeping service for control room, meeting rooms, offices, etc.
	Security & Landscaping		Security for main gate, water intake and residential gate
Material	Material Planning		Receiving, issuing, stocking, monthly reporting

d. Regulations and Manuals of Power Plant O&M

・Rules are hardly documented.

・Regarding the start / stop procedures and operation control values of the units, the maintenance manuals of manufacturers are used.

e. Parts Procurement Procedure

・For necessary parts and consumable supplies such as chemicals and lubricants, the procurement department of the power plant submits a request list to EPGE.

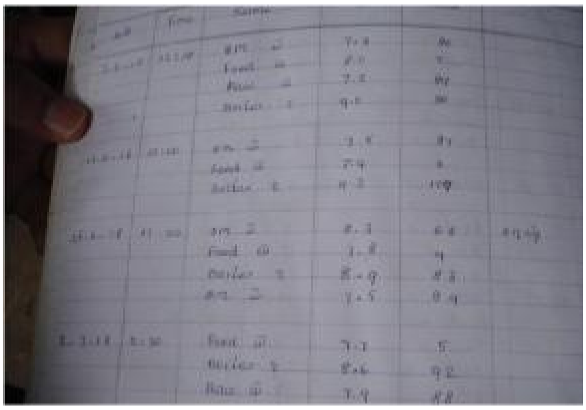
・Regarding the lubricant required at all power plants, EPGE purchases them collectively and distributes them to each power plant. When placing an order, EPGE specifies the required specification and makes bidding. Currently, lube oil made bay Korea; Michang is used.

・For parts costing more than $200, the power plants make a request to EPGE with a list stating the quantity and amount, and EPGE procures what is needed.
・Quality control (confirmation) of delivered parts is not carried out.

（2）Daily Operation

a. Operation System

・2-shift, 4-team system. There are 8 persons per shift. (The person who is in charge of water control operation belongs to the operation department.)
・The operator performs inspection every hour and collects operation data. (Central control room data, local data)
・The maintenance department performs inspection twice in the morning and evening.
・Regarding water quality management, measurements are made once a day with a portable analyzer and recorded in logbook once a week by handwriting.



Water Quality Logbook

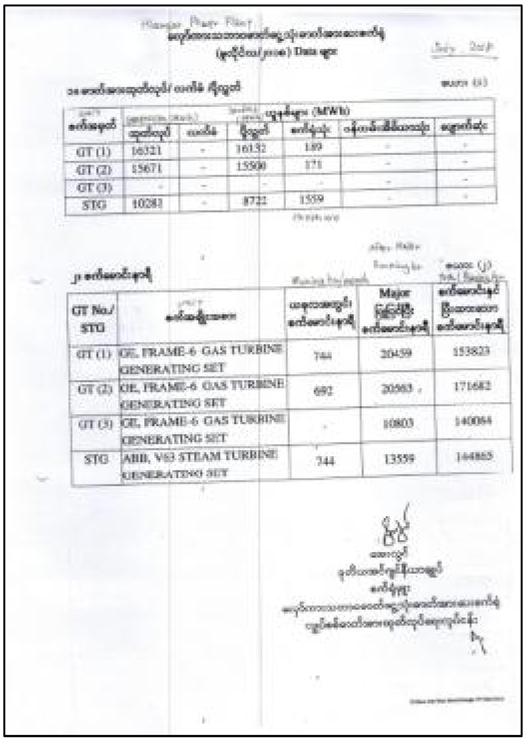
Measurement items：pH、Conductivity
Sampling points：
Raw water (Overflow at raw water tank)
Demineralized water
(Demineralized water equipment outlet)
Boiler water (Feed water pump outlet)
Feed water (Sampling equipment outlet)

Measurer : Person in charge of chemical in maintenance department

b. Quantitative Records Related to Power Generation

・Fuel gas pressure, consumption, MW (GT, ST), and MWh are recorded every hour and organized on a daily basis.
・Also, daily, monthly, and annual reports are submitted to EPGE, but thermal efficiency management based on recorded data is not implemented.
・The daily data (MW, MWh, gas pressure, gas consumption) of the thermal power plant in Yangon is collected at the Hlawga power plant and reported to EPGE by fax.

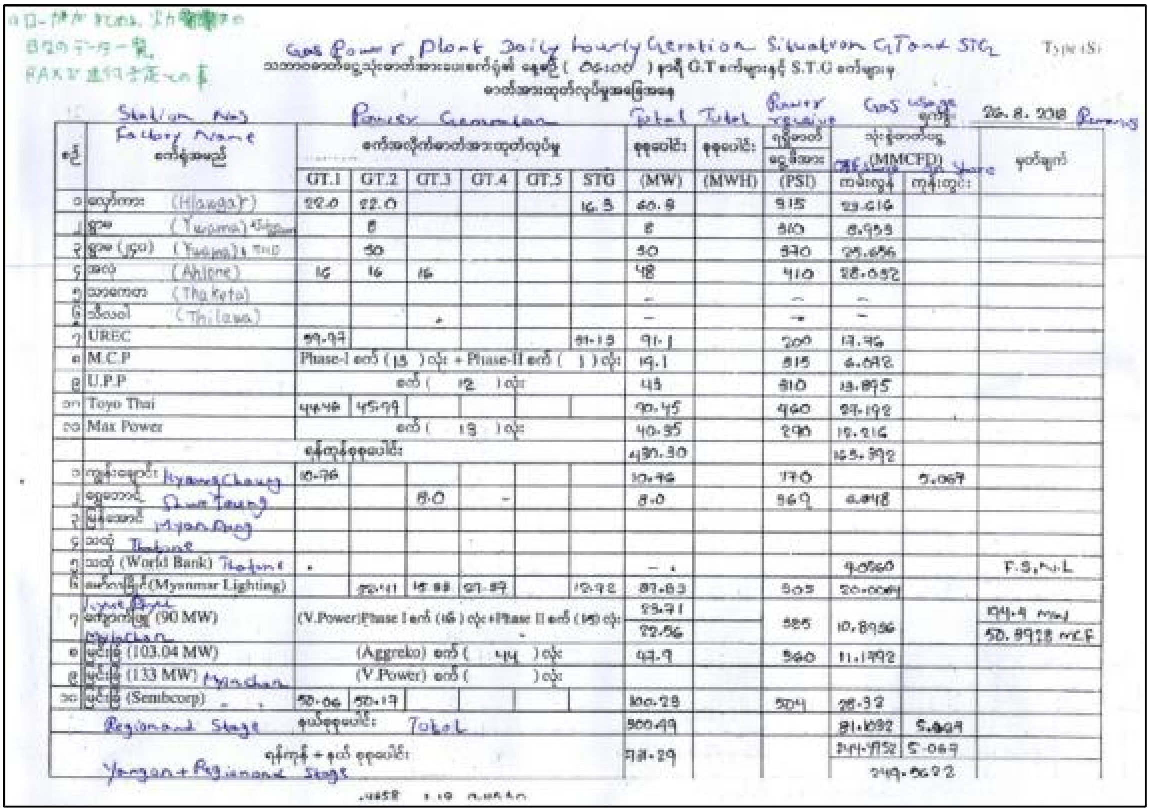
Quantitative Records



[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GT (1)	16321	-	16132	189	-	-
GT (2)	15671	-	15500	171	-	-
GT (3)	-	-	-	-	-	-
STG	10281	-	8722	1559	-	-

GT No./STG	[illegible]	[illegible]	Major [illegible]	[illegible]
GT (1)	GE, FRAME-6 GAS TURBINE GENERATING SET	744	20459	153823
GT (2)	GE, FRAME-6 GAS TURBINE GENERATING SET	692	20563	171682
GT (3)	GE, FRAME-6 GAS TURBINE GENERATING SET	-	10803	140084
STG	ABB, V63 STEAM TURBINE GENERATING SET	744	13559	144865

Fig : Monthly Report to EPGE



Gas Power Plant Daily hourly Generation Situation GT and STG

26. 8. 2018

No.	Station Name / Factory Name	GT.1	GT.2	GT.3	GT.4	GT.5	STG	Total (MW)	Total (MWH)	Power Receive (PSI)	Gas Usage (MMCFD)		Remarks
1	(Hlawga)	22.0	22.0				16.9	60.9		915	23.616		
2	(Ywama)		8					8		810	8.959		
3	(Ywama)		30					30		370	25.656		
4	(Ahlone)	16	16	16				48		410	28.032		
5	(Tha Keta)							-		-	-		
6	(Thilawa)							-		-	-		
7	UREC	59.97					31.13	91.1		200	13.76		
8	M.C.P	Phase-I (13) + Phase-II (1)						19.1		815	6.092		
9	U.P.P	(12)						43		810	13.895		
10	Toyo Thai	44.48	45.79					90.45		960	27.192		
11	Max Power	(13)						40.35		290	19.216		
	[illegible]							430.30			165.392		
1	Kyauk Chaung	10.76						10.76		170		5.067	
2	Shwe Taung			8.0	-			8.0		369	6.418		
3	Myan Aung												
4	Thaton												
5	(World Bank) Thaton							-			4.0560		F.S.N.L
6	(Myanmar Lighting)		22.41	15.88	27.37		12.72	87.83		505	20.0064		
7	Kyaukphyu (90 MW)	(V.Power) Phase I (16) + Phase II (15)						23.71 / 22.56		585	10.8956		94.4 mw / 50.8978 mcf
8	Myingyan (103.04 MW)	(Aggreko) (44)						47.9		560	11.1792		
9	Myingyan (133 MW)	(V.Power)											
10	(Sembcorp)	50.06	50.17					100.23		504	28.32		
	Regional Stage Total							300.49			81.1032	5.067	
	Yangon + Regional Stage							731.29			244.4752	5.067	
											249.5622		

Fig : Thermal Power Plant Operation Data in Yangon（Daily Data）

c. Record of the Implementation Status of O&M

- The contents of troubles found in daily inspections, repair results, inspections, cleaning results etc. are recorded by hand in the maintenance logbook and reported to the plant manager.
- Details of the accident / malfunction situation are not described and, in many cases, the description is no more than "** damage", "parts replacement", or "repaired".
- Operation data (diaries) are recorded in the operation logbook.

d. Spare Parts Management

・Spare parts are kept in a warehouse and managed by spare parts list. Stocktaking is carried out once a year.
・Brand new and used (required for repair) parts exist together.
・Lifetime management by serial management has not been implemented for hot gas parts, and proper management has not been implemented.
・Interchange of spare parts between power stations is possible with the approval of EPGE.


Gas Turbine Rotor Blade（Used）


IGV (Unused)

e. Actions against Events/Abnormalities and Record Management

・Regarding records, as described in subsection C, "Record of the Implementation Status of O&M”.
・The repair workflow is as follows.

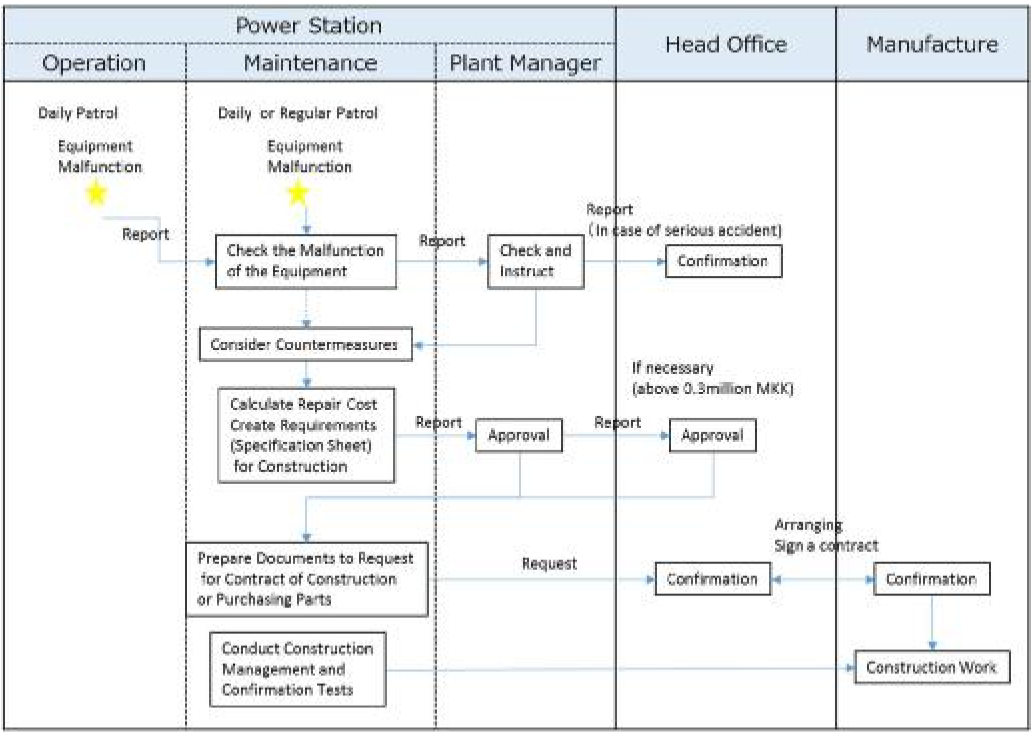


Fig : Repair Workflow

・At the time of trouble (accident) occurrence, the person in charge of the division contacts the power station manager, and the power station manager judges the treatment.
・The decision to stop the plant is as follows.
Normal time: EPGE's MD or CE decides.

Emergency: The power station manager decides.
(When the director is absent such as on holidays or at nighttime, the manager in charge of the maintenance department judges the situation.)

- If it is difficult to repair by power plant staff alone, the Director requests manpower support from EPGE with outsourcing documents.
- EPGE judges whether or not it can be implemented in consideration of budget and necessity.
- When isolation is necessary, attention is drawn by installing a signboard.
- Emergency countermeasures and permanent countermeasures are decided based on experiences.
- Applications to other machines are taken into consideration when trouble occurs.
- In the case of work conducted only by power station staff, since permission can be acquired from EPGE in one day, work can be in after a few days, but in case outsourcing is needed, the power plant will request EPGE with a document, which takes about 1 month for approval and a few months for selecting a subcontractor. It will take more time if construction becomes a bid.
- The repair method, cost, construction period, etc. are decided based on the experience of the engineer.
- Repair work requires technical approval and financial approval.
- Regarding the accident report (letter) contents to EPGE, it was confirmed by interview that it uses almost the same contents as KANSAI, which are as follows.

Information Sharing required ☐
Information Sharing not reuired ☐

Accident Preliminary Report (The Report) · In-House Preliminary Report

Creation Date
Reference Number

Name of Power Plant		
Subject		
Occurrence Date and Time		
Outside Influence	Influence on Third Party	Presence or Absence
	Victims	Presence or Absence (death , injury)
	Outside Report	Presence or Absence （Firefighting · Police）
	Necessity of Accident Report Required or not	【Grounds for Judgment】
Influence on Plant Operation		
Request to Headoffice Support		Presence or Absence
Status of Occurrence (Discovery) as of :		
Measure Details after Discovery		
Surrent Situation		
Follow-up Report Schedule		Presence or Absence Schedulede at :
Remarks	Consideration	※Human Error Analysis Required or not
		※Roll out other unit in Power Plant Presence or Absence
	Cause of Accident (Probable Cause)	
	Manufacturer's Name, Specification etc.	
Filled in by		

Fig : Accident Report

f. Environment Management

・Exhaust gas is not monitored or managed.

g. Entry Management

・People entering the power station check in at the guard room and receive a security card. There is no auto entry management system.
・Regarding staff members, employee cards are checked at the time of entry and managed.

Security Card

Hlawga P/S Guard Room

（3）Periodic Maintenance

a. Maintenance Plan Management (Contents, Cycle, Budget, etc.)

・Regular maintenance items are determined by EPGE in coordination with the power plant.
・EPGE determines the timing of regular inspections based on the operation time reported by the power plant.
・The type and duration of regular inspection are determined at the power plant.
・For the ST and HRSG, inspections are planned according to the manufacturer's recommended inspection cycle.
・For BOP, basically breakdown-maintenance is done.
・Although regular inspections are planned, they are not being carried out periodically because EPGE approval cannot be obtained due to budget deficits.

b. Implementation Status, Frequency, and Method of Periodic Maintenance

・EPGE arranges necessary workers according to the request of the power plant.
・The Hlawga power station manager also serves as EPGE Deputy Chief Engineer. He confirms the mechanical parts removed from thermal power plant in Yangon and judges whether replacement is necessary or not.
・For the necessary parts, the power plant submits a letter of request to EPGE.
・In the past, there were circumstances where parts could not be purchased from GE, etc. because of sanctions, and sometimes had to be purchased from another company (Wood Group, TSL).
・There was a period of inability to contact the OEM, due to sanctions.

c. Initiatives for Continuous Improvement

・After the periodic inspection, the power plant submits the report to EPGE. EPGE considers the next inspection contents based on the report.
・Currently, the power plant owns about 70% of the necessary tools. For the remaining 30%, it is necessary to borrow them from the other power stations.
・Power plant staff may be sent to other power stations during periodic inspections for educational purposes.
・For the Fr 6, power station members have the experience of conducting regular inspections by themselves.
・The upgrade work is carried out by GE including the control unit, and the removed parts are kept without being managed by serial number and operation time.
・EPGE regularly requests investigation on whether or not repair of parts is possible and repairs are being carried out.
・In addition, one spare GT rotor and one generator rotor (damaged) are on site.

Running Hours & Last Date of Major Overhaul

Sr. No	GT	Total Running Hours (29.8.2018)	Last Date of Major overhaul	(29.8.2018) Running hours after Major Overhaul
1.	GT No.1	154517	12.3.2014	21153
2.	GT No.2	172363	27.2.2016	21244
3.	GT No.3	148884	21.11.2013	10803
4.	STG	145561	4.8.2016	14255

Fig：Hlawga P/S Accumulative Operation Time As of 8.29,2018

GTs & STG's Maintenance History

Sr. No	Name	Machine No.	Design Capacity (MW)	Commissioning Date	Combustion Inspection			Hot Gas Path Inspection			Major Overhaul			Steam Turbine Maintenance		
					Date		Firing Hours	Date		Firing Hours	Date		Firing Hours	Date		Firing Hours
					From	To		From	To		From	To		From	To	
1	Hlawga	1	Gas Turbine	5.11.1995	18.1.1999	23.1.1999	27590				8.2.2001	12.8.2002	45388			
		T-746	(33.3)		12.6.2007	14.6.2007	83395				1.6.2006	28.6.2006	77982			
					26.11.2008	27.11.2008	94950				23.7.2011	10.9.2011	114273			
					7.9.2012	9.9.2012	122624				4.12.2013	12.3.2014	133364			
		2	Gas Turbine	19.1.1996	5.1.1999	14.1.1999	25257				3.7.2001	16.7.2002	46258			
		T-754	(33.3)		8.6.2007	9.6.2007	86318				1.3.2006	1.4.2006	77829			
					23.10.2008	24.10.2008	97713				11.11.2010	15.1.2011	109703			
					1.5.2010	3.5.2010	105592				24.1.2016	27.2.2016	151119			
					31.8.2012	2.9.2012	123682									
		3	Gas Turbine	23.2.1996	13.12.1998	25.12.1998	24230				12.2.2004	4.7.2004	67908			
		T-760	(33.3)		11.11.2007	11.11.2007	89285				9.9.2009	3.4.2010	101839			
											9.8.2013	21.11.2013	129281			
			Steam Turbine	1.5.1999										27.2.2004	6.3.2004	40914
			(54.3)											19.2.2016	4.8.2016	131306
			Boiler (1,2,3)											2.11.2010	18.1.2011	

Fig：Hlawga P/S Periodic Inspection Results

	Date of Implementation	Last Date of Major Overhaul		
		Contractor	Replacement Part	Operating Time at Major Inspection
#1GT	2013.12.5 to 2014.3.12	Wamar Engineering (FRA)	【Combustion】 ・Fuel Nozzles（GE) ・Liner（GE) ・Transition Pieces（GE) 【Turbine】 ・Second Stage Nozzle（MJB） ・Third Stage Nozzle（unknown） ・First Stage Buckets（GE) ・Second stage Buckets（GE) ・Third stage Buckets（GE)	133,364h
#2GT	2016.1.25 to 2016.2.27	GE	【Combustion】 ・AFT Flow Sleeves（GE) ・Forward Flow Sleeves（GE) ・Liner（GE) ・Transition Pieces（GE) 【Rotor】(GE) 【Compressor】 ・Blades（GE) ・Vanes（GE) 【Turbine】 ・First Stage Nozzles（GE upgrade） ・Second Stage Nozzles（GE) ・Third Stage Nozzles（GE upgrade） ・First Stage Buckets（GE) ・Second Stage Buckets（GE) ・Third Stage Buckets（GE upgrade） ・First Stage Shroud（GE upgrade） ・Second Stage Shroud（GE) ・Third Stage Shroud（GE) 【Control Device】Mark5→Mark6e	151,119h
#3GT	2013.8.9 to 2013.11.21	Wamar Engineering (FRA)	【Combustion】 ・Fuel Nozzles（GE) 【Turbine】 ・Second Stage Nozzles（GE) ・First Stage Buckets（GE) ・Second Stage Buckets（GE) ・Third Stage Buckets（GE) ・First Stage Shroud（GE) ・Second Stage Shroud（GE) ・Third Stage Shroud（GE)	129,281h

Fig：Latest Major Inspection Result

d. Status of Equipment

(a) Damage Status

No.	Gas Turbine Common Issues（#1GT, #2GT, #3GT）
1	Oil leakage around GT starter equipment
2	GT casing gas leakage
3	Cable trench top cover damage
4	CO2 fire extinguishing equipment deterioration
5	Intake air filter automatic cleaning equipment failure
6	Instrument malfunction of fuel system (gas flow, pressure)

No.	Gas Turbine Common Issues（#1GT, #2GT, #3GT）
7	GT local instrument malfunction
8	Main transformer local instrument malfunction
9	Main transformer silica gel degradation
10	GT enclosure deterioration


GT Common Issue No.1


GT Common Issue No.2


GT Common Issue No.3


GT Common Issue No.4


GT Common Issue No.5


GT Common Issue No.6

GT Common Issue No.7

GT Common Issue No.8

GT Common Issue No.9

GT Common Issue No.10

No.	HRSG Common Issues　（#1HRSG, #2HRSG, #3HRSG）
1	Blowdown tank corrosion damage
2	Casing overheating and external seizure (insulation deterioration)
3	Expansion joints deterioration
4	Bypass damper seal air fan failure
5	Sampling device and instrument malfunction
6	Drum level meter malfunction
7	Feed water control valve malfunction
8	Pipe and valve insulation deterioration
9	Local instrument, transmitter failure
10	Chemical injection pump leakage, injection pipe clogging

HRSG Common Issue No.1

HRSG Common Issue No.2

HRSG Common Issue No.3

HRSG Common Issue No.4

HRSG Common Issue No.5

HRSG Common Issue No.6

HRSG Common Issue No.7

HRSG Common Issue No.8

HRSG Common Issue No.9

HRSG Common Issue No.10

No.	#1GT Issues
1	Oil pump motor power cable terminal processing defects
2	Exhaust gas duct and expansion joints gas leakage
3	Starter unit and GT base oil leakage
4	Oil supply line around starter unit oil leakage
5	Turbine three-stage wheel space temperature rise
6	Exhaust frame cooling fan malfunction or two unit operation due to filter clogging (usually one unit operation)
7	High lube oil temperature
8	#1 and #2 bearing vibration meter malfunction
9	No.2 frame detector malfunction
10	Governor command problem
11	Other alarms · No. 1 exhaust frame cooling fan low outlet pressure · EOP startup command · Control hydraulic low pressure · Bleed valve position problem

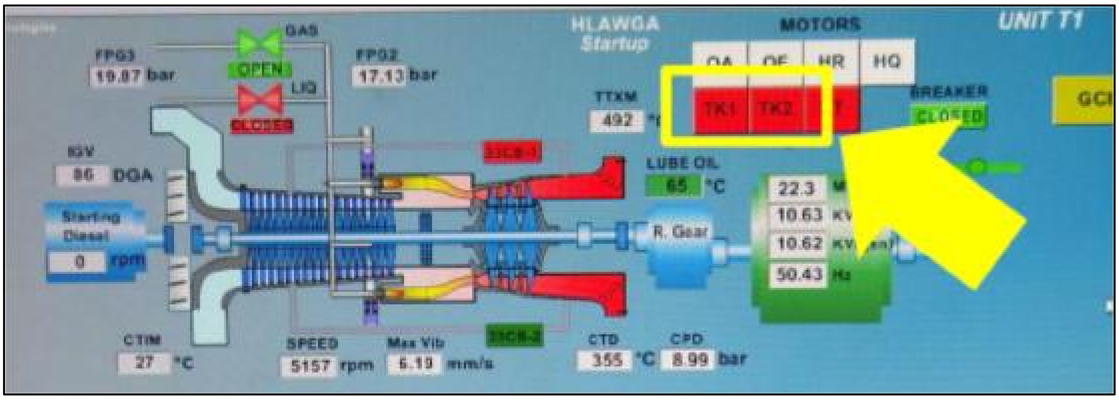
#1GT No.1

#1GT No.2

#1GT No.3

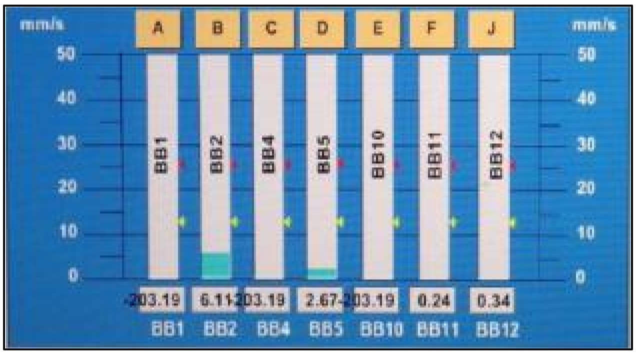
#1GT No.4

#1GT No.5

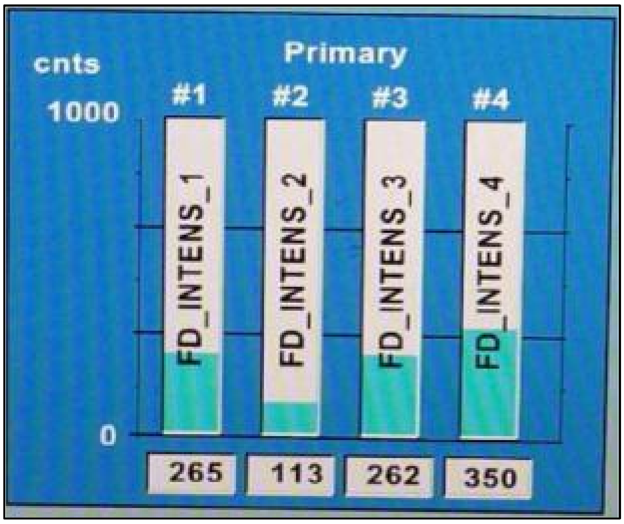


#1GT No.6

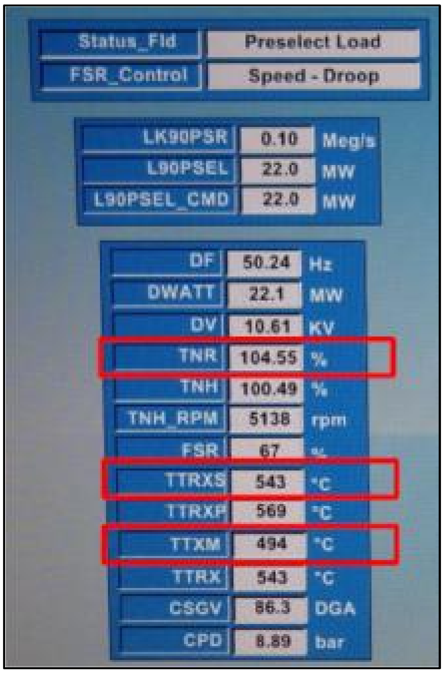
#1GT No.7



#1GT No.8



#1GT No.9

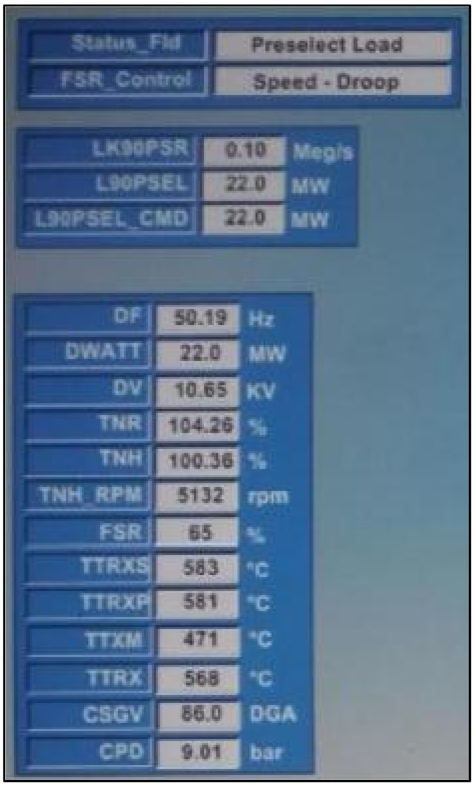


#1GT No.10

No.	#2GT Issues
1	Exhaust gas duct and expansion joints gas leakage
2	Starter unit and GT base oil leakage
3	Governor command problem
4	Other alarms · Inlet filter failure · IGV opening failure · Bleed valve forced open signal

#2GT No.1

#2GT No.2



#2GT No.3

No.	#3GT Issues
1	Fuel gas strainer removed
2	Starter unit parts removed
3	Under inspection due to generator ground fault
4	Dirt around the starter unit due to long-term stoppage

#3GT No.1

#3GT No.2

#3GT No.3

#3GT No.4

No.	#1HRSG Issues
1	Boiler tube leakage
2	SH spray control valve flange leakage
3	Insufficient number of manhole tightening bolts
4	Steam leakage frame drum level gauge flange
5	Economizer vent valve (motor valve) removed

#1HRSG No.1

#1HRSG No.2

#1HRSG No.3

#1HRSG No.4

#1HRSG No.5

No.	#2HRSG Issues
1	Steam leakage from blow valve (manual valve) gland
2	SH spray control valve flange leakage
3	Insufficient number of manhole tightening bolts

#2HRSG No.1

#2HRSG No.2

#2HRSG No.3

No.	#3HRSG Issues (Cannot be confirmed while operation is stopped)
1	HRSG outlet valve/outlet check valve seat leakage (steam reflux from # 1, 2 HRSG)

No.	Steam Turbine Issues
1	Main oil tank exhaust oil separator filter clogging and gas leakage
2	Oil leakage around main oil tank
3	Oil leakage around turbine base
4	Instruments malfunction
5	Oil leakage around generator base
6	Terminal block cover open

ST No.1

ST No.2

ST No.3

ST No.4

ST No.5

ST No.6

No.	BOP Issues
1	A/B vacuum pump coupling cover removed
2	A/B vacuum pump inlet valve (solenoid valve) defect
3	Cooling tower concrete deterioration
4	B cooling tower fan removed due to damaged
5	Oil leakage around condensate pump
6	A/C feed water pump gland leakage
7	B feed water pump coupling disconnected
8	Control air compressor failure (both are stopped)
9	Control air dryer failure (stopped)
10	Chemical injection equipment degradation（NH_3、Na_2SO_3）
11	Fresh water intake pump room submerged


BOP No.1


BOP No.2


BOP No.3


BOP No.4


BOP No.5


BOP No.6


BOP No.7

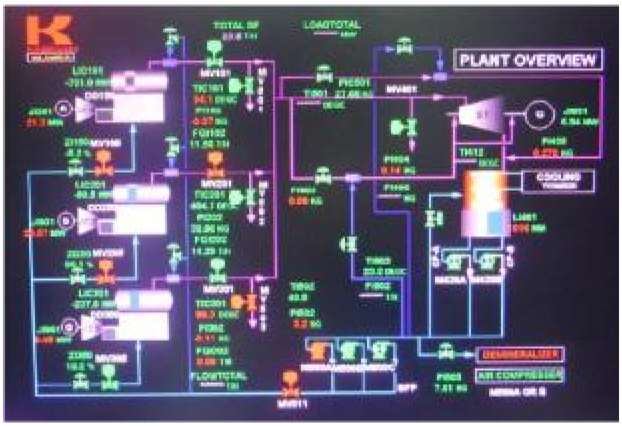
BOP No.8


BOP No.9

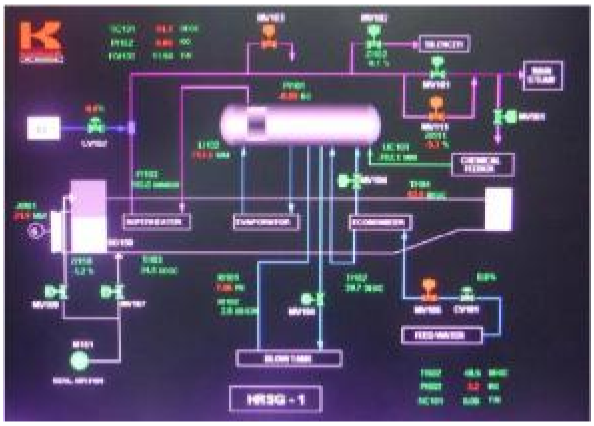

BOP No.10


BOP No.11

No.	Electrical and Instrumentation Issues
1	Many central CRT displays defective (steam turbine) Example) No. 2 GT output (JI 931) ... While 22.0 MW is displayed on the CRT of the GT, 20.57 MW is displayed on the CRT of the ST. No. 3 GT output (JI 961) ... While GT is stopped, 0.05 MW is displayed. Main steam pressure (PI 302) ... No. 3 HRSG is stopped, but -0.11 kg is displayed.
2	Many motor valves and instruments that do not operate properly. The red in the CRT indicates instrument failure.



Electrical and Instrumentation No.1



Electrical and Instrumentation No.2

(b) Simple Diagnosis

Ø Vibration Diagnosis
Vibration measurement is carried out on the steam turbine, etc.

Ø Water Quality Diagnosis
（Hlawga Water Quality Control Method：Phosphate treatment）

ü At Local Site
（Items that are difficult to analyze by taking samples back to Japan were measured with a portable analyzer.）

■Measurement Date：9/03/2018　Measurer：KANSAI Sato, Fujiwara

Item, Criteria / Point	pH	Dissolved Oxygen (Reference)	Electric Conductivity (Reference)
	6.3(Myanmar)	―	≦0.3(KANSAI)
Demineralized Water Equipment Outlet	6.64(29.5℃)	0.47 mg/L	5.90 ms/m(29.6℃)

■Measurement Date：9/03/2018　Measurer：KANSAI Sato, Fujiwara

Item, Criteria / Point	pH	Dissolved Oxygen (Reference)	Electric Conductivity (Reference)
	JIS 9.8~10.7(25℃)	―	JIS ≦40(25℃)
Boiler Water #2HRSG	10.14(38.1℃)	0.30 mg/L	12.18 ms/m(38.1℃)


pH


Dissolved Oxygen


Electric Conductivity

ü In Japan

(Items that are difficult to analyze at the local site were analyzed by taking samples back to Japan.)

■Measurement Date : 12/04/2018 Sampler : KANSAI Sato, MHPS Hiraoka

■Analysis Date : 12/20/2018 Analysis Place : Chemical Room of KANSAI P/S

Item, Criteria / Point	Silica	Chloride Ion	Phosphate Ion	Iron (Reference)	Turbidity (Reference)
	JIS ≦10	JIS ≦10	—	—	—
Boiler Water (#2-HRSG)	3.3 mg/L	4.5 mg/L	0 mg/L	12 μg/L	0 ms/m

Water Quality Management Status (by interview)


Sampling Point

- Since the installed instruments on the pure water apparatus and the boiler water sampling equipment are broken, pH and conductivity are measured manually (portable analyzer).
- The person in charge water quality (expert) is measuring at 9:00 AM on weekdays.
- On Saturdays and Sundays, because the person in charge is off, measurement is not done.
- Water quality management standards refer to the manufacturer manuals at the time of construction; management standards for each power plants are not specified.
- In the manufacturer's manual, there is a chemical injection volume - pH curve, but it is not used in operation.
- If the pH and conductivity deviate from the control range, the chemical concentration is adjusted based on experience, not volume - pH curve of chemical injection curve.
- At present, there are many leaks at the gland of the chemical injection pump to the boiler water supply system, and it is operated limitedly.

u Considerations

- After seeing the measured values, countermeasures were not required immediately, but phosphoric acid injection seemed inappropriate according to the phosphate ion measurement value and the result of interview about water quality control.
- Injection of Na_2SO_3 (Sodium sulfite) may also be inappropriate.
- Dissolved oxygen in feed water at the boiler inlet may be higher than in the boiler water measured at this time.
- The plant uses ammonia for pH adjustment of the boiler feed water, sodium sulfite for oxygen scavenging, and phosphoric acid for pH adjustment of the boiler water, but it is presumed that a high pH is maintained with ammonia, because neither sulfite and phosphate

ions were detected in the water sample.
・It is necessary to investigate whether parts that need attention to corrosion due to high pH are adequately managed.
・Regarding pH, although it tends to be slightly higher, which is within the reference range, there is no turbidity, so it seems that appropriate water treatment is done.

Ø Vibration Diagnosis

Vibration measurement was conducted with the A/C feed water pump and B condensate pump. Some vibrations exceeded the reference values.

Title	Vibration Measurement		
Power Station	Hlawaga		
Object	F6 GTCC A-Feed Water Pump		
Measurer	Hiraoka (MHPS)		
Observer	Ozaki (Kansai)		
Equipment Specification			
Type	Centrifugal Pump	Capacity	48 kgf/cm2
Roating Speed	2980 rpm	Serial Number	RW08432-01 1/3
Current	24.3A	Voltage	6,600V
Manufacturer	EBARA	Made Date	2010
Measurement Result			
Measurement Date		9.1.2018	
Measurement Tool	Type	Portable Vibrometer	
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD	
Pump Bearing (Free Side)	V	20 μm	
	H	50 μm	
	A	37 μm	
Pump Bearing (Coupling Side)	V	35 μm	
	H	70 μm	
	A	20 μm	
Motor Bearing (Coupling Side)	V	15 μm	
	H	15 μm	
	A	14 μm	
Motor Bearing (Free Side)	V	20 μm	
	H	40 μm	
	A	35 μm	

Vibration Reference Value（JIS B 8301): 35μm

Title	Vibration Measurement		
Power Station	Hlawaga		
Object	F6 GTCC C-Feed Water Pump		
Measurer	Hiraoka (MHPS)		
Observer	Ozaki (Kansai)		
Equipment Specification			
Type	Centrifugal Pump	Capacity	48 kgf/cm2
Roating Speed	2980 rpm	Serial Number	RW08432-01 3/3
Current	24.3A	Voltage	6,600V
Manufacturer	EBARA	Made Date	2010
Measurement Result			
Measurement Date		9.1.2018	
Measurement Tool	Type	Portable Vibrometer	
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD	
Pump Bearing (Free Side)	V	15 μm	
	H	35 μm	
	A	25 μm	
Pump Bearing (Coupling Side)	V	25 μm	
	H	40 μm	
	A	30 μm	
Motor Bearing (Coupling Side)	V	30 μm	
	H	60 μm	
	A	20 μm	
Motor Bearing (Free Side)	V	18 μm	
	H	40 μm	
	A	50 μm	

Vibration Reference Value（JIS B 8301): 35μm

Title	Vibration Measurement		
Power Station	Hlawaga		
Object	F6 GTCC B-Condensate Pump		
Measurer	Hiraoka (MHPS)		
Observer	Ozaki (Kansai)		
Equipment Specification			
Type	Centrifugal Pump	Capacity	304 m3/h
Roating Speed	1,485 rpm	Serial Number	1238606/01-3
Current	195A	Voltage	400V
Manufacturer	APOLO	Made Date	1998
Measurement Result			
Measurement Date		9.1.2018	
Measurement Tool	Type	Portable Vibrometer	
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD	
Pump Bearing (Free Side)	V	35 μm	
	H	45 μm	
	A	35 μm	
Pump Bearing (Coupling Side)	V	35 μm	
	H	50 μm	
	A	-	
Motor Bearing (Coupling Side)	V	23 μm	
	H	40 μm	
	A	70 μm	
Motor Bearing (Free Side)	V	30 μm	
	H	60 μm	
	A	55 μm	

bration Reference Value（JIS B 8301): 54μm


Vibration Measurement

Ø Electric Current Diagnosis

Current measurement was carried out with the B condensate pump. No abnormality

Title	Motor Current Meaturement		
Power Station	Hlawaga		
Object	F6 GTCC B-Condensate Pump		
Measurer	Sato (Kansai)		
Observer	Fujiwara (Kansai)		
Motor Specification			
Type	Totally-enclosed Fan-cooled	Capacity	110kW
Number of Poles	4	Serial Number	K11R315S4 TWS
Rotating Speed	1480 rpm	Voltage	400V
Current	195A	Insulation Type	–
Manufacturer	VEM motors	Made Date	1998.5
Measurement Result			
Measurement Date		9.1.2018	
Measurement Tool	Type	HIOKI 3285	
	Serial Number	80523503	
	Calibration Date	2009.8	
Phase Current	A	169.8 A	
	B	164.8 A	
	C	165.1 A	

Current Measurement

Ø Insulation Resistance Diagnosis

Insulation resistance measurement was carried out with the # 3 GT lubricating oil cooler fan (No. 2, No. 3). It was confirmed that the insulation of the No.3 fan was deteriorated.

Title	Insulation Resistance Mearurement of Low Voltage Motor		
Power Station	Hlawaga		
Object	#3GT FIN FAN Cooler #2		
Measurer	Sato (Kansai)		
Observer	Fujiwara (Kansai)		
Motor Specification			
Type	AF1S 180 LS V5	Capacity	11 kW
Number of Poles	8	Serial Number	704211 02FB16
Rotating Speed	724 rpm	Voltage	400V
Current	27A	Insulation Type	F
Manufacturer	unknown	Made Date	unknown
Measurement Result			
Measurement Date		9.3.2018	
Measurement Tool	Type	Insulation Resistance Measuring Device 500V Type	
	Serial Number (Model)	YOKOGAWA MY40-01	
	Calibration Date	2017.8	
Condition	Weather	Cloudy after Rain	
	Temperature (℃)	27.3℃	
	Humidity (%)	51%	
Insulation Resistance	MΩ	4.95 MΩ	
		Reference Value: more than 1MΩ	

Title	Insulation Resistance Mearurement of Low Voltage Motor		
Power Station	Hlawaga		
Object	#3GT FIN FAN Cooler #3		
Measurer	Sato (Kansai)		
Observer	Fujiwara (Kansai)		
Motor Specification			
Type	Totally-enclosed Fan-cooled	Capacity	7.5kW
Number of Poles	8	Serial Number	K11R315S4 TWS
Rotating Speed	720 rpm	Voltage	400V
Current	16.6A	Insulation Type	F
Manufacturer	ELECTROMO	Made Date	–
Measurement Result			
Measurement Date		9.3.2018	
Measurement Tool	Type	Insulation Resistance Measuring Device 500V Type	
	Serial Number (Model)	YOKOGAWA MY40-01	
	Calibration Date	2017.8	
Condition	Weather	Cloudy after Rain	
	Temperature (℃)	27.3℃	
	Humidity (%)	51%	
Insulation Resistance	MΩ	0.026 MΩ	
		Reference Value: more than 1MΩ	

Insulation Resistance Measurement

Ø Lube Oil Diagnosis
Steam turbine and gas turbine lube oil were collected and taken back to Japan for analysis.

■Sampling Date：12/04/2018 Sampler：KANSAI Sato, MHPS Hiraoka
■Analysis Date： Analysis company：Kanden Engineering

Manufacture of Lube Oil：Michang (Korea)-TURBINE OIL VG46

Item	Unit	Reference Value		Analysis Result	Evaluation
		Value	Exhibition		
Acid Number	mgKOH/g	≦0.3	JIS K2213	0.08	ü
RPVOT(RBOT)	min	100	General Reference Value	410	ü
Kinematic Viscosity	$mm^2/s(40℃)$	41.4～50.6	JIS K2213	47.22	ü
Moisture	%	≦0.1	ASTM 4378-01	0.0041	ü
Sludge Content	Mg/100ml	≦10	General Reference Value	0.3 （mesh0.8μm）	ü

ü：The analysis results met the reference values and no degradation was observed.

The reference value is set within ± 10% of the ISO VG46 standard value of 46 mm^2 / s in JIS 2213.

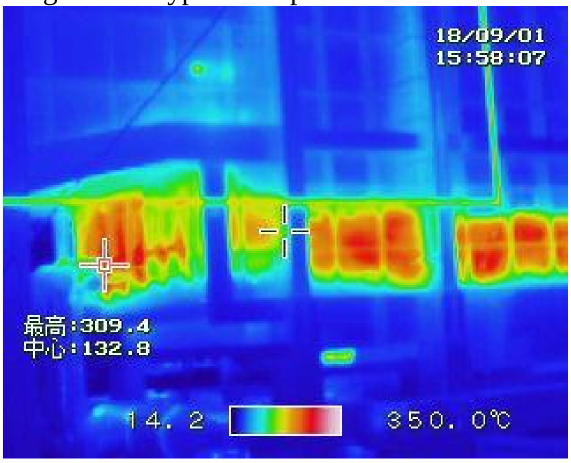
Lube Oil Sampling
Sampling Point：Lube oil strainer blow line

◆Considerations
All other items were within the reference values, therefore it was considered that there was no decline in lubricating oil performance.

Ø Leakage Location Diagnosis

Surveys such as gas leakage, steam leakage, overheating, etc. of equipment (GT, HRSG) during operation were conducted using a thermal camera.

Overheating of the HRSG casing and gas leakage of the bypass damper were found.



HRSG Casing Overheating（#1HRSG, #2HRSG）

HRSG Bypass Stack Overheating due to Damper Gas leakage（#1HRSG, #2HRSG）

Leakage Diagnosis by Thermal Camera

Gas leakage diagnosis of NG station was carried out using a portable gas detector.
Gas leakage at the strainer inlet/outlet flange was found.


Strainer Inlet/Outlet Flange Gas Leakage


Gas Leakage Check

※The flange was not tightened by bolts; it was isolated with front and rear valves.
(Sheet leakage of front valve or rear valve)

- Unit Performance Diagnosis

The thermal efficiency of a Combined Cycle Power Plant is theoretically calculated as follows.

$$\eta C = \eta G + (1 - \eta G) * \eta B * \eta S \quad \cdots \text{Equation A}$$

The definition of each variable and the calculation are as follows.

ηC：Thermal Efficiency of CCGT

$$= \frac{3600}{\frac{\text{NG } heating\ value \text{ LHV[kJ/kg]} \times Total \text{ NG } flow\ rate \text{ [kg/h]}}{Total \text{ GT } output\text{[kW]} + \text{ST}output\text{[kW]}}}$$

(*)Equation A does not consider some losses (GT-HRSG duct loss, HRSG-ST steam pipe loss). Therefore, thermal efficiency of CCGT calculated by the above equation is likely more accurate than Equation A.

ηG：Thermal Efficiency of Gas Turbine

$$= \frac{3600}{\frac{\text{NG } heating\ value \text{ LHV[kJ/kg]} \times \text{NG } flow\ rate\text{[kg/h]}}{\text{GT } output\text{[kW]}}}$$

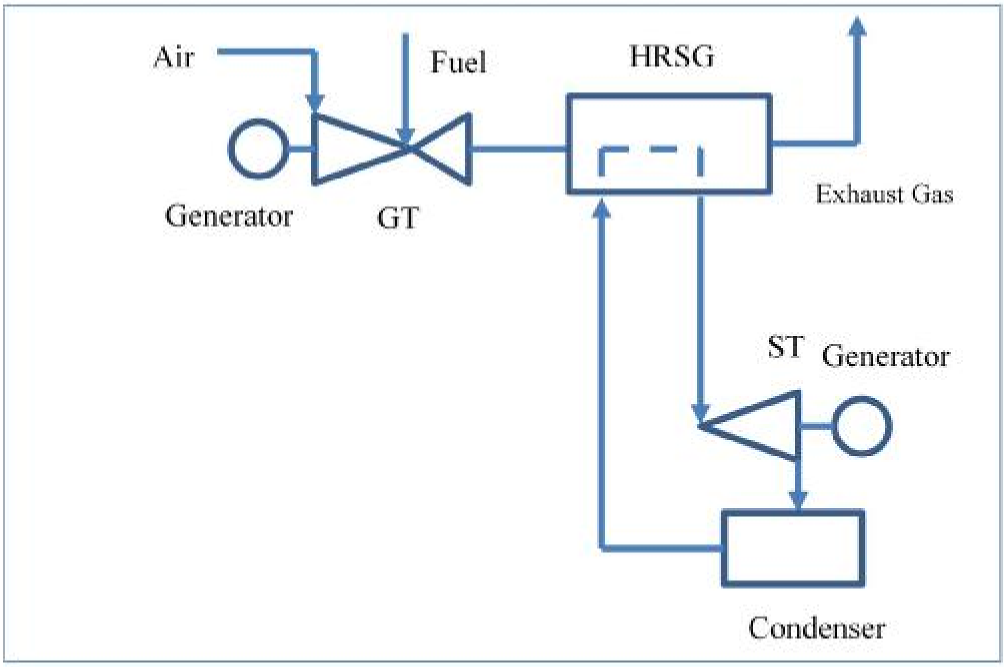
ηB：Thermal Efficiency of Boiler (HRSG)

$$= \left(1 - \frac{Heat\ loss}{Heat\ input}\right) \times \mathbf{100}$$

$$= \left(1 - \frac{(HRSG\ outlet\ h\text{[kJ/kg]} - Atmosphere\ h[kJ/kg]) \times Exhaust\ gas\ flow\ rate[kg/h] \times Constant\ pressure\ specific\ heat[kJ/kg \cdot K]}{(HRSG\ inlet\text{[kJ/kg]} - Atmosphere\ h[kJ/kg]) \times Exhaust\ gas\ flow\ rate[kg/h] \times Constant\ pressure\ specific\ heat[kJ/kg \cdot K]}\right) \times \mathbf{100}$$

ηS：Thermal Efficiency of Steam Turbine

$$= \frac{3600}{\frac{(\text{ST } inlet\ h\text{[kJ/kg]} - \text{ST } outlet\ h[kJ/kg]) \times Steamflow\ rate[kg/h]}{ST\ output\text{[kW]}}}$$



The result of the site survey is as follows. The condition is LHV, gross basis (output, efficiency, Yadana gas).

※Because it was the rainy season, the plant was under partial load operation and performance evaluation was not possible. (The following shows the values at partial load.)

Item		Design	Measurement Data (2017.2)		Measurement Data (2018.9.3)	
Operation Mode		Full Load	Partial Load		Partial Load	
		3-3-1	2-2-1		#1GT:Simple #2GT:1-1-1	
Ambient Temperature		30℃	30℃		30℃	
Output	gross	157MW	75MW		50MW	
	net	154MW	-		-	
Efficiency	gross	46.3%	32.8%		24.7%	
	net	45.5%	-		-	
Unit			#1	#2	#1	#2
GT Output		35.0MW/unit	26.7MW	27.0MW	21.8MW	21.6MW
ST Output		51.9MW	21.3MW		6.9MW	
GT Efficiency		31.0%	23.2%	23.7%	18.8%	19.6%
HRSG Efficiency		74.3%	61.5%	58.0%	-	-
ST Efficiency		30.8%	26.7%		19.1%	
Fuel Consumption		43.35t/h	14.72t/h	14.53t/h	14.91t/h	14.13t/h

2018.9.3 #1GT : Partial load operation (Dispatching)
#2GT : Partial load operation (Dispatching)
#3GT : Stopped due to GEN grand fault
ST : Normal operation

#1HRSG : Stopped due to tube leakage
#2HRSG : Normal operation
#3HRSG : Stopped due to GT problem

(4) Predictive Maintenance

a. Control Status of Records

- Various data are recorded and managed in the log sheet.

b. Accumulation and Analysis of Operation Data

- Operation data is compared with the reference values to check for problems, but data is not accumulated or analyzed.
- Operation data, various records, etc. are stored on a bookshelf, etc., but they do seem not to be utilized.

Storage Conditions of Recorded Data

c. Past Performance of Predictive Maintenance Based on Data Analysis

- None

d. Remarks

- Since no surveillance cameras have been installed, it is requested to introduce them for safety management.
- Rehabilitation situation

  The #2 GT was already upgraded and, at the same time, the Mark VIe was upgraded.
  A local company (Golden Green Energy) plans to implement #3 GT Generator repair.
  The rewinding of the rotor is scheduled in Dubai.
  At the same time, it is planned to upgrade the #3 GT and Mark VIe. Construction is scheduled to start in 2018.
  HRSG tube bundle replacement is scheduled for March and April 2019. Parts for 6 rows have been purchased from GE. (Original manufacture is Kawasaki.)
  Other rehabilitation is under consideration by GGE and EPGE.
- Tubes for the HRSG economizer were replaced in 2010 and 2011.
- Even in the #1 GT, a generator ground fault occurred in 2016. Restoration work was carried out utilizing the generator rotor stored at the Ahlone power station. The removed rotor is left on site. (No rust prevention treatment)
- Also, in the #3 GT, a ground fault accident occurred in 2006. At that time, only the end wires were replaced at the local site.
- The output and gas consumption of each thermal power plant in Yangon are summarized at the Hlawga power station every day at 6 am and reported to the EPGE head office from Hlawga. (The reason is unknown.)

Appendix 3

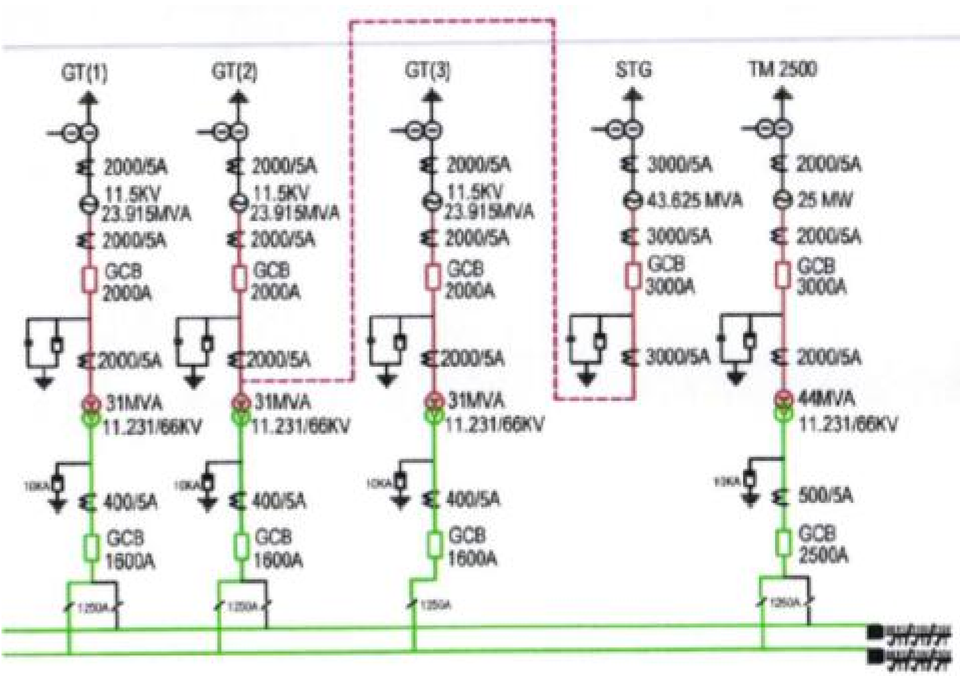
Thaketa Power Station Survey Results

■Thaketa　(Site Survey 2018.8.27～8.28、2018.11.30、12.3)

(1) O&M System Survey

a. Outline of Facility

Location (Address)		9, Ward, Ayayarwon Road, Thaketa Power Station, Thaketa, Yangon, Myanmar
Configuration		3-3-1 CCGT
EPC		Marubeni- Kawasaki (GT&GEN [Hitachi, ST [Fuji], HRSG [Kawasaki])
GT	Model	Frame5 (PG5361)
	Output	23.915 MW
	COD	1990
ST	Model	Fuji Electric Single Casing Condensing
	Output	34.9 MW
	COD	1997
Power Plant Output		92 MW　(3on1 CCGT)
Fuel		NG（Zawtika, Yadana Gas）
Connection to Transmission Line		Connect to Thaketa S/S（66kV⇒230kV）



Fig：　Thaketa P/S Single Line Diagram

Equipment Specifications

Gas Turbine		
Gas Turbine	Manufacture：	GE
	Model：	Frame5 (PG5361)
	Rotating Speed：	5,100 rpm
Generator	Model：	FEZBiL
	Output：	23915 kVA
	Power Factor：	0.8
	Rotating Speed：	3,000 rpm
	Voltage：	11.5 kV

HRSG	
Number of HRSG：	3
Model ：	Kawasaki-Vogt natural circulation
GT Fuel：	Zawtika Gas
Steam Flow：	44.05 ton/h
Steam Pressure：	52.0 kg/cm^2
Steam Temperature：	470 ℃
Feed Water Temperature：	56.5℃
Bypass Stack ：	Available

Steam Turbine		
Steam Turbine	Manufacture：	Fuji Electric
	Output：	34.9 MW
	Rotating Speed：	3,000 rpm
Generator	Model：	FTLR1484/55-2
	Output：	43,625 kVA
	Power Factor：	0.8
	Frequency：	50 Hz
	Rotating Speed：	3,000 rpm
	Voltage：	11.5 kV

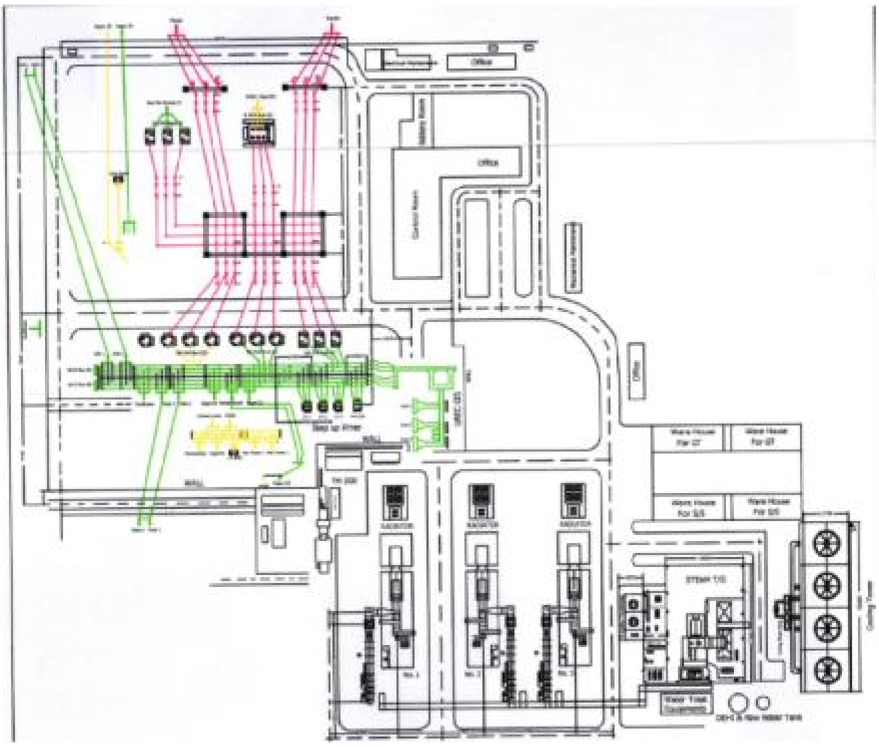
Main Transformer	
Manufacture：	GT:Hitachi / ST:EKARAT-DAIHEN
Model：	Three Phase Power Transformer
Output：	GT: 31 MVA / ST:44MVA
Voltage：	11 kV/66 kV
Cooling Type：	GT: ONAN / ST: ONAF

Condenser	
Manufacture：	HOLTEC ITERNATIONAL
Model：	Shell and Tube Type
Steam Flow：	131.72 t/h
Cooling Water Flow Rate：	9750 m^3/hr

Waste Water Treatment
Processing Capacity：120 m^3/day
Type：Reverse Osmosis
Chemical：Chlorine Treatment (NaOCl),PH Control (Na3PO4, NH4OH), Antioxidant （Na2SO4)
Designed Demineralized Water：Conductivity Less than 10 μS/cm, Silica Less than0.5 ppm

b. Layout

There is no chemical analysis room at the power station to conduct water quality, lubricant, control oil, or fuel management.

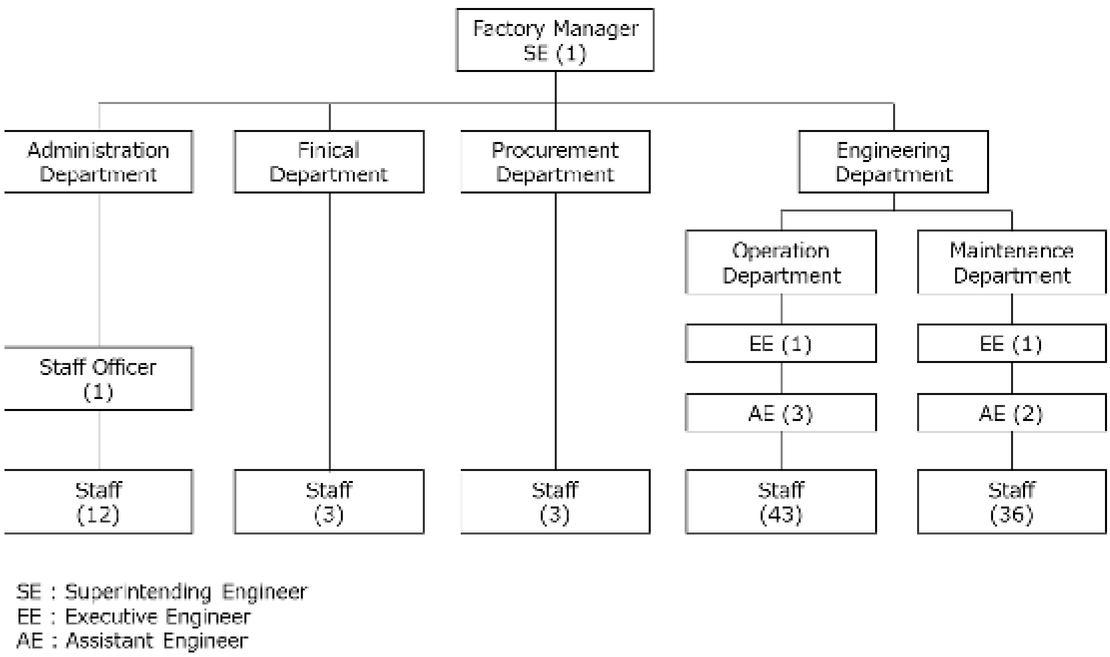


Fig：Thaketa P/S Layout

c. Power Station Management and Education System

According to interview at the site survey, the plant is staffed by 160 people. But, the organization chart received at the site survey states 107 people. Because there are day workers, it seems that there are members other than those listed in the organization chart.

Education of new employees is carried out at the Pounloung training center.



Fig：Organization Chart

d. Regulations and Manuals of Power Plant O&M

- Rules are hardly documented.
- Maintenance manuals of the manufacturers, etc. are used.

e. Parts Procurement Procedure

Necessary parts less than 200USD can be procured under the authority of the power station manager. It is necessary to get approval for procurements of 200USD or more.

(2) Daily Operation

a. Operation System

- 2-shift, 4-team system. There are 8 to 9 person per shift.
- Handover using the Operation Logbook.
- Operators check operation data such as the power generation and vibration every hour.
- During the rainy season, the peak operation is carried out. It has not been operated after stopping in early August.

b. Quantitative Records Related to Power Generation

- Daily inspection records are collected by hand.
- Daily reports, weekly reports, monthly reports, and annual reports are submitted to EPGE.
- Although a fuel meter is installed, the accuracy is low and the thermal efficiency cannot be managed.
- The power plant demanded the installation of a new fuel meter, but it was not approved by EPGE.


Operation Record (Generator, Switchyard)

c. Record of the Implementation Status of O&M

When major troubles are repaired, power station members make a report on each occasion and report it to EPGE.

d. Spare Parts Management

- Spare parts are organized with inventory cards in the warehouse.
- It is shared with other CCGT power plants, and the installation and use of spare parts is decided by EPGE.
- Operation time and serial management is not conducted for removed items.
- It seems that EPGE has repaired old goods and made bidding for repair work irregularly.
- A new HGPP (4 inner tail cylinders) is stored in the warehouse, but it is unusable due to the upgrade.

Spare Parts Warehouse

Rotor Blade (Unused)

e. Actions against Events/Abnormalities and Records Management

- When a problem occurs, the operator verbally informs the maintenance staff and the maintenance staff repairs it by themselves.
- When power generation needs to stop for more than one day, it is necessary to get permission from EPGE.

f. Environment Management

- Exhaust gas is not monitored or managed.

g. Entry Management

- People entering the power station check in at the guard room and receive an entry card.

(3) Periodic Maintenance

a. Maintenance Plan Management (Contents, Cycle, Budget, etc.)

- The power station procures necessary tools and keeps them on site.
- Regarding heavy equipment such as cranes, EPGE possesses some. If not enough, EPGE borrows equipment from other ministries and deals with it.

b. Implementation Status, Frequency, and Method of Periodic Maintenance

- CI is carried out only by Thaketa power station members.
- HGPI is carried out by Thaketa power station members and approximately 20 other power plant members.
- There is no dispatch of TA from the manufacturer.
- The frequency of implementation is as recommended by the manufacturer.
- There is no maintenance standard for hot gas parts; EPGE judges whether repair is necessary or not.
- Parts are purchased from UNOG (United National Oil & Gas Co., Ltd) or IGE in Myanmar.
- Sometimes, third party (Chrom Alloy United) products are used for the first stage rotor blade.
- Whether to adopt a third party is decided by EPGE (or higher level organization).

c. Initiatives for Continuous Improvement

- Rehabilitation projects are basically coordinated and determined by the EPGE head office and OEM. Detailed information comes down to the power station after decision.
- Operating time is as follows, however some of the instruments were broken, so accurate records could not be confirmed.

Table : Thaketa Power Station Accumulated Operation Time (As of 8/27/2018)

	Total S/S	Fired Start	Fast Load Start	Manual Initiated Start	Peak Fired Time	Fired Time
Unit 1	3135	2624	250 (Malfunction ?)	2478	1 (Malfunction ?)	54670
Unit 2	3628	2721	26 (Malfunction ?)	2473	6 (Malfunction ?)	31306
Unit 3	2942	2374	13 (Malfunction ?)	2620	68947	71808

Control and Operation Panel

Operation Data Counter

d. **Status of Equipment**
(a) Damage Status

No.	Gas Turbine Common Issues（#1GT, #2GT, #3GT）
1	Intake air filter deterioration
2	Instrument malfunction of fuel system (flow meter)
3	Oil leakage around GT starter equipment
4	Gas leakage at gas station

GT Common Issue No.1

GT Common Issue No.2

GT Common Issue No.3

GT Common Issue No.4

No.	HRSG Common Issues（#1HRSG, #2HRSG, #3HRSG）
1	Sampling device malfunction
2	Instrument malfunction
3	Insufficient number of manhole tightening bolts
4	Pipe thermal insulation deterioration
5	Blowdown tank deterioration
6	Drum level meter malfunction
7	Feed water control and motor valve malfunction
8	Casing overheating and external seizure (insulation deterioration)


HRSG Common Issue No.1


HRSG Common Issue No.2


HRSG Common Issue No.3


HRSG Common Issue No.4


HRSG Common Issue No.5


HRSG Common Issue No.6

HRSG Common Issue No.7

HRSG Common Issue No.8

No.	#2GT, HRSG
1	Cooling water pump removed
2	GT intake filter inlet door deterioration
3	Start-up motor removed

#2GT, HRSG No.1

#2GT, HRSG No.2

#2GT, HRSG No.3

No.	#3GT
1	GT intake filter inlet door deterioration
2	Gas flow control valve gas leakage

#3GT No.1

#3GT No.2

No.	ST
1	Inadequate storage condition after pulling out the generator rotor
2	Inadequate storage condition after pulling out the turbine rotor
3	Turbine shaft sealing part deterioration
4	Feed water instrument deterioration

ST No.1

ST No.2

ST No.3

ST No.4

No.	BOP
1	Control air compressor malfunction
2	Feed water pump deterioration
3	B cooling tower fan removed due to malfunction
4	Cooling tower deterioration
5	Demineralized water equipment control panel malfunction

BOP No.1

BOP No.2

BOP No.3

BOP No.4

BOP No.5

(b) Simple Diagnosis

- Since both the GT and ST were stopped during the first site survey, simple diagnosis was not carried out.
- Gas leakage inspection was carried out at the gas station, and there was a lot of gas leakage at the strainer lid, etc.

(4) Predictive Maintenance

a. Control Status of Records

- Operation and maintenance records are kept mainly on a paper basis, but there are also records that were lost in the 2008 cyclone.
- Regarding operation data, MW and gas consumption are sometimes converted into soft data and stored.

b. Accumulation and Analysis of Operation Data

- Operation data is not accumulated or analyzed.

c. Past Performance of Predictive Maintenance Based on Data Analysis

- None

d. Remarks

- The installation of a thermal imager and handy vibration monitor is desired.
- CCTVs are installed only for substation monitoring. It is requested to install more for monitoring the GT and main gate.
- Because the ST and HRSG are under suspended operation, efficiency is expected to be low, so it is necessary to consider the need of rehabilitation.
- The gas turbine is planned to be rehabilitated by JICA and is scheduled for construction in January 2019.
- Because the ST was not included in the rehabilitation program (due to budget shortage), the ST has been damaged and remains unrepaired.
- Maintenance of the HRSG is carried out every month.
- Unit 2 cannot operate due to heavy IGV damage (occurred at 11.15, 2018), but because rehabilitation by JICA (Marubeni / GE / MHPS) is planned, no repair work has been carried out.
- The contents of rehabilitation will include upgrade (rotor replacement) of the GT and a major overhaul on the generator.
- Control equipment will also be updated and changed from Mark II to Mark V-e.
- Since the bypass door opens with the differential pressure at the time of operation of the intake air filter, remodeling from the pulse filter to the stage filter was carried out by themselves.
  *The cause of the differential pressure is waste not dropping even if a pulse is blown, which seems to be due to dust being blocked by moisture.
- It is reported that EPGE made UNOG do a site survey in order to supply parts at the previous regular major inspection.
- The Unit 2 start-up diesel engine and other auxiliary equipment were sent to the Myanaungra power station where under operation.
  * Because there was a problem with the start-up diesel engine at the Myanaungra power station.
- The compressor of Unit 2 was confirmed to be heavily damaged in the major inspection of 2010. At that time, the rotor was transported to France (probably GE's plant) and the rotor removed from the Myanaungra power station was installed at the Thaketa power station.
- After the repair, the rotor was returned to the Thaketa power station again, but after that, it was necessary to change the rotor at the Kyunchaung power station, which was replaced with a damaged rotor.
  * Therefore, the damaged rotor removed from the Kyunchaung power station is stored at the Thaketa power station.
- (It seems that something broke in the turbine 2 stage. It is already in a rusted and unusable state.)
- Gas can only be used for 2 units (14.5 m^3/day). High calorific Zawtika Gas is used from an IPP. EPGE uses low calorific Yadana Gas.

Appendix 4

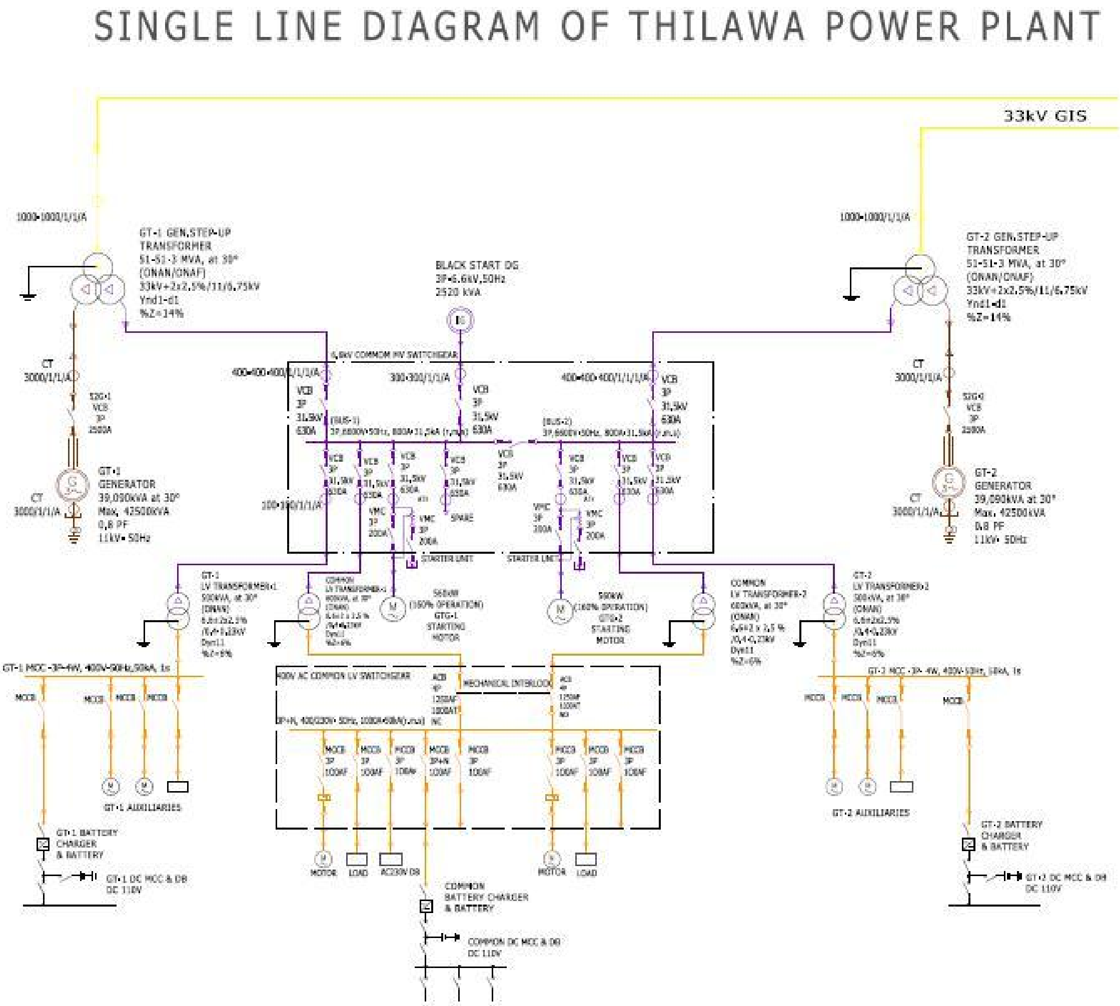
Thilawa Power Station Survey Results

■Thilawa（First Site Survey：2018.9.7～9.8、Second Site Survey：2018.12.14）

（1）O&M System Survey

a. Outline of Facility

Location		Kyaunktan Township, Yangon, Myanmar
Configuration		GT×2 Simple Cycle
EPC	GT	Sumitomo- MHPS
GT	Model	H-25 (Hitachi)　32C
	Output	30.27 MW
	COD	5.25,2016　8.23,2016
Power Plant Output		60.54 MW　(GT×2)
Fuel		NG（Yadana Gas　・Zawtika Gas） Light distilled oil
Connection to Transmission Line		Connect to Thilawa S/S（33 kV）



Fig：Thilawa P/S Single Line Diagram

Equipment Specification

Gas Turbine		
Model：	H-25 C32（Hitachi） (Air Temperature 30℃)	
	Designed Output：	30,270 kW
	Designed Heat Rate：	11,492 kJ/kWh
	Designed Heat Consumption：	347,863 MJ/h
	Designed Exhaust Gas Flow：	93.3 kg/s
Gas Turbine	Type：	Heavy Duty Type / Single Shaft
	Stage：	3 Stage
	Turbine Inlet Temperature：	1,300℃
	Turbine Outlet Temperature：	572℃
	Rotating Speed：	7,258 rpm
Combustor	Type：	Standard Diffusion Dual Combustor (Cannular Type)
	Number：	10
Compressor	Stage：	17 Stage
	Outlet Pressure：	15.64 ata
Generator	Type：	DG215ZC-04 (BRUSH) 39.09 MVA－1500 rpm, 11 kV

Waste Water Treatment	
Capacity：	480 m^3/day
Type：	Reverse Osmosis Continuous Electrical Deionization
Designed Demineralized Water：	TDS 2.0 mg/L pH 7～8.5 Conductivity 10 μS/cm or less

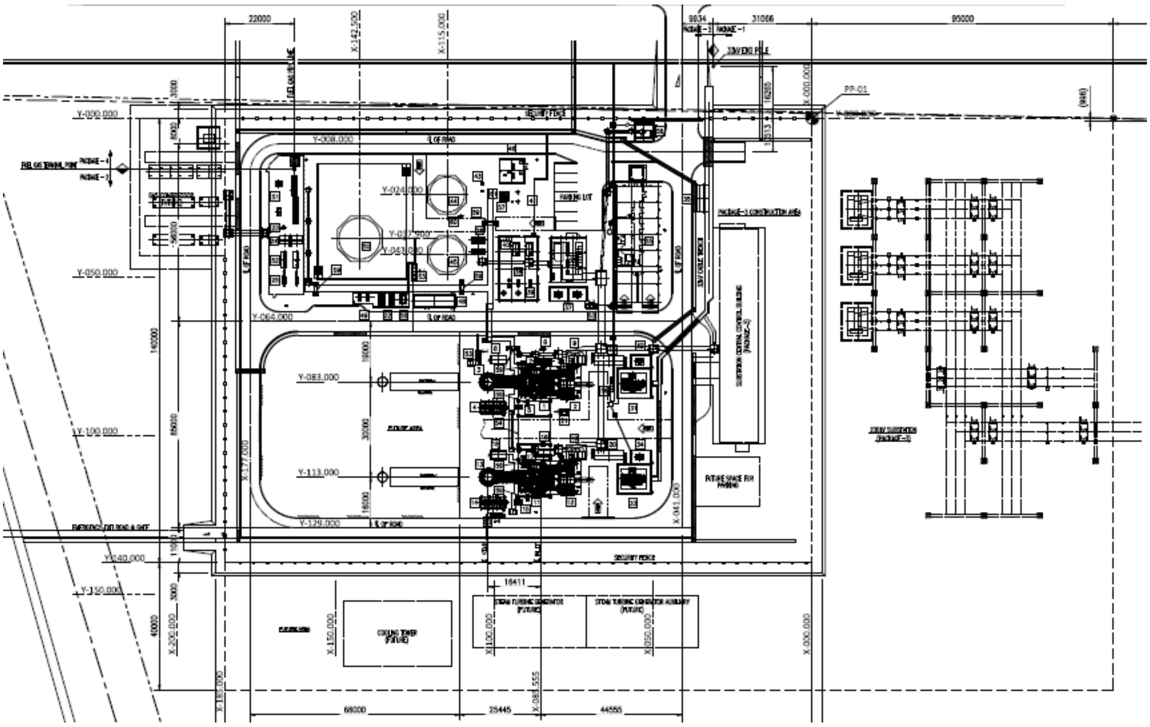
燃料設備		
1)Fuel Gas Methane	:	69.8801 mol%
（Yadana Gas）	Ethane :	1.0106 mol%
	Propane :	0.1694 mol%
	i-Butane :	0.0184 mol%
	n-Butane :	0.0279 mol%
	i-Pentane：	0.0065 mol%
	n-Pentane：	0.0037 mol%
	Neo-Pentane：	0.0214 mol%
	Hexane and Heavier：	0.0211 mol%
	CO2：	4.1294 mol%
	N2：	24.727 mol%
	H2S：	0.0021 mol%
	H2O：	0.0011 mol%
（Zawtika Gas）		
	Methane：	91.786 mol%
	Ethane：	0.401 mol%
	Propane：	0.111 mol%
	i-Butane：	0.035 mol%
	n-Butane：	0.021 mol%
	i-Pentane：	0.01 mol%
	n-Pentane：	0.007 mol%
	Hexane and Heavier：	0.031 mol%
	N2：	7.531 mol%
2) Gas Delivery Condition		
Gas Station	High Temperature：	45℃

Low Temperature：	15℃
High Pressure：	25 barg
Low Pressure：	22 barg
Max Flow Rate：	12,939 kg/h (Yadana) 8,381 kg/h (Zawtica)

b. Layout

・There is no chemical analysis room at the power station to conduct water quality, lubricant, control oil, or fuel management.

・Since well water contains salt, rainwater is stored in the fuel oil tank yard in the rainy season and used as fresh water. Since pure water is used when carrying out compressor water cleaning and combustor water spraying, the frequency of using a pure water system is about once every three months.



Fig：Thilawa P/S Layout

Demineralized Water System

Fuel Tank Yard Storing Rain Water

c. Power Station Management and Education System

・Under the plant manager (superintendent engineer), the number of staff is 92.

・The shift system will be changed from one shift a day to two shifts a day when the dormitories being built next to the power plant are completed.

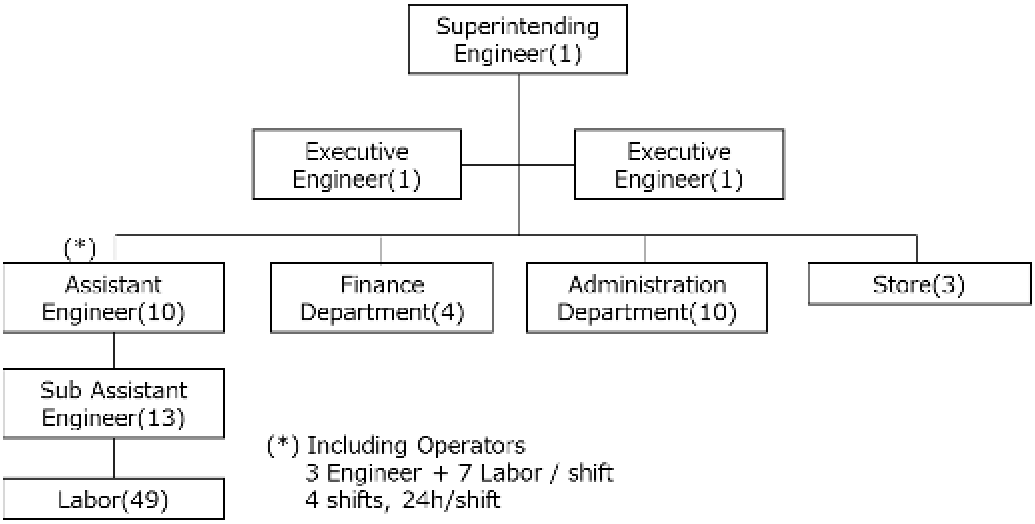


Fig : Organization Chart

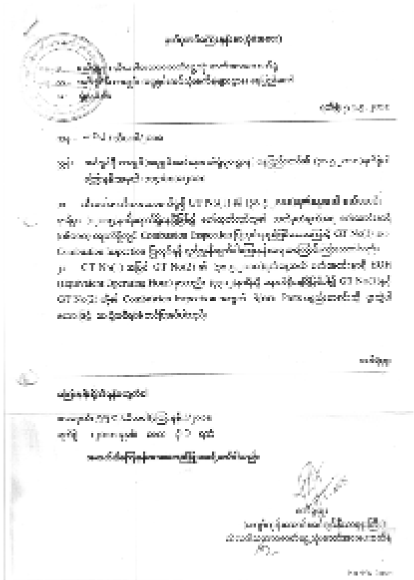
d. Regulations and Manuals of Power Plant O&M

・Regarding the start / stop procedures and operation control values of the units, the maintenance manuals of manufacturers are used.

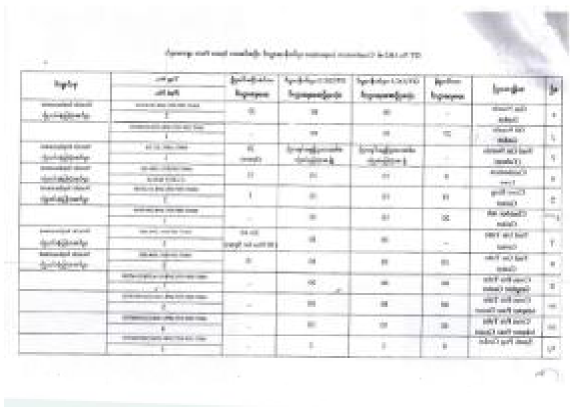
e. Parts Procurement Procedure

・The power plant does not have the right to make procurement decisions.

・The power plant requests EPGE to procure materials.



Request Letter of Part Procurement (1/2)



Request Letter of Part Procurement (2/2)

(2) Daily Operation

a. Operation System

・1-shift 4-team system. There are 10 persons per shift.

・The senior shift engineer performs inspection three times a day, the Junior shift engineer performs inspection four times a day, and other operators perform inspection every hour.

・The operator collects operation data.

b. Quantitative Records Related to Power Generation

・For each unit, various parameters such as generator output, fuel consumption, exhaust gas temperature, etc. are recorded every hour and summarized on a daily basis. And, cumulative operation time and thermal efficiency are managed. The Log Sheet is divided into data collected from the control room (control panel, DCS) and data collected from local instruments. A part of the recording table prepared by the manufacturer (MHPS) is used. The amount of gas consumed (total power station usage) is checked by telephone.

・There are two types of Operation Log Book. One is for hourly data recording, and the other is for takeover.

Quantitative Records

c. Records of the Implementation Status of O&M

・Daily operation data and maintenance results are recorded by hand in the logbook. And. the monthly operation data is reported to EPGE.

・There are two types of logbook: Mechanical and Electrical. Although the content of work is described in the Mechanical logbook, no detailed information on trouble is described. The events related to electrical events are dealt with in the following flow.
Failure occurrence → Cause investigation or contact Sumitomo Corporation → Repair (support by MHPS or Allos Copco (Air Compressor), etc. is arranged) → Describe the contents of repairs in the logbook

d. Spare Parts Management

・Five years' worth of spare parts for 2 units are stored in the warehouse.

・There is no spare parts list of the power plant's own, and records are kept on the 5-year spare parts list created by OEM.

・Because of the change in fuel from Zawtica to Yadana in two years' time, the existing combustor nozzle will not be usable.

・A budget of 5.1 million yen has been allocated.

・Space is insufficient because spare parts, consumables and work tools are stored in the same warehouse.

e. Actions against Events/Abnormalities and Records Management

・When a problem occurs (accident), the operator reports to the plant manager, and the plant manager checks the conditions and reports to EPGE and LDC.

・The content of the problem is recorded in the logbook.

f. Environment Management

・MJTD (Myanmar Japan Thilawa Development) and Nippon Koei conducted environmental measurements during construction, but no environmental management is currently implemented.

・Water sprays for NOx reduction are not usually used.

g. Entry Management

・People entering the power station will check in at the guard room, sign a check list, and receive a security card. There is no auto entry management system.

・The premises are surrounded by a fence, and CCTVs are installed in 13 locations and monitored from the central control room.

Security Card

Thilawa P/S Guard Room

CCTV Monitor

（3）Periodic Maintenance

a. Maintenance Plan Management (Contents, Cycle, Budget, etc.)

・Regular maintenance items are determined by EPGE.

・The duration of regular inspections is determined by the power station and reported to LDC.

b. Implementation Status, Frequency, and Method of Periodic Maintenance

・Although regular inspections of the GT have not been implemented yet, the No.1 GT has exceeded the cumulative operation time recommended for periodic inspections and is currently being prepared for the inspection.

・Necessary parts will be selected based on OMM and requested to EPGE by letter and procured by EPGE.

c. Initiatives for Continuous Improvement

・Although the power plant currently has general tools, tools can be borrowed from other power plants as needed.

d. Status of Equipment

(a) Damage Status

No.	Gas Turbine Common Issues（#1GT, #2GT）
1	#1,2 GT first bearing cooling fan intake filter dirt
2	#1,2 GT lube oil cooling system intake section fin dirt
3	#1,2 GT cable penetration water seal of control compartment deterioration
4	#1 GT submersion of cables in the pit


Gas Turbine Common Issue No.1


Gas Turbine Common Issue No.2


Gas Turbine Common Issue No.3


Gas Turbine Common Issue No.4

No.	BOP Issues
1	Paint peeling off major transformers firefighting water piping
2	Gas station condenser tank manhole bolt corrosion
3	Outdoor storage of spare cable, etc.


BOP No.1


BOP No.2

BOP No.3

(b) Simple Diagnosis

- Vibration Diagnosis

  Vibration measurements were conducted with the #1 GT No.1 Main Oil Pump and the #2 GT No.2 Main Oil Pump. No abnormality.

  Reference Value：35 mm/s

Title	Vibration Measurement
Power Station	Thilawa
Object	#2GT No.2 Main Oil Pump
Measurer	Hiraoka (MHPS)
Observer	Ozaki (Kansai)

Equipment Specification

Type	Centrifugal Pump	Capacity	120 m3/h
Roating Speed	2900 rpm	Serial Number	-
Current	76 A	Voltage	400 V
Manufacturer	ALLWEILER	Made Date	2013

Measurement Result

Measurement Date		9.7,2018
Measurement Tool	Type	Portable Vibrometer
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD
Motor Bearing (Upper Side)	V	23 μm
	H	25 μm
	A	25 μm
Motor Bearing (Lower Side)	V	16 μm
	H	26 μm
	A	33 μm

Title	Vibration Measurement		
Power Station	Thilawa		
Object	#1GT No.1 Main Oil Pump		
Measurer	Hiraoka (MHPS)		
Observer	Ozaki (Kansai)		

Equipment Specification

Type	Centrifugal Pump	Capacity	120 m3/h
Roating Speed	2900 rpm	Serial Number	-
Current	76 A	Voltage	400 V
Manufacturer	ALLWEILER	Made Date	2013

Measurement Result

Measurement Date		9.7,2018
Measurement Tool	Type	Portable Vibrometer
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD
Motor Bearing (Upper Side)	V	20 μm
	H	30 μm
	A	31 μm
Motor Bearing (Lower Side)	V	32 μm
	H	19 μm
	A	35 μm

No.1 Main Oil Pump

Title	Vibration Measurement		
Power Station	Thilawa		
Object	#2GT No.2 Main Oil Pump		
Measurer	Hiraoka (MHPS)		
Observer	Ozaki (Kansai)		

Equipment Specification

Type	Centrifugal Pump	Capacity	120 m3/h
Roating Speed	2900 rpm	Serial Number	-
Current	76 A	Voltage	400 V
Manufacturer	ALLWEILER	Made Date	2013

Measurement Result

Measurement Date		9.7,2018
Measurement Tool	Type	Portable Vibrometer
	Serial Number	VA-10 00280204 Vibration Meter Rion Co,. LTD
Motor Bearing (Upper Side)	V	23 μm
	H	25 μm
	A	25 μm
Motor Bearing (Lower Side)	V	16 μm
	H	26 μm
	A	33 μm

No.2 Main Oil Pump

- Electric Current Diagnosis
  Current measurements were carried out with the #1 GT and #2 GT Main Oil Tank Oil Separator.
  No abnormality

Title	Motor Current Meaturement		
Power Station	Thilawa		
Object	#1GT Main Oil Tank Oil Separator		
Measurer	Sato (Kansai)		
Observer	Ozaki (Kansai)		

Motor Specification

Type	–	Capacity	5.5 kW
Number of Poles	2	Serial Number	
Rotating Speed	2930 rpm	Voltage	400V
Current	10.6 A	Insulation Type	F
Manufacturer	Weg	Made Date	2015.5

Measurement Result

Measurement Date		9.7,2018
Measurement Tool	Type	HIOKI 3285
	Serial Number	80523503
	Calibration Date	2009.8
Phase Current	A	5.8 A
	B	5.9 A
	C	5.7 A

No.1 Main Oil Tank Oil Separator

Title	Motor Current Meaturement		
Power Station	Thilawa		
Object	#2GT Main Oil Tank Oil Separator		
Measurer	Sato (Kansai)		
Observer	Ozaki (Kansai)		

Motor Specification

Type	–	Capacity	5.5 kW
Number of Poles	2	Serial Number	
Rotating Speed	2930 rpm	Voltage	400V
Current	10.6 A	Insulation Type	F
Manufacturer	Weg	Made Date	2015.5

Measurement Result

Measurement Date		9.7,2018
Measurement Tool	Type	HIOKI 3285
	Serial Number	80523503
	Calibration Date	2009.8
Phase Current	A	6.0 A
	B	5.8 A
	C	5.7 A

No.2 Main Oil Tank Oil Separator

Ø Insulation Resistance Diagnosis

Insulation resistance measurements were carried out with the #1 GT and #2 GT Generator Cooling Fan.　No abnormality

Title	Insulation Resistance Measurement of Low Voltage Motor
Power Station	Thilawa
Object	#1GT Generator Cooling Fan
Measurer	Sato (Kansai)
Observer	Ozaki (Kansai)

Motor Specification

Type	–	Capacity	22kW
Number of Poles	2	Serial Number	–
Rotating Speed	2956rpm	Voltage	400V
Current	38.1A	Insulation Type	F
Manufacturer	ABB	Made Date	2015

Measurement Result

Measurement Date		9.7,2018
Measurement Tool	Type	Insulation Resistance Measuring Device 500V Type
	Serial Number (Model)	YOKOGAWA MY40-01
	Calibration Date	2017.8
Condition	Weather	Rain
	Temperature (℃)	22.9℃
	Humidity (%)	48%
No.1	MΩ	2000 MΩ or More
No.2	MΩ	2000 MΩ or More
No.3	MΩ	2000 MΩ or More

Reference Value:　more than 1MΩ

No.1 Generator Cooling Fan

Title	Insulation Resistance Measurement of Low Voltage Motor
Power Station	Thilawa
Object	#2GT Generator Cooling Fan
Measurer	Sato (Kansai)
Observer	Ozaki (Kansai)

Motor Specification

Type	–	Capacity	22kW
Number of Poles	2	Serial Number	–
Rotating Speed	2956rpm	Voltage	400V
Current	38.1A	Insulation Type	F
Manufacturer	ABB	Made Date	2015

Measurement Result

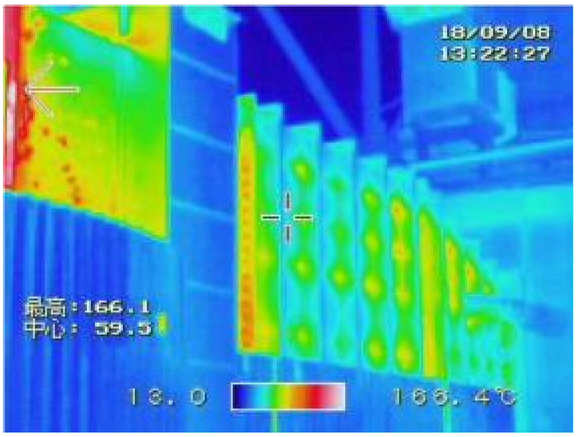
Measurement Date		9.7,2018
Measurement Tool	Type	Insulation Resistance Measuring Device 500V Type
	Serial Number (Model)	YOKOGAWA MY40-01
	Calibration Date	2017.8
Condition	Weather	Rain
	Temperature (℃)	22.8℃
	Humidity (%)	49%
No.1	MΩ	2000 MΩ or More
No.2	MΩ	2000 MΩ or More
No.3	MΩ	2000 MΩ or More

Reference Value:　more than 1MΩ

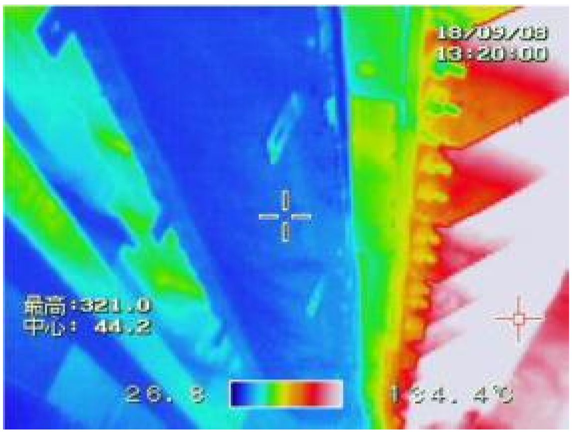
No.2 Generator Cooling Fan

Ø Leakage Location Diagnosis

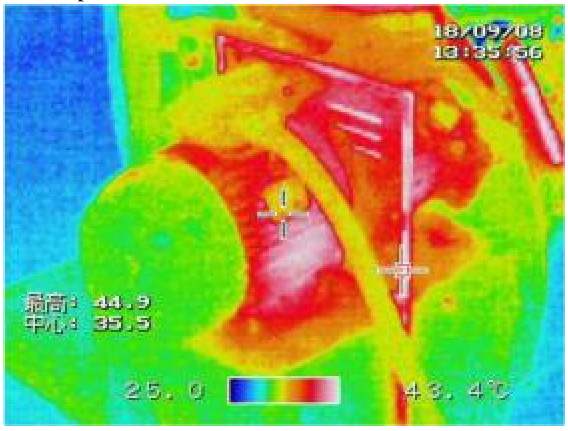
Surveys for gas leakage and equipment overheating (#2 GT which is under operation) were conducted by using a thermal camera. No abnormality



#2 GT Exhaust Gas Duct



#2 GT Chimney Inlet Expansion



#2 GT Motor of Lube Oil Mist Separator Fan

Gas leakage diagnosis of the NG station was carried out by portable gas detector.
No gas leakage

Gas Leakage Check

- Unit Performance Diagnosis

The thermal efficiency of the gas turbine is theoretically calculated as follows.

ηG : Thermal Efficiency of Gas Turbine

$$= \frac{3600}{\dfrac{\text{NG } heating\ value \text{ LHV}\left[\frac{\text{kJ}}{\text{kg}}\right] \times \text{NG } flow\ rate[\text{kg/h}]}{\text{GT } output\ [\text{kW}]}}$$

The result of the site survey is as follows. The condition is LHV, gross basis (output, efficiency, Yadana gas).

※Because it was the rainy season, the plant was under partial load operation and performance evaluation was not possible. (The following shows the values at partial load.)

Item		Design	Measurement Data (2018.9)	
Operation Mode		Full Load	Partial Load	
		#1GT:Running #2GT:Stop	#1GT:Stop #2GT:Running	
Ambient Temperature		30℃	31.4℃	
Output	gross	60.5MW	14.7MW	
	net	60.1MW	-	
Efficiency	gross	31.3%	23.77%	
	net	31.1%	-	
Unit			#1	#2
GT Output		30.3MW/unit	-	14.7MW
Fuel Consumption		7.97t/h (Zawtica)	-	7.0t/h (Yadana)

(4) Predictive Maintenance

a. Control Status of Records

・Various data are recorded and managed in the log sheet.

b. Accumulation and Analysis of Operation Data

・Operation data is compared with reference values to check for problems. The senior shift engineer checks the records to determine if there is something wrong.

・There is no horizontal deployment with other power plants as it is not possible to share operating data without the permission of EPGE. However, air compressor operation data is sent to manufacturers (Atlas) and plant manager's mobile phones.

c. Past Performance of Predictive Maintenance Based on Data Analysis

・None

d. Remarks

・There is a request to be able to monitor MWh, fuel compressor status, transformer temperature and fuel gas consumption data in the central control room.
In addition, there is a request for correcting the deviation between the clock of the control device of # 1, 2 GT and the substation control device.

・Currently there is no water supply to the plant. It is planned to receive water supply in the future.

Appendix 5

Ywama Power Station Survey Results

■Ywama（First Site Survey：2018.8.29～8.31, Second Site Survey：2018.12.6,12.7,12,10）

（1）O&M System Survey

a. Outline of Facility

Location	Ywama West Ward, Insein Township, Ywama Power Plant, Yangon, Myanmar
Configuration	GT(F5) GT×2 Simple Cycle GT(M701D) GT×2 Simple Cycle GT(H-25) 1-1-1 CCGT
GT(F5) GT×2 Simple Cycle	
Power Plant Output	36.9 MW
EPC	JBE
COD	1980
Connection to Transmission Line	Connect to 33 kV bus Distribution from 33 kV loop bus to each load
GT(M701D) GT×2 Simple Cycle	
Power Plant Output	240 MW
EPC	MHPS
COD	2014
Connection to Transmission Line	Connect to 230 kV BUS Hlalngcharyar Line
GT(H-25) 1-1-1 CCGT	
Power Plant Output	33.4 MW
EPC	MHPS
COD	2004
Connection to Transmission Line	Connect to 33 kV bus Distribution from 33 kV loop bus to each load

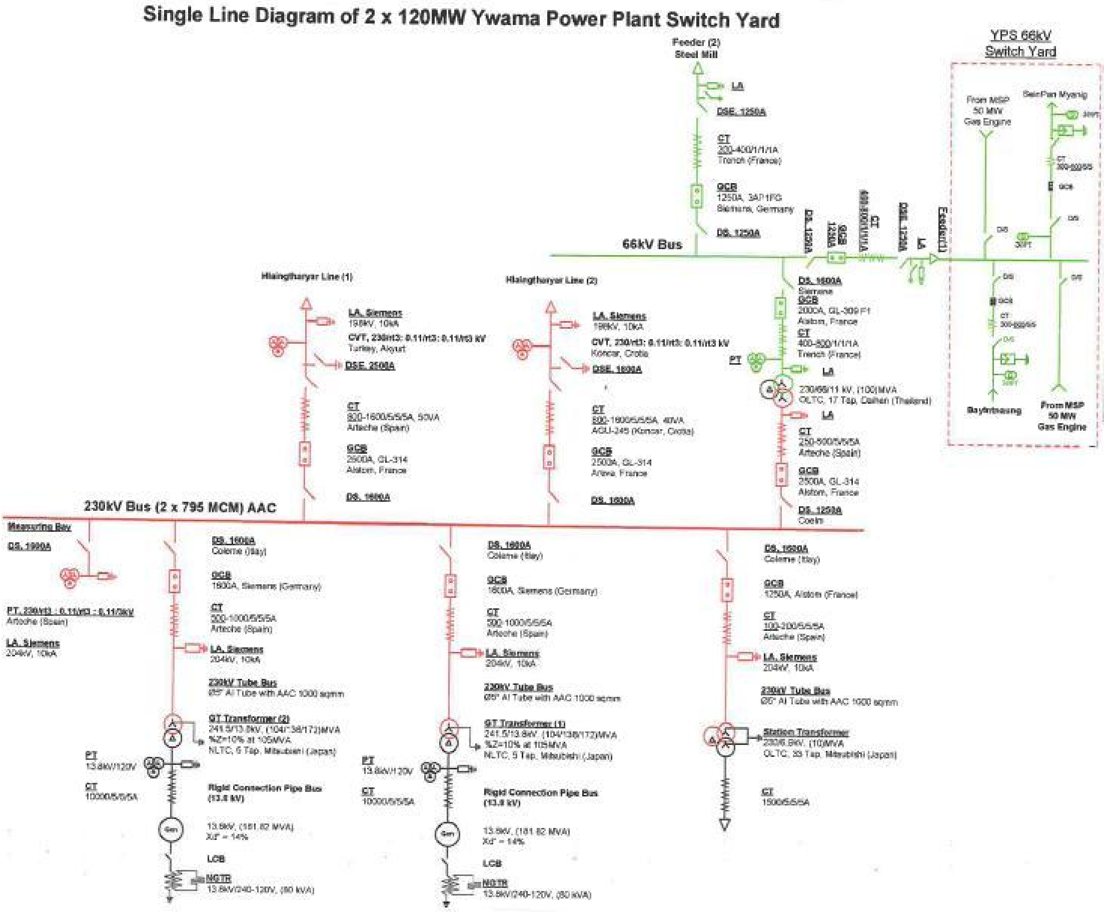


Fig. Ywama Power Plant Single Line Diagram

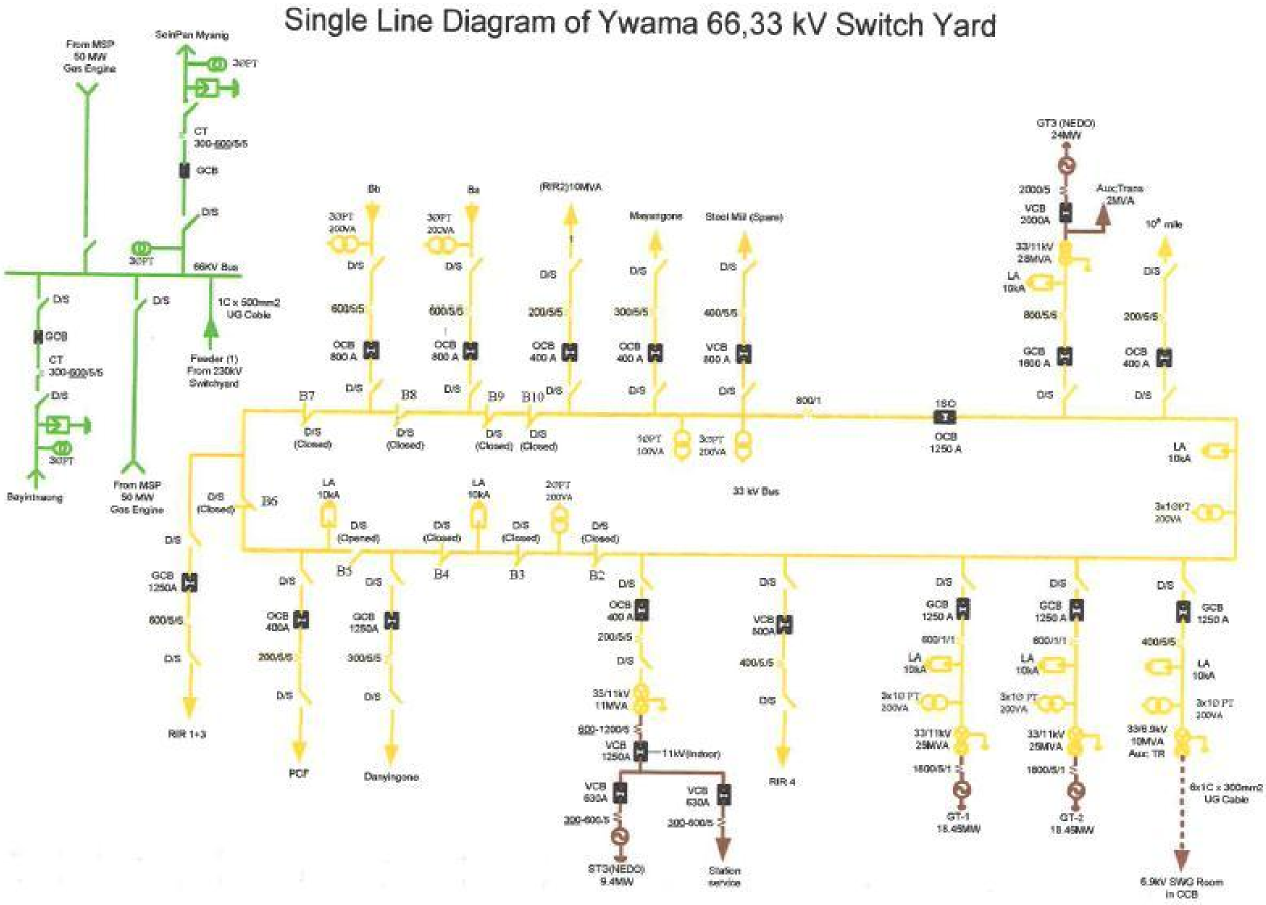


Fig. Ywama Power Plant Single Line Diagram

Equipment Specifications

GT(F5) GT×2 Simple Cycle

Gas Turbine
Manufacture : GE
Model : Frame 5
Designed Air Temperature : 95F
Designed Output : 23210 kW
Fuel : Yadana Gas
Rotating Speed : 5094 rpm

Generator
Manufacture : BRUSH
Model : BDAX 7084
Output : 25000 kVA
Voltage : 11 kV
Power Factor : Leg 0.8
Rotating Speed : 3000 rpm

Main transformer
Manufacture : YORKSHIRE ELECTRIC
Type : Three Phase Power Transformer
Capacity : 18.75/25 MVA
Voltage : 33/11 kV
Cooling method : ONAN/ONAF

GT(M701D) GT×2 Simple Cycle

Gas Turbine
Manufacture : MHPS
Model : M701D
Designed Air Temperature : 32.7℃
Designed Output : 120MW
Fuel : Yadana Gas
Rotating Speed : 3000 rpm

GT Generator
Manufacture : Mitsubishi ELECTRIC
Model : MB-H
Output : 181820 kVA
Voltage : 13.8 kV
Power Factor : Leg 0.85
Rotating Speed : 3000 rpm

Main transformer
Manufacture : Mitsubishi ELECTRIC
Type : SRB Three Phase Shell type
Capacity : 104/138/172 MVA
Voltage : 241.5/13.8 kV
Cooling Method : OA/FA/FA

GT(H-25) 1-1-1 CCGT

Gas Turbine
Manufacture : MHPS

Model	: H-25(28)
Designed Air Temperature	: 30℃
Designed Output	: 24 MW
Rotating Speed	: 7280 rpm

GT Generator

Manufacture	: MEIDENSHA
Model	: EP-AIT
Output	: 28300 kVA
Voltage	: 11 kV
Power Factor	: Leg 0.85
Rotating Speed	: 3000 rpm

HRSG

Manufacture	: BABCOCK HITACHI K.K.
Model	: Single Pressure, Horizontal Gas Flow
Steam flow	: 42.9 t/h
Steam temperature	: 469 ℃
Steam pressure	: 4.0 MPa
Bypass stack	: none

Steam Turbine

Manufacture	: Shin-Nippon Zoki
Model	: C6-R7-R
Output	: 9.4 MW
Rotating Speed	: 7778 rpm
Steam temperature	: 466 ℃
Steam pressure	: 3.7 MPa

ST Generator

Manufacture	: MEIDENSHA
Model	: EP-AFT
Output	: 10,500 kVA
Voltage	: 11kV
Power Factor	: Leg 0.9
Rotating Speed	: 1500 rpm

Main transformer

Manufacture	: FORTUNE ELECTRIC
Type	: SRB Three Phase Core type
Capacity	: 28 MVA
Voltage	: 33/11 kV
Cooling method	: ONAF

Condenser

Manufacture	: HITACHI
Type	: 1_6241-CD-001
Cooling Water Flow	: 2060 m^3/h

Cooling Tower

Capacity	: 460,000 kg/h
Number of Fan	: 3

Fuel
1)Fuel Gas Methane : 69.8801 mol% （Yadana Gas） Ethane : 1.0106 mol% Propane : 0.1694 mol% i-Butane : 0.0184 mol% n-Butane : 0.0279 mol% i-Pentane : 0.0065 mol% n-Pentane : 0.0037 mol% Neo-Pentane : 0.0214 mol% Hexane and Heavier : 0.0211 mol% CO_2 : 4.1294 mol% N_2 : 24.727 mol% H_2S : 0.0021 mol% H_2O : 0.0011 mol% （Zawtika Gas） Methane : 91.786 mol% Ethane : 0.401 mol% Propane : 0.111 mol% i-Butane : 0.035 mol% n-Butane : 0.021 mol% i-Pentane : 0.01 mol% n-Pentane : 0.007 mol% Hexane and Heavier : 0.031 mol% N_2 : 7.531 mol% 2) Gas Delivery Condition Gas Station High Temperature : 45℃ Low Temperature : 22℃ High Pressure : 35 barg Low Pressure : 27 barg Max Flow Rate : 54,000 Nm^3/h GT Inlet High Temperature : 45℃ Low Temperature : 20℃ High Pressure : 30 barg Low Pressure : 18 barg Max Flow Rate : 18,000 Nm^3/h

b. Layout

- There is no chemical analysis room associated with water quality, lubricating oil, control oil, or fuel management.
- Analytical equipment for environmental management is not installed and there are no management standa.

Fig. Ywama Power Plant Layout

c. Power Station Management and Education System

- The plant is staffed by 151 people.
- OJT is conducted for transferees and new assignees. There is no other training.
- Engineers conduct OJT under a senior engineer.

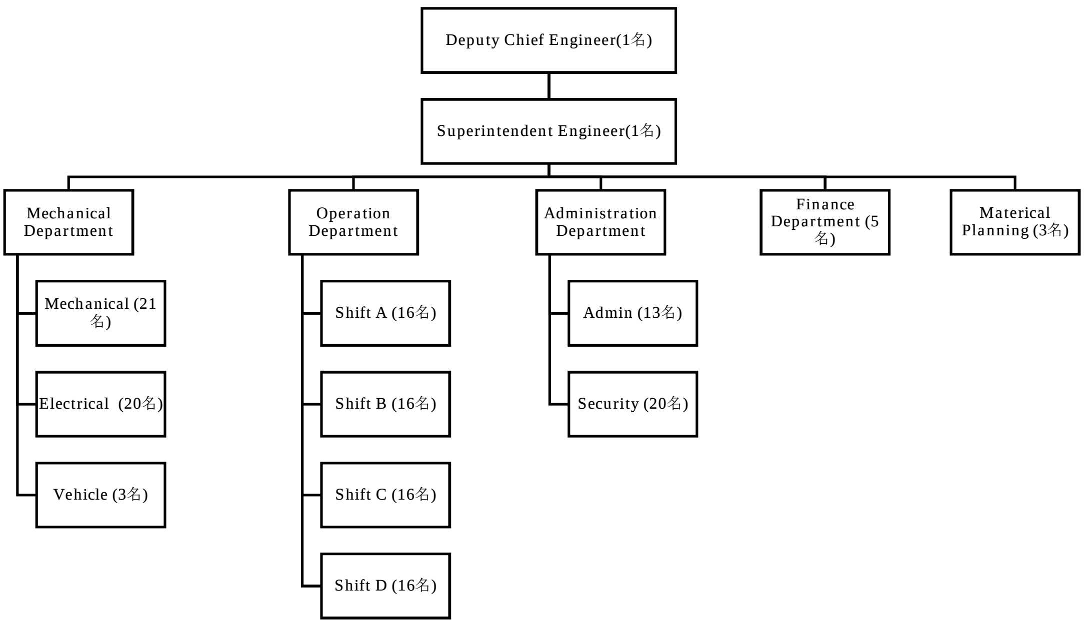


Fig. Organization Chart

d. Regulations and Manuals on Power Plant O&M

None.

e. Parts Procurement Procedures

- The procurement department of the power plant requests the necessary items by submitting a list to the EPGE (Material department).
- When the Power Plant needs to procure materials in a hurry, the power plant submits a request form directly to MD.

(2) Daily Operation

a. Operation System

- They operate on a 2-shift, 4-group system. Among them, four are daily workers called “Watchers”, who monitor the instruments at the direction of the manager. The handover uses a logbook. In the logbook are entered the name of the transferee, the LDC command, the generator H2 pressure, etc.
- Operators carry out regular inspections (including record collection and meter checks). Basically, the purpose is to collect local records, and there is no time for checking the soundness of the equipment. The time required for one inspection is about 20 minutes.
- The maintenance department carries out two inspections -- morning and evening.
- There are instruments used for daily inspections. (Tester, MEG, thermo gun, vibration measuring device, gas detector)

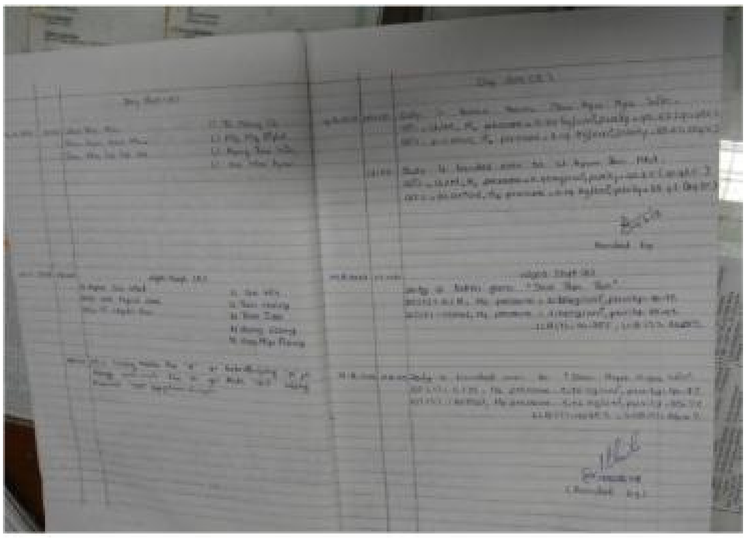


Fig. Logbook

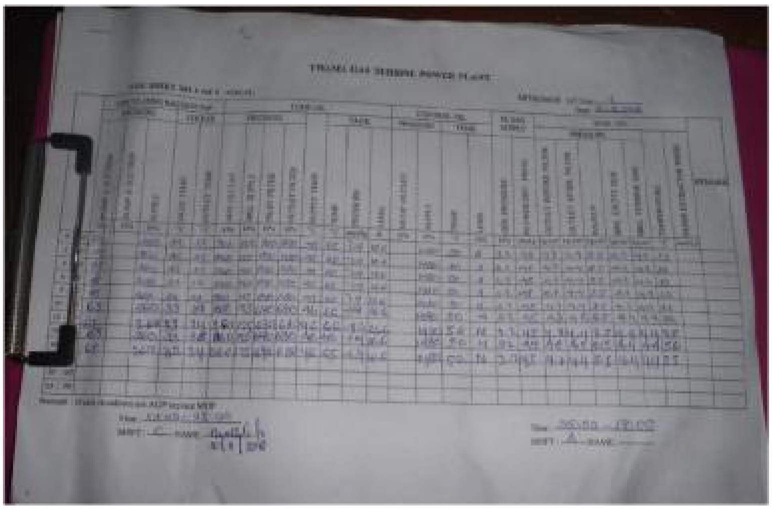


Fig. Quantitative Records

b. Quantitative Records Related to Power Generation

- Only MW and gas consumption are reported to the Hlawga power plant, and are input into Excel at the time of the report. The Hlawga power plant aggregates data of each power station and reports to EPGE every morning.

- The amount of gas used is notified by phone from the MOGE (Ministry of Gas and Energy). There is one gas meter installed at the power plant, and the amount of gas used can be checked using that gas meter.
- The thermal efficiency is calculated and recorded. (No use as thermal efficiency data)

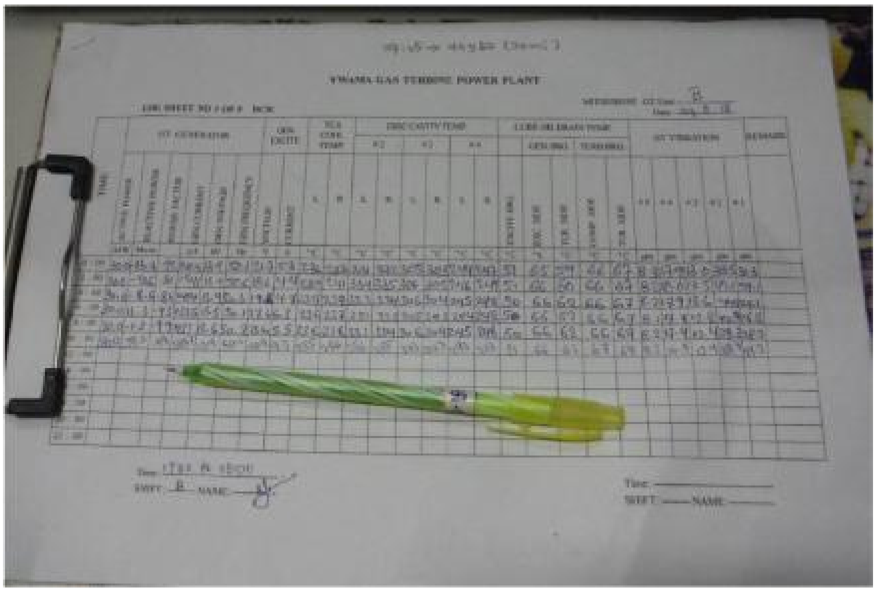


Fig. Hourly Power Generation Record

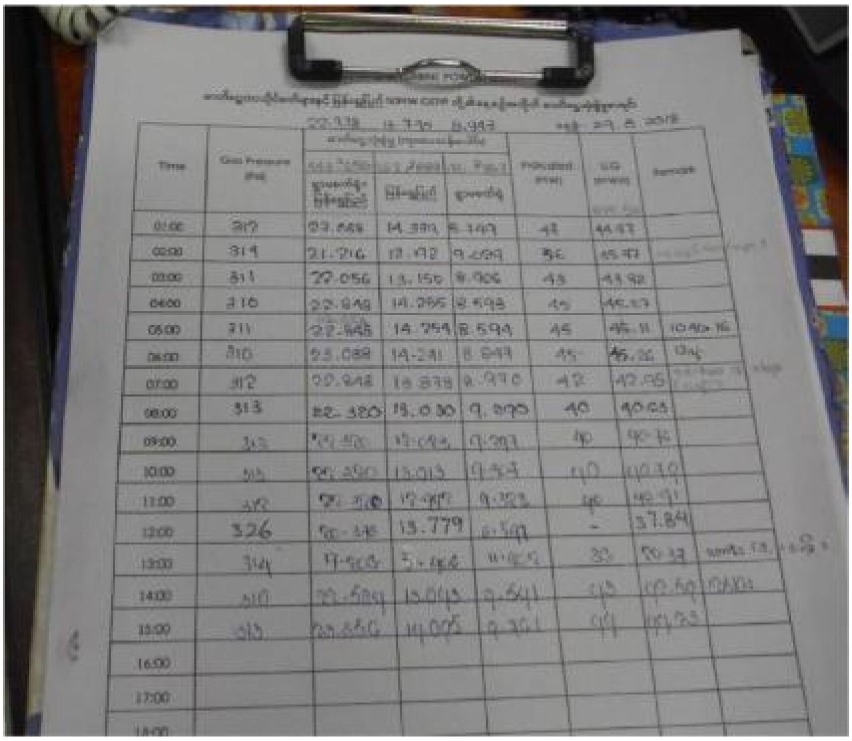


Fig. Record of Gas Usage

c. Record of the Implementation Status of O&M

- The place where the field instrument is located is recorded every hour. (There is data not recorded in part.) The collected records are not used for predictive maintenance. However, it is confirmed whether the recorded values are rapidly increasing or decreasing, and if any abnormalities are found, the equipment is checked.
- There is almost no graphing.
- Concerned matters are described in the operation logbook, and the takeover at the time of the change of duty is performed using the logbook.The records are reviewed by the Shift Chief Engineer at the end of the day and submitted to the Operation Department. The operation record is also checked by the Operation Department. If a defect is confirmed, the content of the defect is reported to the

Maintenance Department.

- The damage items found in daily inspections are described in the maintenance logbook.
- They report trouble points to the maintenance department and plant manager.
- The repair record is also written in the maintenance logbook by hand. However, it is basically a record of only the event and the corresponding fact, and no detailed repair method is described.

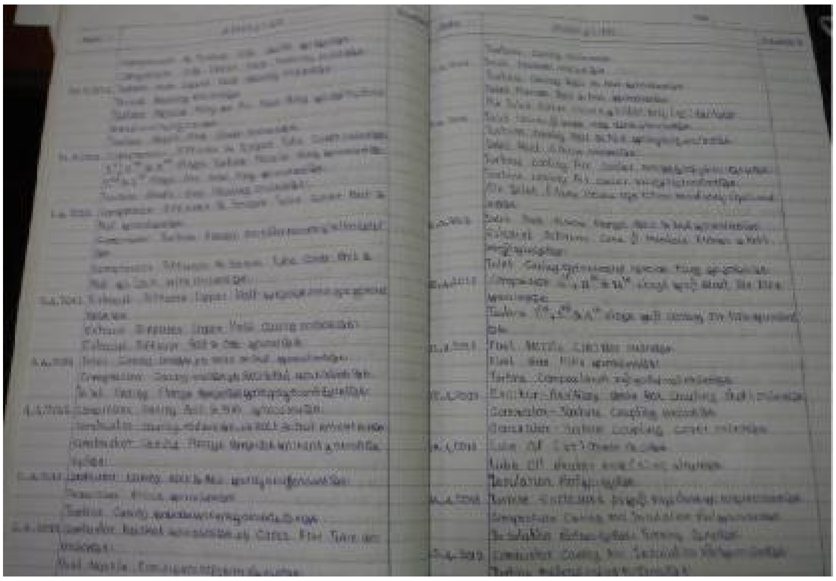


Fig. Maintenance Record

- Records are kept permanently.
- The procurement of parts requiring maintenance is ordered by the EPGE from the Ethos.
- Maintenance records of cooling water and pure water are stored for 10 years. (Cleaning only conducted) The tire company manages and retains them.

d. Spare Parts Management

- There are multiple warehouses on the premises, and spare parts are stored. Although indoors, there is no temperature or humidity control. Rustproofing treatment is not particularly performed, and parts are in the state they were at the time of shipment.
- Management is done by three warehouse managers who belong to the Material Planning department. However, only a monthly visual inspection (quality and quantity control) is conducted; no management system has been introduced.
- The storage location is not decided for each part.
- When spare parts are delivered, it is checked whether they are parts ordered. Also, the spare part management slip is updated regularly.
- The power plant applies to the EPGE for the type and quantity of parts required. There are no spare parts for the controller. The use of spare parts is determined by the EPGE. EPGE approval is required when using spare parts elsewhere.
- Since the HGPP(Hot Gas Path Parts) are not managed the life, the power plant replaces it by looking at the condition of the parts. Basically, it is only replaced and not repaired. If the budget allows, it may be repaired at the discretion of the EPGE. (H30.12, 701D No. 1, No. 1 burner and replacement of blades used repaired products.) When repairing, it is indicated that it has been repaired in the spare parts list. Also, management by serial number is not performed.

e. Actions against Events/Abnormalities and Records Management

- If a problem is found during a patrol inspection, the operator reports to the senior engineer, and the senior engineer reports to the manager of the maintenance department and the plant manager.
- A request for the EPGE Chief Engineer is made if urgently required.
- The person who performs trouble analysis is appointed by the director as needed.
- In the event of a trip or alarm, they refer to the OEM manual or respond based on experience. The OMM (Operation & Maintenance Manual) can be viewed by all employees
- After an abnormality occurs, the plant is restarted at the discretion of the director.
- The power plant does not contact the OEM even when a failure occurs. (Forbidden by EPGE)
- The accident bulletin is submitted to the EPGE and saved. However, there is no system for

managing accident records.

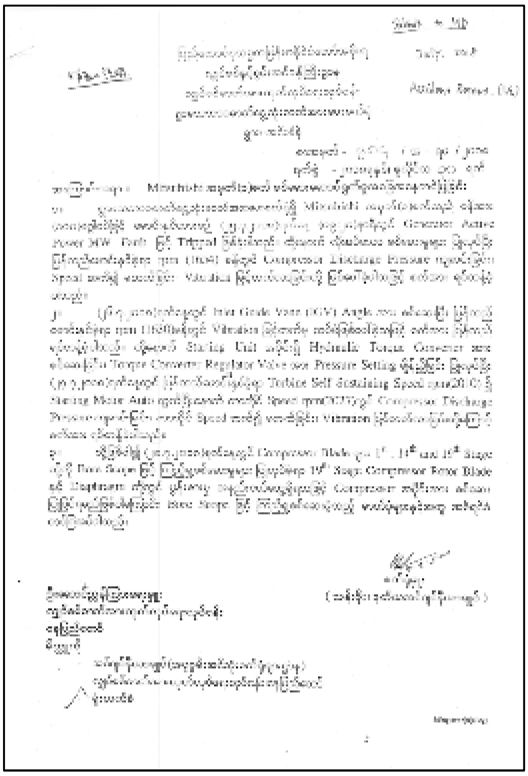
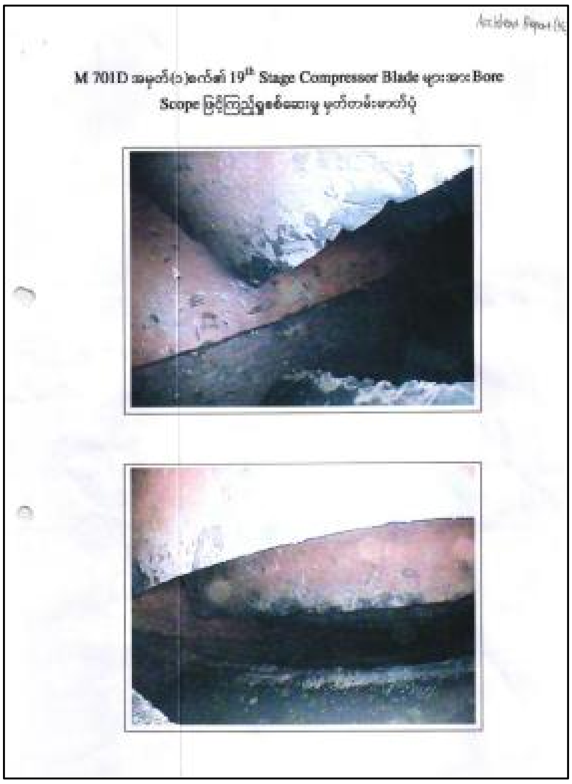



Fig. Accident Report

f. Environment Management

None.

g. Entry Management

- Visitors are managed using visitor cards and a record sheet. Staff members are also distributed employee cards and are required to present their employee cards when entering the power plant.
- The maximum number of visitors is around 30 even during regular inspections. (701D # 1 results)
- There is no management system.

Fig. Security Card

(3) Periodic Maintenance

a. Maintenance Plan Management (Contents, Cycle, Budget, etc.)

- The EPGE (Chief Engineering Office) decides the items for regular maintenance while coordinating with the power plant. The chief engineer reports to the MD and the power outage work is decided with the approval of the MD.
- The power plant will inform the EPGE of the periodic inspection period and schedule, and EPGE

will decide the timing of the final periodic inspection based on the power demand and budget.

- The inspection cycle is defined as the GT: OEM recommended cycle, the HRSG: once a year, and the generator: the GT mejor inspection cycle.
- Failure status of the device has not been recorded and managed. Therefore, the maintenance plan is not based on those information.
- Repair work such as future rehabilitation is planned by The World Bank for in Frame 5 and H25 GT, but it is known only by the EPGE.
- The construction schedule of the Frame 5 was decided at the power plant.
- t is necessary to apply for a budget to EPGE if the cost is 0.3M or more for parts purchase.

b. Implementation Status, Frequency, and Method of Periodic Maintenance

- Necessary personnel are secured by EPGE according to the power plant requirements. In addition, when heavy equipment such as cranes and their drivers are required, it is also necessary to request EPGE.
- They outsource construction work that cannot be done directly.
- Most inspections are conducted by members from the EPGE and other power stations. Basically, inspections are implemented directly even with first-time equipment, since manufacturers disclose control values such as clearance. Inspections are outsourced only when special tools are required or when technically difficult. The currently underway inspection of the 701D, which must be completed by summer, is being implemented by Ethos.
- Periodic inspection of the Frame 5 GT is carried out under direct management. Ten workers from other power stations came to support and cooperate with 40 Ywamaworkers. The workers are specialized staff members called “Skilled Workers”, and most have about 20 years of work experience.
- The manager from the Hlawga power station, who also serves as Deputy Chief Engineer of the EPGE, judges the corresponding method based on the inspection results of mechanical parts such as GT combustor. The directors of Ywama power plant and Ahlone power plant also hold the position of EPGE Deputy Chief Engineer, and they decide on the inspection results of transmission equipment and transformation and electrical equipment, respectively.
- They have not digitized inspection records.
- In order to obtain the necessary parts, the plant needs to issue a letter and make a request to the EPGE.
- The power plant has prepared special tools, but, for the Frame 6, GE provided special tools in 2010 and Ethos in 2016, and they are currently stored at the power plant.
- When replacing the control system in 2016, special tools were arranged by GE. (The cost was included in the maintenance cost)
- For parts repairs, the EPGE solicits bids for repairs on a regular basis every year.
- At the time of the on-site survey, we confirmed the implementation status of the periodic inspection of the H-25. In regular inspections, size and clearance management and wear dimensional inspection of high temperature parts are not conducted, and any replacement of high temperature parts is determined by the director from the Hlawga power station. In addition, there is no safety management, and dangerous work can be seen.
- If problems are found in the regular inspection, the power plant reports to the EPGE.

Fig. Periodic Inspection Execution Scene

c. Initiatives for Continuous Improvement

- After periodic inspection, the power plant submits a report to the EPGE, and the EPGE determines the next scope of work based on the contents.

d. Status of Equipment

(a) Damage Status

No.	M701D Common Issues
1	There is no bellows limit rod.
2	Lubricant cooler fin deformation
3	Start-up device burnt oil stain

M701D Common Issue No.1

M701D Common Issue No.2

M701D Common Issue No.3

No.	M701D #1GT Issues
1	Scaffolding leaned against local board
2	Cooler fan motor for generator cooling water removed
3	Stack exterior plate peeling
4	Lubricating oil storage cooler flange oil seepage
5	TCA (A rack) thermal insulation off
6	Intake filter element scattering
7	Compressor wing damage


M701D #1GT No.1

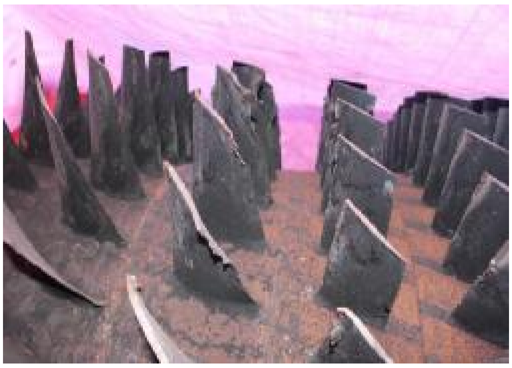

M701D #1GT No.2


M701D #1GT No.3


M701D #1GT No.4

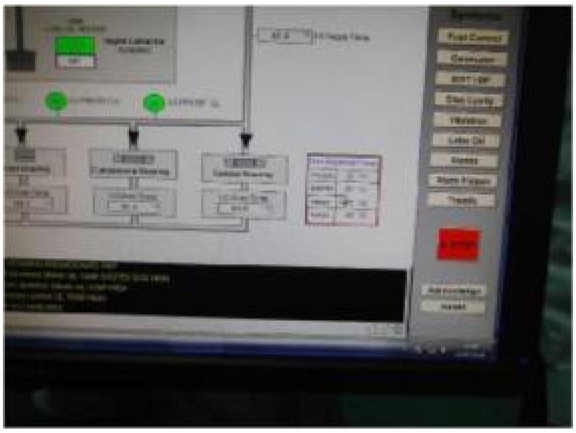

M701D #1GT No.5


M701D #1GT No.6


M701D #1GT No.7

No.	M701D #2GT Issues
1	Gas shutoff valve ground leak
2	GEN bearing temperature rise (load limit)

M701D #2GT No.1



M701D #2GT No.2

No.	F5 Common Issues
1	Gas detector damage at gas station
2	Widespread enclosure corrosion

F5 Common Issue No.2

F5 Common Issue No.2

No.	F5 #2GT Issues
1	Start-up device burnt oil stain
2	Oil is oozing


F5 #2 Issue No.1


F5 #2 Issue No.2

No.	H25 common Issues
1	Condensate pump outlet valve drive flooded
2	Circulating water pump ground corrosion
3	Widespread cooling tower concrete deterioration
4	Widespread cable rack corrosion
5	Gas station gas detector damage
6	Instrument malfunction

H25 common Issue No.1


H25 common Issue No.2


H25 common Issue No.3


H25 common Issue No.4

H25 common Issue No.5

H25 common Issue No.6

No.	H25 GT Issues
1	Start-up device burnt oil stain
2	Partial removal of instruments

H25 GT No.1

H25 GT No.2

No.	H25 ST Issues
1	Oil bleed from ST reduction gear bearing

H25 ST No.1

(b) Simple Diagnosis

- Gas leakage diagnosis of NG

  Gas leakage diagnosis of the NG station was carried out using a portable gas detector. There are gas leaks at the NG gas station.

Gas Leakage Check

- Vibration Diagnosis

  Vibration measurement was conducted with the Frame5 and #2GT main oil tank exhaust fan. No abnormality.

◆Vibration diagnisis measurement

Record name	Vibration diagnisis measurement
Power station	Ywama Power station
Target equipment	F5 #1GT #1 bearing
Measurer	MHPS Hiraoka Toshiyuki
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	Frame5	Capacity	18.45MW
Rotation speed	5094rpm	Serial number	–
Motor rated current	–	Motor rated voltage	–
Manufacturer	GE	Date of measurement August	–

Measurement result

Date of measurement		30-Aug-18
Measurement tool	Type	Portable Vibration Meter
	Serial number	Rion Corporation Vibration Analyzer VA-10 00280204
Measured value	V	22 μm
	H	18 μm
	A	100 μm

Refrence value (JEAC 3704) :130μm p-p

◆Vibration diagnisis measurement

Record name	Vibration diagnisis measurement
Power station	Ywama Power station
Target equipment	M701D #2GT #2 bearing
Measurer	MHPS Hiraoka Toshiyuki
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	M701D	Capacity	120MW
Rotation speed	3000rpm	Serial number	–
Motor rated current	–	Motor rated voltage	–
Manufacturer	MHPS	Date of measurement August	–

Measurement result

Date of measurement		30-Aug-18
Measurement tool	Type	Portable Vibration Meter
	Serial number	Rion Corporation Vibration Analyzer VA-10 00280204
Measured value	V	65 μm
	H	35 μm
	A	30 μm

Refrence value(JEAC 3704) :130μm p-p

◆Vibration diagnisis measurement

Record name	Vibration diagnisis measurement
Power station	Ywama Power station
Target equipment	M701D #2GT Main oil tank exhaust fan
Measurer	MHPS Hiraoka Toshiyuki
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	Vertical fan	Capacity	–
Rotation speed	–	Serial number	–
Motor rated current	–	Motor rated voltage	–
Manufacturer	–	Date of measurement August	–

Measurement result

Date of measurement		30-Aug-18
Measurement tool	Type	Portable Vibration Meter
	Serial number	Rion Corporation Vibration Analyzer VA-10 00280204
Motor upper bearing	V	40 μm
	H	52 μm
	A	15 μm
Motor lower bearing	V	40 μm
	H	29 μm
	A	36 μm

Refrence value(JIS B 8330) : 100μm


Vibration Measurement Scene

Ø Electric Current Diagnosis

Current measurement was carried out with the M701D #2GT main oil tank exhaust fan. No abnormality.

◆Motor current measurement

Record name	Motor current measurement
Power station	Ywama Power station
Target equipment	M701D #2GT Main oil tank exhaust fan
Measurer	Kansai Electric Power Sato Ryo
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	–	Capacity	–
Number of poles	–	Serial number	–
Number of rotations	–	Rated voltage	–
Rated current	–	Insulation type	–
Manufacturer	–	Made date	–

Measurement result

Date of measurement		30-Aug-18
Measurement tool	Type	–
	Serial number	–
Measured value	Phase A	1.0 A
	Phase B	1.1 A
	Phase C	1.2 A


Current Measurement Scene

- Insulation Resistance Diagnosis
  Insulation resistance measurement was carried out with the M701D #1GT c-package ventilation fan. No abnormality

◆Insulation Resistance Diagnosis

Record name	Low voltage motor Insulation Resistance Diagnosis
Power station	Ywama Power station
Target equipment	M701D #1GT C-PACKAGE VENTILATION FAN
Measurer	Kansai Electric Power Sato Ryo
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	–	Capacity	–
Number of poles	–	Serial number	–
Number of rotations	–	Rated voltage	–
Rated current	–	Insulation type	–
Manufacturer	–	Made date	–

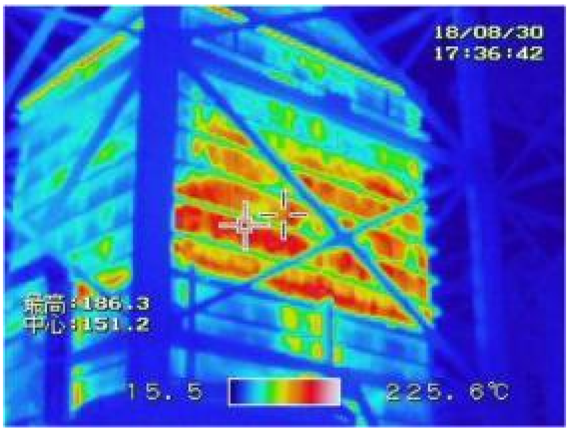
Measurement result

Date of measurement		30-Aug-18
Measurement tool	Type	Insulation resistance measuring instrument 500V M
	Serial number	–
Environment	Weather	Cloudy
	Temperature (℃)	–
	Humidity (%)	–
Measured value	MΩ	223 MΩ

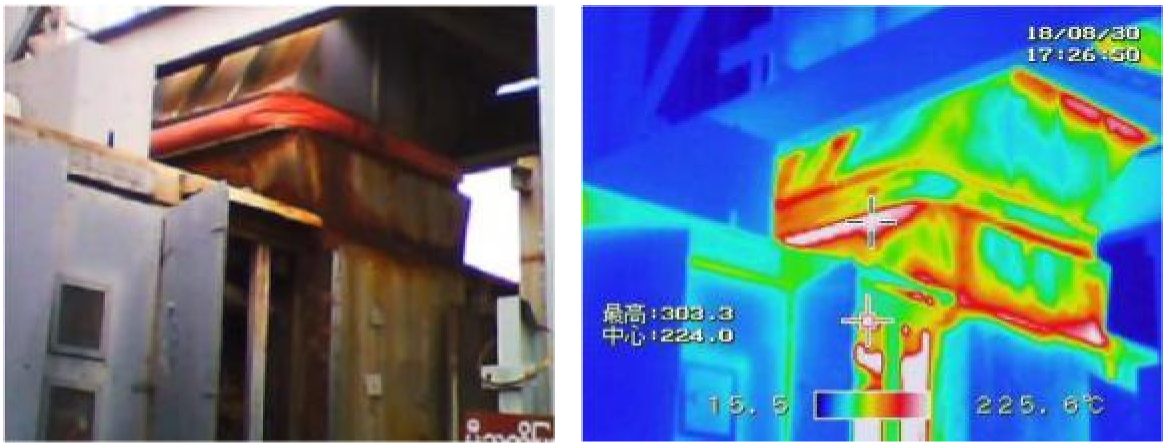
Refrence value : over 1MΩ

Resistance Diagnosis Scene

- Leakage Location Diagnosis
  Surveys for gas leakage and overheating of equipment (M701D #2GT and F5-#2GT which are under operation) were conducted by using a thermal camera. Some parts are hot.



M701D #2GT Exhaust Gas Duct



F5-#2GT Exhaust Gas Duct

(4) Predictive Maintenance

a. Control Status of Records

- They record not only the main items about power generation such as the amount of power generated, but also operation state (disk cavitation, vibration, oil temperature in various locations, blade path temperature, exhaust temperature, gas consumption, etc.). CWP operation state, transformer oil, and winding line temperature are also recorded.
- Recording is managed using a log sheet.

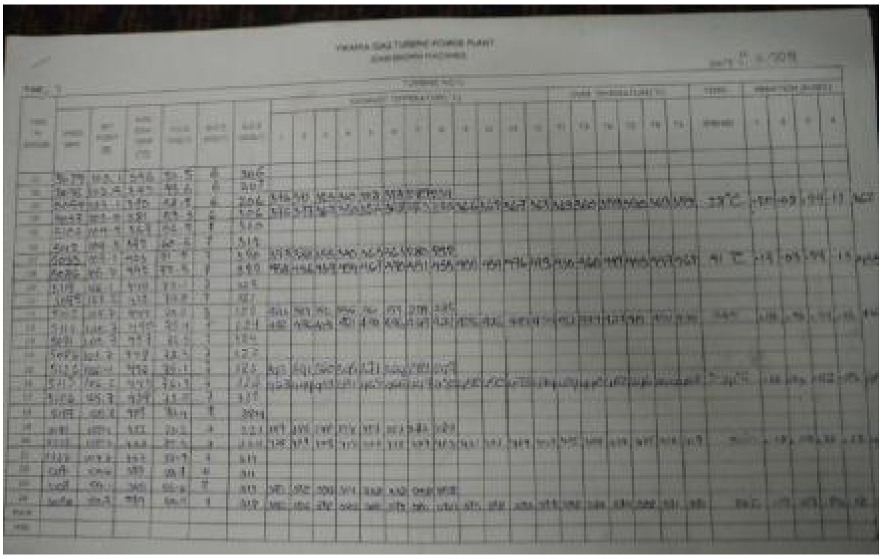


Fig. Operation Status Hourly Records

Fig. Inspection Record Status

b. Accumulation and Analysis of Operation Data

- Analysis of operating data has not been conducted. The operating data is stored in the control system for three months.
- Operation data can be stored in CSV format but such capabilities are not used.

c. Past Performance of Predictive Maintenance Based on Data Analysis

- None

d. Remarks

(a) OM method

- The output of the power plant follows the instructions from the LDC. Every time that the output does not reach the target value, the power plant contacts the LDC. There is no target value for efficiency.
- The annual operation plan is decided by applying to the EPGE at the beginning of the year for the regular inspection time.
- When ordering parts from the OEM, they send drawings, specifications, photos, etc.
- There is no plan for updating control devices. The control unit performs cleaning and loop checks in accordance with the regular inspection.
- Water quality management is carried out by periodically injecting chemicals into the boiler drum and cooling tower.

Dossing Chemicals. Ywama.

Sr.	Name	Required Qty. for 1, month	Required Qty. for 6, months	Required Qty. for 1, year	Remarks
1.	**Boiler Drum** Tri Sodium Phosphate (Na_3PO_4)	60 kg	360 kg	720 kg	
2.	**Condensate and Feed Water Line**				
(a)	Ammonium Hydroxide (NH_4OH)	125 kg	750 kg	1500 kg	
(b)	Hydrazine Hydrate ($N_2H_4.H_2O$)	40 kg	240 kg	480 kg	
3.	**Cooling Tower**				
(a)	Sodium Hypocholorite (NaOCL)	450 kg	2700 kg	5400 kg	Cooling Tower & Demineralizer used.
(b)	Phosphoric Acid (90% H_3PO_4).	280 kg	1680 kg	3360 kg	
4.	**Demineralizer**				
(a)	50% Sulphuric Acid	200 kg	1200 kg	2400 kg	
(b)	Poly Aluminium Chloride	30 kg	180 kg	360 kg	
(c)	45% Sodium Hydroxide	100 kg	600 kg	1200 kg	
(d)	Citric Acid	-	-	200 kg	RO Membrane Cleaning Chemical
(e)	Oxalic Acid	-	-	200 kg	Cartridge Filter Cleaning Chemical
5.	**Refilling and Calibration Chemical**				
(a)	PH_4 Buffer Solution	-	-	2 lit	
(b).	PH_7 Buffer Solution	-	-	2 lit	
(c)	3.3 M Potassium Chloride	-	-	3 kg	

Fig. Water Treatment Chemicals

(b) Local needs

- The power plant wants improvements because it is difficult to monitor, as the 701 GT intake filter differential pressure cannot be monitored in the central control room and the alarm is a set of other alarms.
- A surveillance camera has been introduced for security. (In the unit 701D, the monitoring camera is installed in a control room or the like.) However, there is no security camera at the front gate, so there is a demand to install one. (Mainly for security purposes, they would like to install cameras in the vicinity of the fence between the main gate and the river on the back side of the power plant. A cameras in the vicinity of the fence on the back side would serve to prevent intrusion by suspicious persons.)
- Usually, lubricating oil analysis is not performed. However, there is a record of analysis at the time of failure occurrence. The analysis is conducted by the MOEE testing organization. In addition, lubricating oil is replaced about every 4 to 6 years.
- Hydrogen gas concentration has dropped and it is regularly replenished manually. The operator confirms and manages the concentration. (Monitoring by trend is not implemented.)
- There is demand for purchase portable instruments because these are not at the power plant.

(c) Other

- The GT # 1 and GT # 2 of the Frame 5 are in operation. In addition, as the HRSG was added by funding from the adjacent tire plant in 2012, steam is supplied to the tire plant free of charge. The required volume can be met with one GT. GT # 1 was remodeled to MarkVIe in 2016.
- At COD, three Frame 5 GTs from JBE were installed. With assistance from NEDO, Marubeni served as the EPC, and one Frame 5 was replaced with the H-25 GT, and it was launched as a CCGT in 2004. In 2009, the turbine one-stage vanes were damaged and stopped. Rehabilitation was implemented in 2013. Although Hitachi instructed that the rusting of GT cooling systems, etc. be thoroughly cleaned, the power plant could not implement the work due to budget shortages. In 2014, the cooling system of the two-stage moving blades rusted and seized, resulting in a burnout. Since then, both the GT / ST have been in long-term storage. However, long-term storage management is not implemented.
- In 2018.2, a compressor surge accident occurred in 701D GT # 1. The power plant responded

and recovered, but the surge recurred on 2018.7.26 but then stopped. Operation was continued regardless of the intake filter differential pressure, so the element partially scattered. Operation was continued with the bypass door opened slightly, and the compressor was damaged due to the suction of dust, as presumed by MHPS. GT # 2 is in operation at base load. And the controller has been converted to Ethos.

- There is a plan to remove the Frame 5, H25 GT and other equipment, and construct a new plant with the support of The World Bank.
- In 2008, the power plant lost many materials (include records) due to Cyclone Nargis. The power plants in Yangon suffered similar damage.
- There is no safety education, but no accidents have occurred.
- There are no results or plans for LTSA / LTPM contracts with the OEMs.
- Driving is conducted by basic management, daily inspections are conducted by direct management, and there are no specific on-site contractors.
- There are no legal / internal rules regarding cybersecurity / data handling.
- The ICT skills of site staff (operators, assumed users) go only as far as using Excel.

Appendix 6

Yeywa Power Station Survey Results

■**Yeywa（Site Survey：2018.8.23, 8,24、2018.12.8）**

（1）O&M System Survey

a. Outline of Facility

Location (Address)	Yeyemen Village, Kyaukse Township, Mandalay Division, Myanmar
Configuration	Four turbines, dam
Capacity	3550 GWh (nominal annual power output)
EPC	Electromechanical: CITIC & CCYW Hydraulic Steel Structures: CITIC&CCYW、CNEEC Transmission Lines & S/S: CHMC
COD	2010
Connection to Transmission Line	230 kV Belin, Meiktila Line
Maximum Power Plant Output	780[MWh]@Sep.2014
Annual Power Output（Nominal / Performance @2017）	3550[GWh] / 2581[GWh]
Annual Operating Hours	18151 h (2017)
Power Generation Method	Dam
Catchment Area	2,780,00 m^3
River Name	Myitnge River
Maximum Water Consumption	840 m^3/s
Dam / Cough	RCC dam (Length/Height=690/132m)
Effective Water Head	91 m

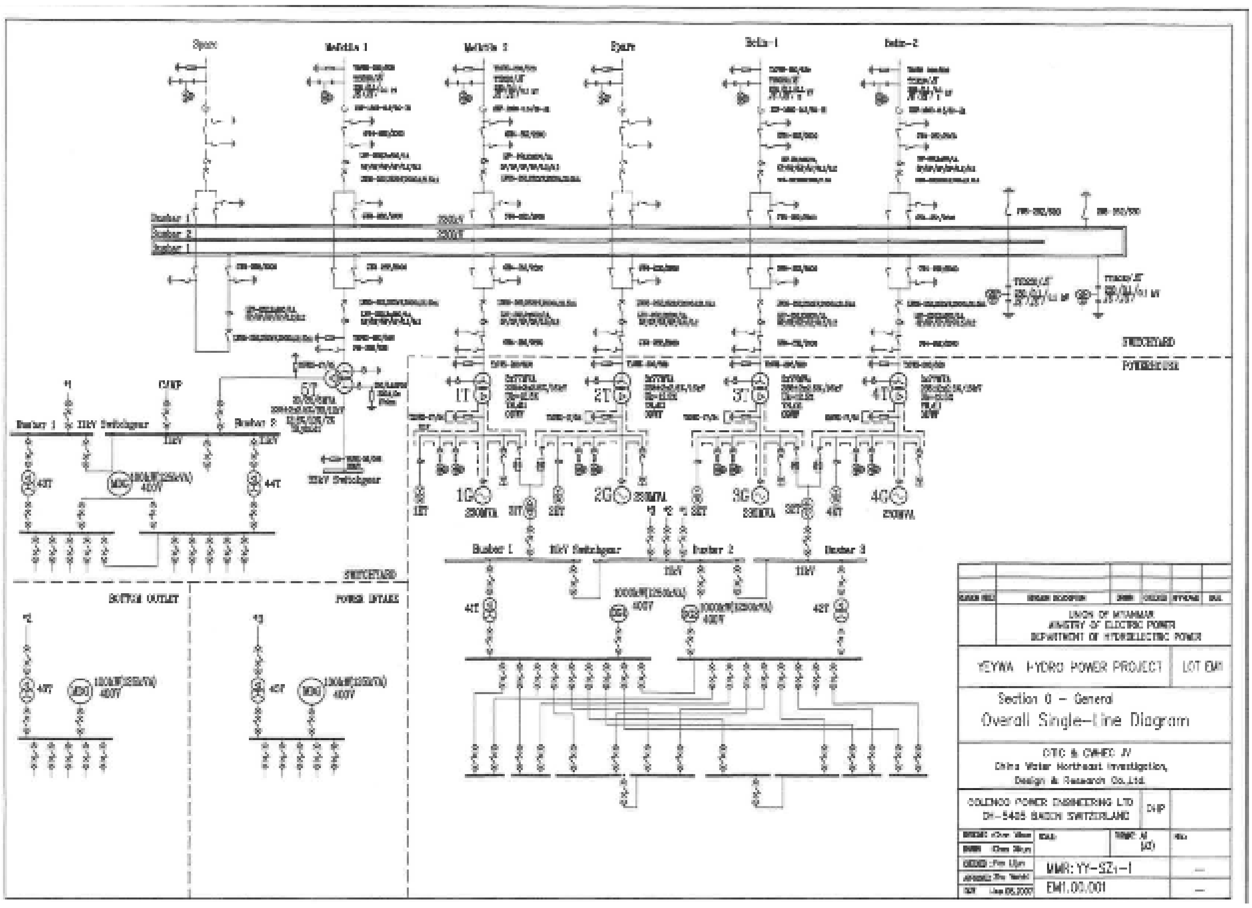


Fig.　Yeywa P/S Single Line Diagram

Equipment Specifications

Turbine	
Turbine type	: Francis turbine
Manufacturer	: SINOHYDRO
Model	: HLV180-LJ-492
Turbine size	: 49.20 dm
Rotation speed	: 142.86 rpm
Rated discharge volume	: 213.7 m^3 / s
Rotation (view from above)	: Clockwise
Rated water head	: 91.7 m
Minimum head	: 69.0 m
Maximum water head	: 106.3 m
Rated output	: 178.5 MW
Maximum output	: 199.4 MW
Momentary maximum output	: 219.4 MW
Maximum intake level	: 196.5 m
Maximum discharge level	: 95.8 m
Generator	
Manufacturer	: SINOHYDRO
Model	: 1DH7951-3WE21-Z
Rated output	: 230 MVA
Maximum output	: 255 MVA
Rated voltage	: 16 kV
Power factor	: 0.85
Rated current	: 8299 A
Frequency	: 50 Hz
Rated speed	: 142.9 rpm
Overspeed	: 285.0 rpm
Installation altitude (sea level)	: 84.36 m
Rated excitation current (IFN)	: 2444 A
No-load excitation current (IF0)	: 1380 A
Excitation type	: 130℃(at 234 V)
Excitation type	: Static excitation
Maximum winding temperature at rated output	: Stator / Rotor 80/90℃
Maximum winding temperature at maximum output	: Stator / Rotor 100/115℃

b. Layout

ž Lubricant analysis is conducted at the P/S.

Fig. Yeywa P/S Layout

c. Power Station Management and Education System

- The station is staffed by 148 people.
- 2-shift, 4-group system (approximately 17 duty persons per group, 7: 00 ～ 17: 00: day shift, 17: 00 ～ 7: 00 night shift)
- There are a large number of operators because the operators are collecting data from the local turbine generator control panel every hour.
- The Procurement Department manages spare parts and creates a list, but does not make purchases. In addition, the Accounting Department performs procedures after purchasing parts, and payroll management of power plant workers.
- The technical education system is shown below. New employee education is conducted at Paunglaung and Baluchaung No. 2 of Yeywa power station, and safety training is organized by EPGE.

Table: Technical Education System

	Matters stipulated at Yeywa power plant	Education organized by EPGE	Others
Operator	Training once a year (without license)	—	—
Engineer	One year training in China	Education for 2-3 months for 2-3 people	OJT at power stations

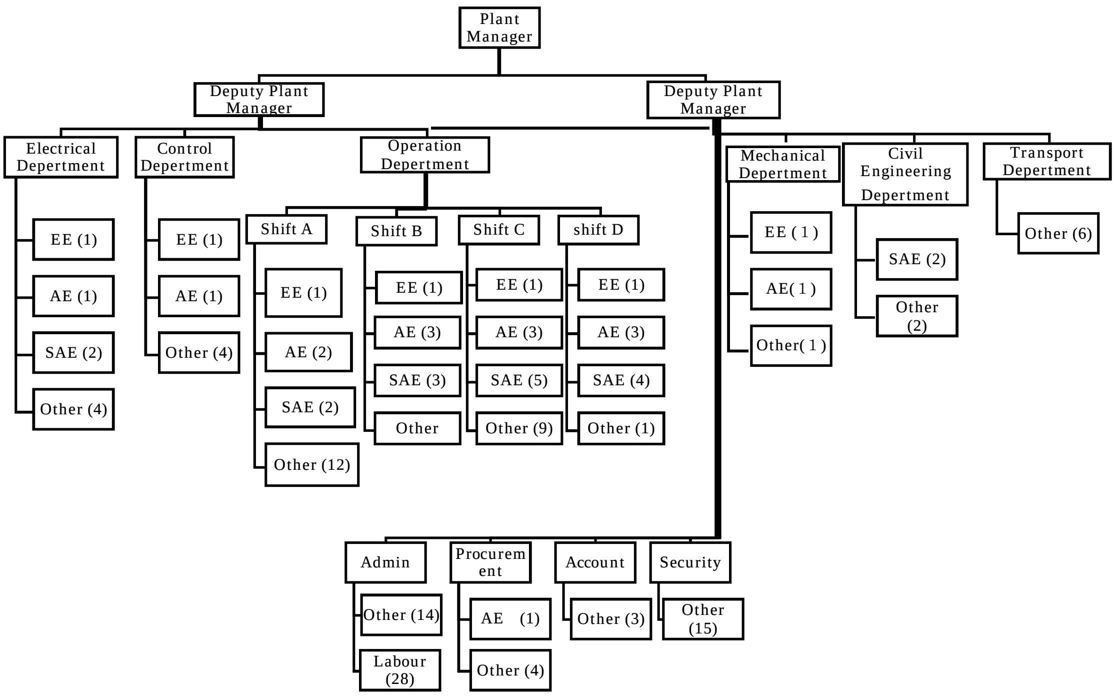


Fig. Organization Chart

d. Regulations and Manuals of Power Plant O&M

- The rules for O&M are created by the power plant. However, there are no manuals such as maintenance standards. Inspections are also conducted based on the MOM. There is no original manual. The correspondence with EPGE and LDC is also OJT, and there are no prescribed documents.

e. Parts Procurement Procedures

- The procurement of machine parts is mainly conducted by the EPGE headquarters. However, some inexpensive parts are procured by P/S.
- The equipment and parts that can be arranged at the discretion of the plant manager is $200 / instance, and the approver is the plant manager. If the price is higher than this, a budget request is

made to the EPGE headquarters, and EPGE (Procedure Department) tenders the order. However, in the case of the plant manager's approval, it is necessary to contact EPGE before purchasing. In that case, the department (electric, mechanical) that needs the parts writes a letter, and the director signs and sends it to the EPGE. Employees can also buy parts on the local market. In this case, employees can receive the payment at a later date by sending a budget document (P/S Account creation) to the EPGE Accounting Department.

（2）Daily Operation

a. Operation System

- Full load driving is done in the daytime, but the output is limited during the night. At night, there are also units that stop.
- When changing load, the LDC will contact the P/S. If the P/S cannot meet the LDC's required load, the P/S communicates the available output to the LDC. From the LDC, it is a command only for the total output (MW) of the power plant, and the assignment of each unit is decided by the Shift Chief Engineer or Plant Manager (basically the Shift Chief Engineer). If total output is satisfied, no LDC permission is required to start and stop the unit.
  Example: 780 MW command → 4 units operation → 550 MW command 4 →4 or 3 units (whether to stop 1 unit or not) is determined by the Shift Chief Engineer.
- Report data daily by phone. (Report to: EPGE's GCC (Generation Control Center), shift system available 24 hours) Also, monthly and annual reports will be reported to EPGE each time. EPGE reports data from power plants to the LDC.
  6 AM：Water Level, Inflow, Outflow, Reserve Capacity
  12PM：Total generation(MWh), each units power output

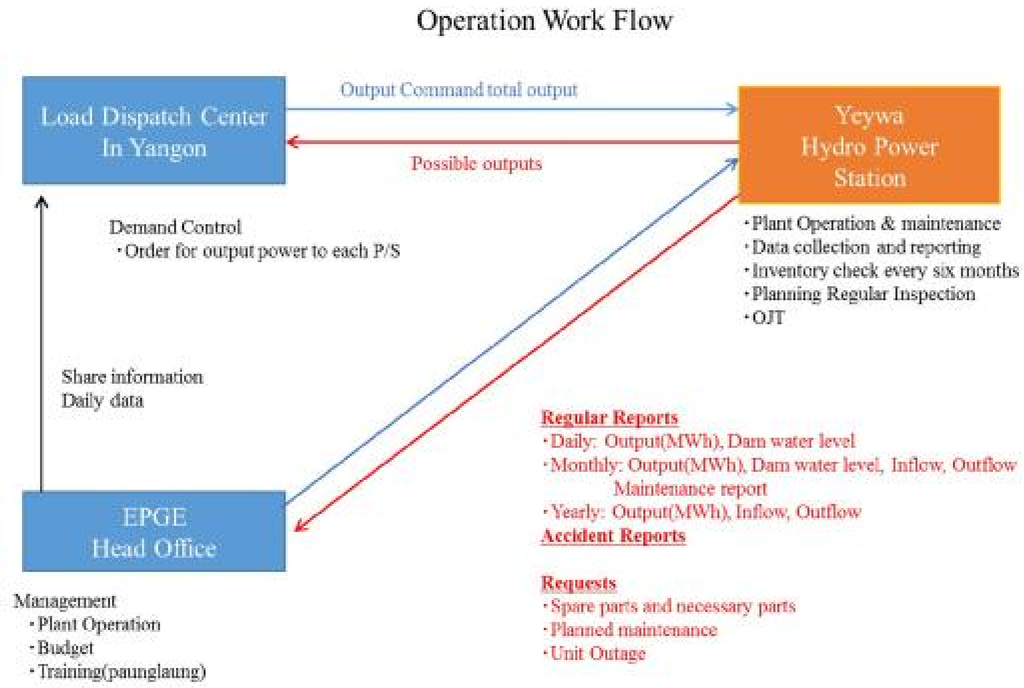


Fig. Report Route of Generation Record

- 2-shift, 4-group system (approximately 17 duty persons per group, 7: 00 ～ 17: 00: day shift, 17: 00 ～ 7: 00 night shift)
- There are a large number of operators because the operators are collecting data from the local turbine generator control panel every hour.
- Information transmission between on-duty teams uses handwritten notes.
- Daily inspections are conducted based on information obtained from the OEM. One year after the plant was handed over, OEM (Shynohydro) performed OJT. The minimum knowledge was acquired during OJT.
- The inspections are conducted by the operator every hour (patrol) and by the Mechanical Department three times a day.
- The maintenance engineer checks and controls the temperature, pressure, etc. by monitoring, and

records each value in the maintenance book.

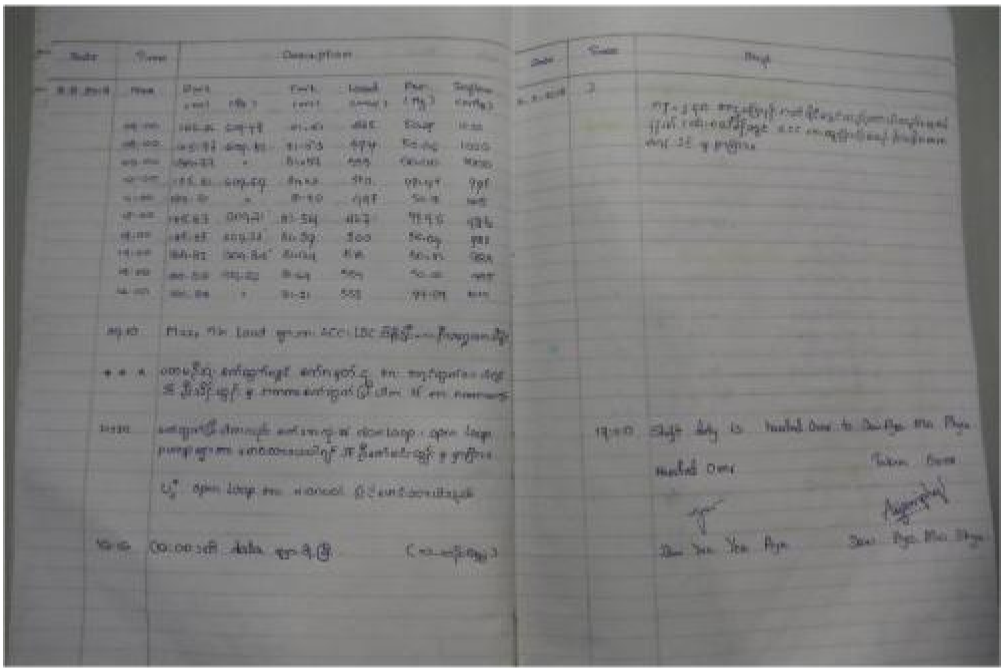


Fig. Handover Notes between Duty Teams

b. Quantitative Records Related to Power Generation

- Some important results (output, water level, etc.) are stored as data on Excel. In addition, the dam water level at the end of each month is recorded on a line graph. Other data are kept by handwriting.

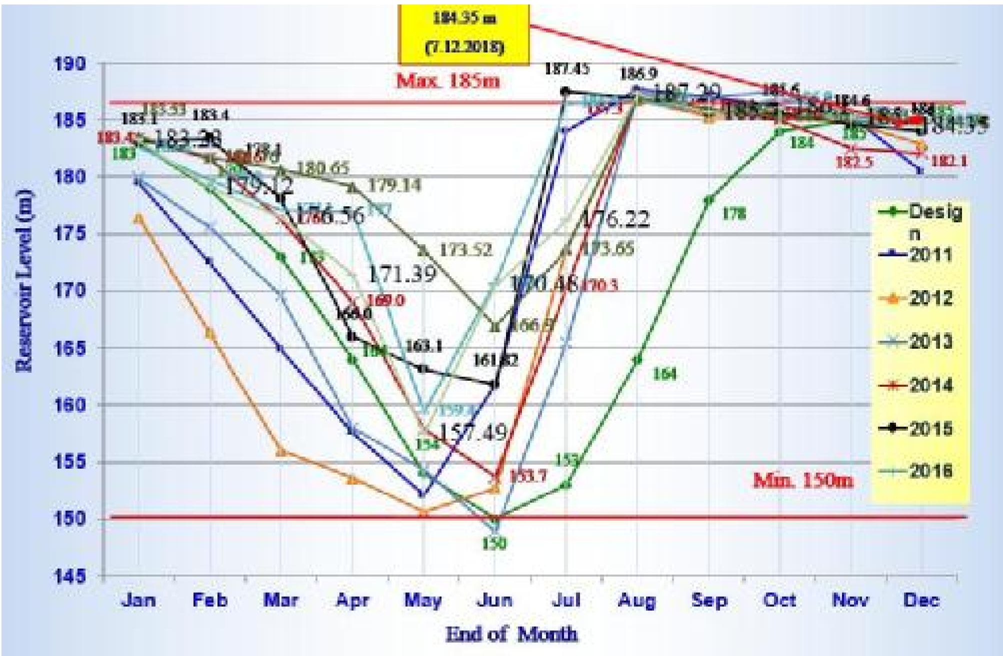


Fig. Change in Dam Water Level at the End of Every Month

- Operational results (water level, inflow volume, power generation volume) of each month are managed and saved since COD.
- Governor performance tests are conducted. Tests are conducted by engineers from other countries.

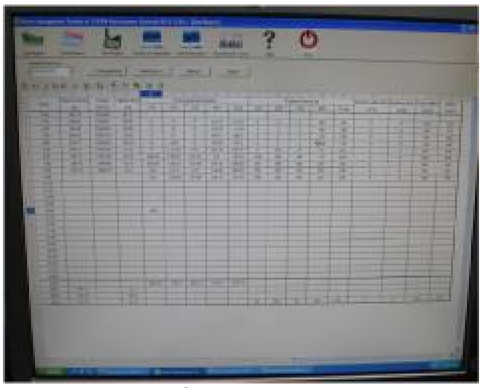


Fig. Operation Performance (Every Year)

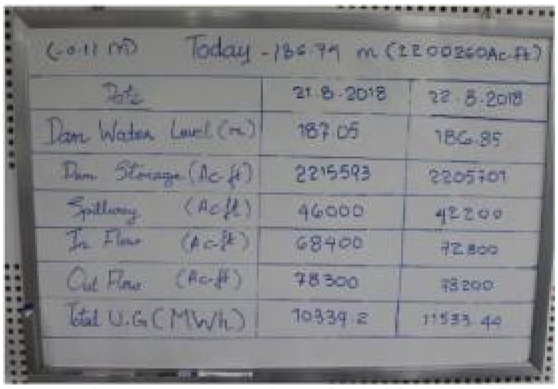


Fig. Daily Driving Results (Shared by Whiteboard)

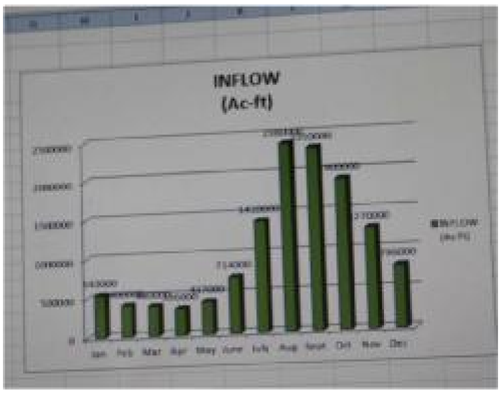


Fig. Operation Performance (Monthly)

Fig. Operation Performance (After COD)

c. Records of the Implementation Status of O&M

- For handover log and record collection, see “(2) a. Operation System”.
- For large-scale repairs, employees of the power plant prepare and submit a report to the EPGE headquarters.
- A dam water level monitoring device is installed, but it is only for data collection and it is not utilized for dam operation (control of discharge water).
- Repair records are prepared monthly. In addition, records such as CB replacement construction are also stored.

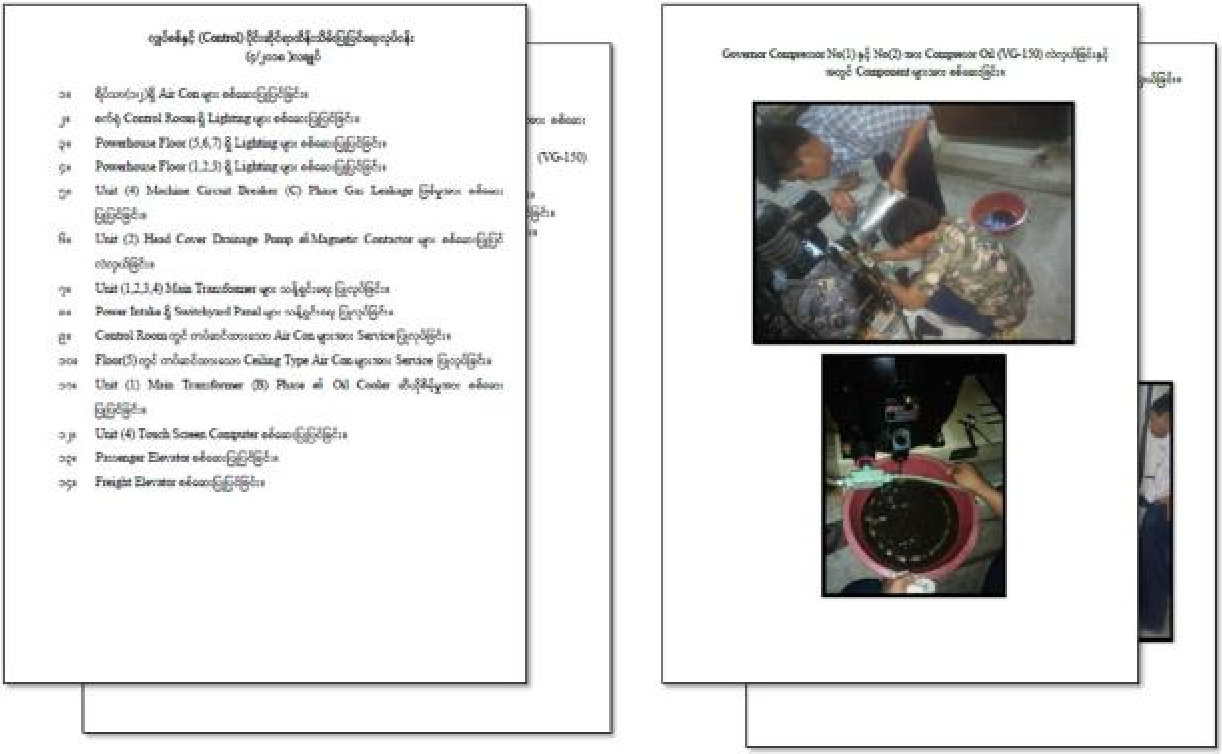


Fig. Monthly Report

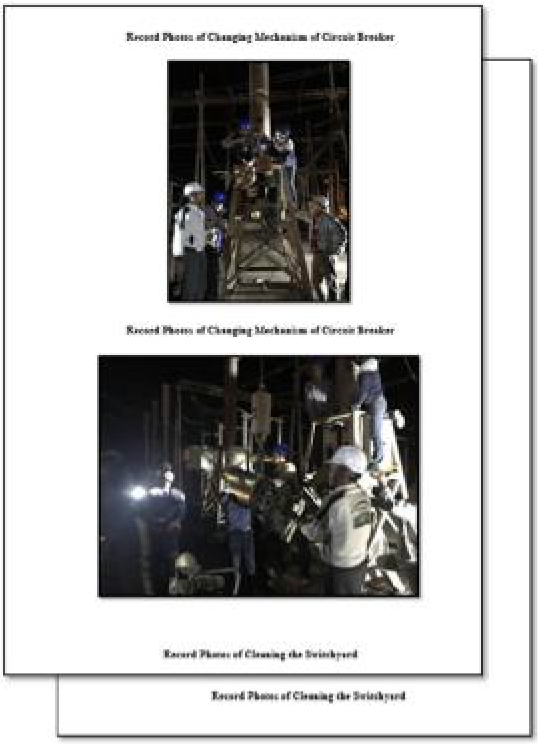


Fig. Record of CB Replacement Work

d. Spare Parts Management

- Spare parts are organized in a warehouse with stock cards. In addition, they check and report inventory every six months to the EPGE headquarters.
- Spare parts include mechanical parts (such as bearings) and parts prepared during construction. It is confirmed every day by five people.
- No spare parts control system

Fig. Spare Parts Storage Status

e. Actions against Events/Abnormalities and Records Management

- They cope with equipment trouble using manuals prepared by equipment manufacturers. In addition, the power station staff will notify the headquarters, the countermeasure headquarters and other power stations about the details of the trouble.
- If there is an abnormality in temperature, vibration, etc. recorded by the operator, the operator will contact the manufacturer.
- When a problem occurs, the operator verbally communicates with the maintenance personnel. Maintenance personnel carry out repair by themselves. (For important equipment, repairs are conducted under the guidance of the manufacturer.)
- If a problem occurs and the unit needs to be stopped, the response method will be determined by the flow in the below figure. First, the P/S reports to the GCC, the GCC contacts the EPGE head office, the EPGE head office requests the action of the LDC, and the LDC approves the action and notifies the GCC. Reporting and requests are made by phone or letter. In case of an emergency, the P/S directly contacts the GCC or LDC and obtains post-approval from the EPGE. The person in charge of maintenance of machinery and electricity at the P/S judges the necessity of communication. Mobile phones and transceivers are also available at holidays and at night.

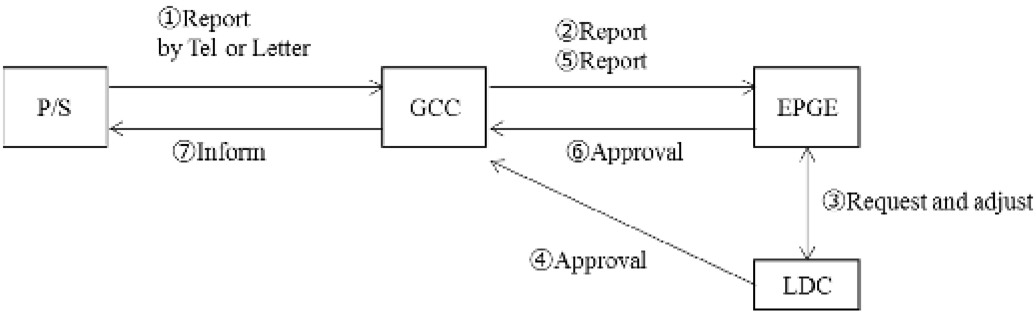


Fig. Approval Route for Unit Stop

f. Environment Management

Not performed.

g. Entry Management

It is necessary to obtain permission from the security room to enter the facility. (The person who obtained the permission receives the entry proof card)

(3) Periodic Maintenance

a. Maintenance Plan Management (Contents, Cycle, Budget, etc.)

- They make repair plans for the next year at the P/S. If a planned outage of the plant is required, it is necessary to request the EPGE separately in a letter.
- The EPGE coordinates with the DPTSC (NLDC, LDC), ESE, MESC, and YESC to get approval. There are many places of concern and it is not easy to get approval. See the relationship diagram below.

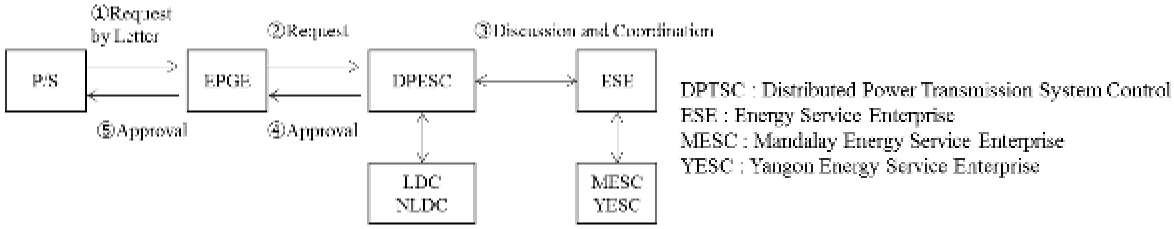


Fig. Approval Route for Planned Plant Stop

- Operation started in 2010, and periodic inspection has not been conducted yet.
- Implementation contents are decided by the EPGE every year.
- Facility inspection standards are planned based on manufacturer recommendations. Equipment inspection standards are created by plant employees based on OEM and past manufacturer OJT (1 year). Deployment to other plants has not been carried out.
- The members necessary for the regular inspection are dealt with by members from the EPGE, using support from other power stations.
- Yearly maintenance budget of Yeywa power plant: US $ 30,000

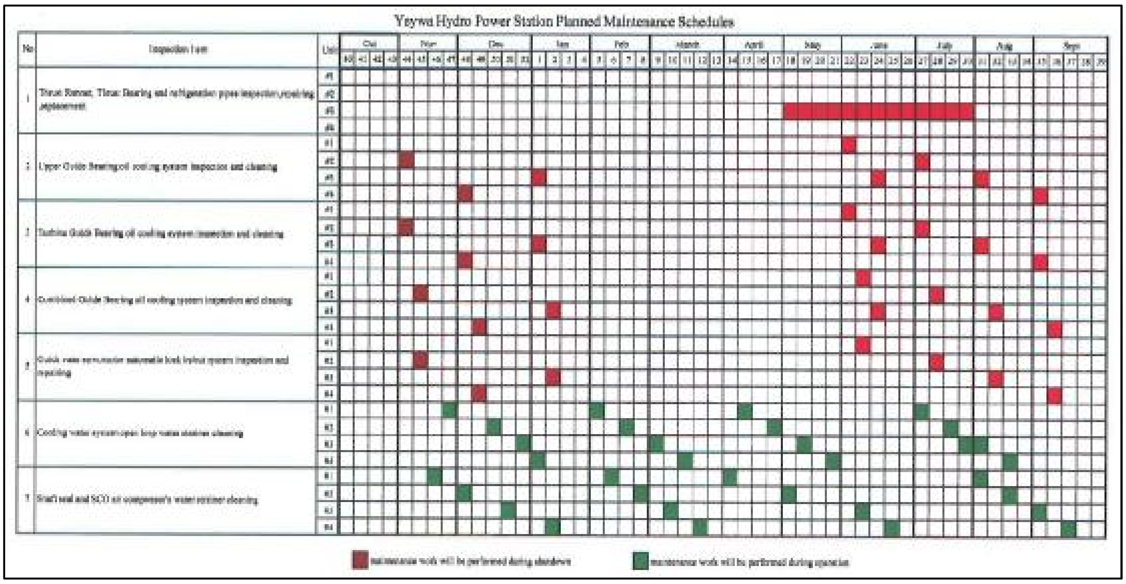


Fig. Annual Maintenance Plan

b. Implementation Status, Frequency, and Method of Periodic Maintenance

- In the case of major repairs, the power station staff prepares and submits a report to the EPGE headquarters.
- The turbine building has a machine room and there are processing machines such as a lathe.

c. Initiatives for Continuous Improvement

Not performed.

d. Status of Equipment

(a) Damage Status

Problems recognized by on-site inspection

No.	Issues at Unit #1
1	Cooling water pump bearing grease outflow (grease overfilling)
2	Cooling water pump (# 1 Unit B1) , motor overheated
3	Pressure gauge indication failure
4	Oil drips on generator floor, generator oil bleeds


Unit #1 Issue No.1


Unit #1 Issue No.1


Unit #1 Issue No.2


Unit #1 Issue No.3

Unit #1 Issue No.3


Unit #1 Issue No.4

No.	Issues at Unit #3
1	Failure due to damage to the # 3 unit generator thrust bearing due to equipment assembly failure during construction

Unit #3 Issue No.1

No.	Other Common Issues
1	Switching station failure due to spillover water from dam
2	Air conditioning problems in the turbine building

Other Common Issue No.1

Other Common Issue No.1

Other Common Issue No.1

Other Common Issue No.2 Other Common Issue No.2

Other Common Issue No.2

(b) Simple Diagnosis

- Ø Vibration diagnosis results

No. 1 B1 and B2 vibration measurement with coolant water pump and turbine generator. The reference value was exceeded in B1's cooling water pump. (Reference value: JIS B 8301)

Record name	Vibration diagnisis measurement
Power station	Yeywa Power station
Target equipment	# 1 unit B1 cooling water pump (closed)
Measurer	MHPS Yuichi Kuwahara Apichart Nootprasert
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	Capacity Pump	Capacity	751 m3/h
Rotation speed	1,480 r/min	Head	30 m
Motor rated current	-	Motor rated voltage	90 kW
Manufacturer	CHINA SHANGHAI KAIQUAN PUMP	Date of measurement August	2009-5

Measurement result

Date of measurement		24-Aug-18
Measuring Instrument	Type	Portable Vibration Meter
	Serial number	Rion Corporation Vibration Analyzer VA-10 00280204
Pump (fan) bearing Free side	V	45 μm
	H	25 μm
	A	55 μm
Pump (fan) bearing Motor side	V	63 μm
	H	62 μm
	A	87 μm
Motor bearing Coupling side	V	31 μm
	H	120 μm
	A	59 μm
Motor bearing Free side	V	43 μm
	H	120 μm
	A	51 μm

※Motor overheat (coupling side bearing temperature: 52.3 ° C), vibration control value (54μm) exceeded in each part. Vibration Reference Value (JIS B 8301):54μm

Record name	Vibration diagnisis measurement
Power station	Yeywa Power station
Target equipment	# 1 unit B2 coolant pump (open) pump for coolant cooler
Measurer	MHPS Yuichi Kuwahara Apichart Nootprasert
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

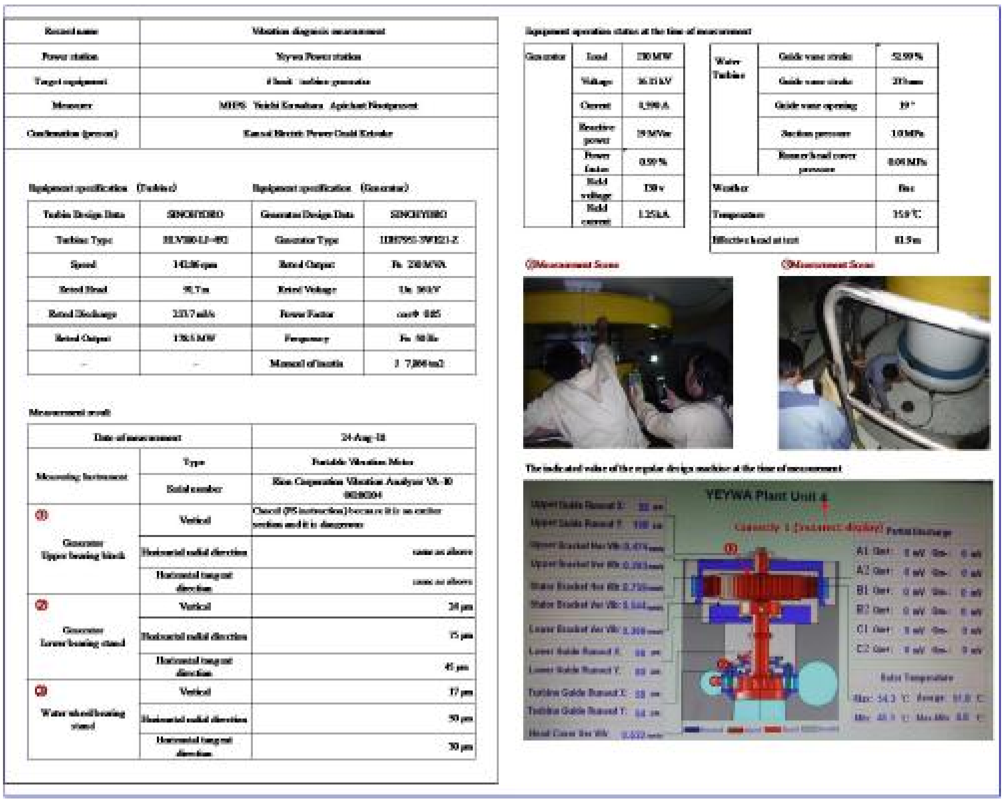
Equipment specification

Model	Capacity Pump	Capacity	703 m3/h
Rotation speed	1,480 r/min	Head	10 m
Motor rated current	-	Motor rated voltage	30 kW
Manufacturer	CHINA SHANGHAI KAIQUAN PUMP	Date of measurement August	2009-5

Measurement result

Date of measurement		24-Aug-18
Measuring Instrument	Type	Portable Vibration Meter
	Serial number	Rion Corporation Vibration Analyzer VA-10 00280204
Pump (fan) bearing Free side	V	18 μm
	H	24 μm
	A	23 μm
Pump (fan) bearing Motor side	V	31 μm
	H	34 μm
	A	36 μm
Motor bearing Coupling side	V	35 μm
	H	44 μm
	A	29 μm
Motor bearing Free side	V	19 μm
	H	18 μm
	A	41 μm

Vibration Reference Value (JIS B 8301):54μm



Record name	Vibration diagnosis measurement
Power station	Yeywa Power station
Target equipment	4 bank turbine generator
Measurer	MHPS Yoichi Kawahara Apichart Noolpanont
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification (Turbine) / Equipment specification (Generator)

Turbine Design Data	SINOHYDRO	Generator Design Data	SINOHYDRO
Turbine Type	HLV180-LJ-492	Generator Type	11H7955-3WE21-Z
Speed	142.86rpm	Rated Output	Pn 230MVA
Rated Head	91.7m	Rated Voltage	Un 16kV
Rated Discharge	233.7 m3/s	Power Factor	cosΦ 0.85
Rated Output	178.5 MW	Frequency	Fn 50Hz
-	-	Moment of inertia	J 7,800 t·m2

Measurement result

Date of measurement		24-Aug-18
Measuring Instrument	Type	Portable Vibration Meter
	Serial number	Rion Corporation Vibration Analyzer VA-10 00180204
① Generator Upper bearing block	Vertical	Cancel (PS instruction) because it is an earlier section and it is dangerous
	Horizontal radial direction	same as above
	Horizontal tangent direction	same as above
② Generator Lower bearing stand	Vertical	28 μm
	Horizontal radial direction	75 μm
	Horizontal tangent direction	45 μm
③ Water wheel bearing stand	Vertical	17 μm
	Horizontal radial direction	50 μm
	Horizontal tangent direction	30 μm

Equipment operation status at the time of measurement

Generator	Load	230 MW
	Voltage	16.15 kV
	Current	8,990 A
	Reactive power	19 MVar
	Power factor	0.99 %
	Field voltage	150 v
	Field current	1.25kA

Water Turbine	Guide vane stroke	52.99 %
	Guide vane stroke	215mm
	Guide vane opening	19 °
	Suction pressure	1.0 MPa
	Runner head cover pressure	0.08 MPa
Weather		fine
Temperature		15.9 ℃
Effective head at test		81.5m

②Measurement Scene

③Measurement Scene

The indicated value of the regular design machine at the time of measurement

Ø Current measurement results
We conducted measurements on the coolant pump motor. None of the reference values were exceeded.

◆Motor current measurement

Record name	Motor current measurement
Power station	Yeywa Power station
Target equipment	Cooling water pump(open)
Measurer	Kansai Electric Power Sato Ryo
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	-	Capacity	30kW
Number of poles	2	Serial number	-
Number of rotations	1470rpm	Rated voltage	400V
Rated current	55A	Insulation type	-
Manufacturer	-	Made date	2009.4

Measurement result

Date of measurement		24-Aug-18
Measurement tool	Type	-
	Serial number	-
Measured value (A)	Phase A	48.6
	Phase B	49.8
	Phase C	49.2

◆Motor current measurement

Record name	Motor current measurement
Power station	Yeywa Power station
Target equipment	Cooling water pump(close)
Measurer	Kansai Electric Power Sato Ryo
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	Y21230M-4	Capacity	30kW
Number of poles	2	Serial number	-
Number of rotations	1470rpm	Rated voltage	400V
Rated current	159A	Insulation type	-
Manufacturer	-	Made date	2009.4

Measurement result

Date of measurement		24-Aug-18
Measurement tool	Type	-
	Serial number	-
Measured value (A)	Phase A	143.3
	Phase B	149.3
	Phase C	148.3

Ø Insulation resistance measurement result
We conducted measurements on the drainage pump motor. None of the control values were exceeded.

◆ Motor current measurement

Record name	Low voltage motor current measurement
Power station	Yeywa Power station
Target equipment	Drainage pump
Measurer	Kansai Electric Power Sato Ryo
Confirmation (person)	Kansai Electric Power Ozaki Keisuke

Equipment specification

Model	-	Capacity	132kW
Number of poles	4	Serial number	-
Number of rotations	-	Rated voltage	400V
Rated current	-	Insulation type	-
Manufacturer	-	Made date	2009

Measurement result

Date of measurement		24-Aug-18
Measurement tool	Type	Insulation resistance measuring instrument 500V M
	Serial number	-
Environment	Weather	Cloudy
	Temperature（℃）	35.9
	Humidity（%）	61.3
Measured value	MΩ	1.2

Refrence value 1MΩ over

Drain Pump Motor Measurement Scene

（4）Predictive Maintenance

a. Control Status of Records

Daily check results are recorded by hand. Some important data (output, water level, etc.) are stored in Excel files. They manage the operation results (water level, inflow volume, power generation volume) of each month and have been keeping records since operation started.

b. Accumulation and Analysis of Operation Data

- Predictive maintenance that utilizes data of inspections by shift and maintenance personnel has not been implemented.
- Operators report to the machinery department if they find abnormalities in parameters such as temperature and vibration.

c. Past Performance of Predictive Maintenance Based on Data Analysis

Not performed.

d. Remarks

- Repair work is basically carried out under direct management. At the time of construction of the power plant, the EPC and the Ministry of Power and Energy cooperated to focus on acquiring technology. (Operation of crane, Slinging) There is no skills certification system. The P/S requested the EPGE to employ a Chinese operator as a backup during thrust repair work, but was rejected by the President. At the time of GCB replacement, the EPGE purchased a GCB from Siemens and replaced it without outsourcing. They do not outsource inspections of generators, etc. Only the building's chiller system and elevator inspection are outsourced. (There is an inspection contract with the local manufacturer.)
- The Deputy Minister (Dr. Tan Nei), who holds a doctoral degree, specializes in power transmission. The plant received a textbook on electrical installation prepared by the Deputy Minister. It is placed in the central control room and operators are learning from it.
- There is a satellite communication device as the communication environment. However, the communication speed is very slow.
- There is a need for remote monitoring (turbine, generator vibration) in the central control room.
- There is a need for introducing a cooling system. The area where the local control unit is located is so hot that you want to install a cooling system.
- There is no spare OPS. There is a demand for spare parts.
- Regarding spillover water problems at substations, the EPGE's role is maintenance and repair, and operation commands (management) are conducted by the DPTSC. Therefore, power cannot be generated as the EPGE thinks. According to the design curve, the P/S would like to make effective use of water resources, but there are problems with the transmission system and IPP operation rate guarantee (Take or Pay), so the P/S cannot operate as the EPGE wishes.
- Although portable measuring instruments are held, they are made in China and there is a need for

more reliable Japanese measuring instruments such as YOKOGAWA measuring instruments.

Model	Name
HZBB-10A	Transformer Turns Ratio Tester
HZJQ-1B-2	Transformer Oil Breakdown Voltage Tester (0-100 kV) With Mushroom Type Electrode, Desktop Specification
HZ-120kV/5m	5m Winding Tester (120 kV / 5 mA DC)
HZJQ-10K	Insulation Resistance Tester (10 kV)
HZ-3110A	Resistance Measuring Instrument

- Lubricant analysis is conducted. Testing of lubricating oil is requested by a testing organization within the MOEE.

Date - [illegible]

Hydraulic Oil (L-HM-46) [illegible] Technical Data Sheet [illegible] Characteristics Value [illegible]

NO.	CHARACTERISTICS	TEST METHOD	Hydraulic Oil (L-HM-46)	
			[illegible] Technical Data Sheet [illegible] Characteristics Value [illegible]	[illegible]
1.	Appearance	Visual	-	Bright & Clear
2.	Specific Gravity @ 60/60°F	ASTM D-1298	-	0.8833
3.	Colour	ASTM D-1500	-	< 2.0
4.	Flash Point ,(COC)°C	ASTM D- 92	238	220
5.	Pour Point , °C	ASTM D- 97	-33	<-24
6.	Kinematic Viscosity @ 40°C,cSt	ASTM D- 445	46.0	45.3
7.	Kinematic Viscosity @ 100°C,cSt	ASTM D- 445	-	6.7
8.	Viscosity Index	ASTM D-2270	100	100
9.	Grade	-	46	ISO VG 46
10.	Demulsifying Properties,(mins)	PN-86/C-04076	16	-
11.	Filterability: oil without water(s)	PN 90/C 04188	300	-

Tested by (Thi Shwe) Assistant Plant Manager

Checked by (San San Win) Assistant Plant Manager

Fig. Lubricant Analysis Results

- Of the 12 GCBs, 4 (BUS communication, 1, 2 and 4) have been replaced. It was planned to replace Nos.1 to 4, but there was a problem with the bus communication and it was urgently replaced. The future replacement schedule is undecided (waiting for approval of the EPGE).

စမ်းသပ်ခဲ့သည့် Testing လုပ်ငန်းများ

No	Test Name	1	2	3	Remark
1	Local Closed Test	Ok	Ok	Ok	
2	Local Opened Test	Ok	Ok	Ok	
3	Phase Disagreement Test (Local	Phase A Trip	Phase B Trip	Phase C Trip	Ok
4	Remote Closed	Ok	Ok	Ok	From PLC
5	Remote Trip	Ok	Ok	Ok	From PLC
6	Remote Closed	Ok	Ok	Ok	Synchro
7	Remote Trip	Ok	Ok	Ok	Manual Panel
8	Protection Trip	Ok	Ok	Ok	1.Shaft Seal 2.Temperature High 3.Buchholz Trip
9	Contact Resistance Test (Closed)	Ø A ok	Ø B ok	Ø C ok	Supply-100A Result-0.000mΩ
10	Insulation Test (Opened)	Ø A ok	Ø B ok	Ø C ok	Supply-5000V Result-α

Fig. GCB Test Results