The Republic of the Union of Myanmar
Ministry of Electricity and Energy
Electric Power Generation Enterprise

PREPARATORY SURVEY ON HYDROPOWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF THE UNION OF MYANMAR

FINAL REPORT

November 2016

Japan International Cooperation Agency

NEWJEC Inc.
Nippon Koei Co, Ltd.
The Kansai Electric Power Co., Inc.

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Preparatory Survey on Hydropower Plants Rehabilitation Project in the Republic of the Union of Myanmar

Final Report

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Abbreviations

Symbol	Abbreviation
AC	Alternating Current
ACB	Air Circuit Breaker
ACSR	Aluminum Conductor Steel Reinforced
ADB	Asian Develoment Bank
AIS	Air Insulated Switchgear
AVR	Automatic Voltage regulator
CBO	Community Based Organization
CCGT	Combined Cycle Gas Turbine
CDC	City Development Committee
CDT	Cyclic Digital Data Transmission
CFD	Computational Fluid Dynamics
COAX cable	Coaxial cable
COD	Commercial Operation Date
CT	Current Transformer
D/D	Detailed Design
D/L	Distribution Line
DC	Direct Current
DEPP	Department of Electric Power Planning
DHPI	Department of Hydropower Implementation
DHPP	Department of Hydropower Planning
DRD	Department of Rural Development
E/M	Electro-Mechanical
ECC	Environmental Compliance Certificate
ECD	Environmental Conservation Department
ECL	Environmental Conservation Law
ECR	Environmental Conservation Rules
EDG	Emergency Diesel Generator
EGAT	Electric Generating Authority of Thailand
EHS	Environmental Health and Safety
EIA	Environmental Impact Assessment
EIAP	Environmental Impact Assessment Procedure
EIRR	Economic Internal Rate of Return
EMoP	Environmental Monitoring Plan
EMP	Environmental Management Plan
ENPV	Economic Net Present Value
EPGE	Electric Power Generation Enterprise
EQG	Environmental Quality Guidelines
EQS	Environmental Quality Standards
ESE	Electricity Supply Enterprise
ETSI	European Telecommunications Standards Institute
FCB	Field Circuit Breaker
FERD	Foreign Economic Relation Department
FIRR	Financial Internal Rate of Return
FNPV	Financial Net Present Value
FWL	Full Water Level
GAD	General Administration Department
GAD	General Administration Department

Symbol	Abbreviation
GCB	Gas Circuit Breaker
GHG	Green House Gas
GIS	Gas Insulated Switchgear
GOJ	Government of Japan
GOM	Government of Myanmar
GOV	Governor
GOV-Reg	Governor-Regulator
HDCC	Hard-Drawn Copper Conductor
HH	Household
HIV/AIDS	Human Immunodeficiency Virus / Acquired Immune Deficiency Syndrome
HPGE	Hydropower Generation Enterprise
HPP	Hydropower Plant
IBAs	Important Bird and Biodiversity Areas
ICB	International Competitive Bidding
ID	Irrigation Department
IDC	Interest During Construction
IDPs	Internally Displaced Persons
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IHA	International Hydropower Association
IMG	International Management Group
INGO	International NGOs
IPP	Independent Power Producer
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
JV/BOT	Joint Venture / Build Operate and Transfer
KNG	Kayan National Guard
KNLP	Karenni New Land Party
KNPLF	Karenni Nationalities People's Liberation Support
KNPP	Karenni National Progressive Party
L/A	Loan Agreement
LED	Light Emitting Diode
LNG	Liquid National Gas
LNGO	Local NGOs
LOCCB	Low Oil Content Circuit Breakers
LTC	Line Terminal Cubicle
MCB	Miniature Circuit Breaker
MCC	Machine Control Center
MCCB	Molded Case Circuit Breaker
MEPE	Myanma Electric Power Enterprise
MESC	Mandalay Electricity Supply Corporation
MOAI	Ministry of Agriculture and Irrigation
MOALI	Ministry of Agriculture, Livestock and Irrigation
MOCB	Minimum Oil Circuit Breaker
MOECAF	Ministry of Environmental Conservation and Forestry
MOEE	Ministry of Electricity and Energy
MOEP	Ministry of Electric Power
MOLFRD	Ministry of Livestock, Fisheries and Rural Development
MONREC	Ministry of Natural Resource and Environmental Conservation

Symbol	Abbreviation
NBSAP	National Biodiversity Strategy and Action Plan
NDT	Nondestructive test
NEQEG	National Environmental Quality (Emission) Guidelines
NFB	Non-Fuse Breaker
NGO	Non-Government Organization
NPED	Ministry of National Planning and Economic Development
NPV	Net Present Value
NTFPs	Non-Timber Forest Products
O&M	Operation & Maintenance
OCB	Oil Circuit Breakers
ODA	Official Development Assistance
P/S	Power Station
PAP	Project Affected Person
PCB	Polychlorinated Biphenyl
PID-GOV	PID-Governor
POPs	Persistent Organic Pollutants
PPA	Power Purchase Agreement
PPE	Proper Protective Equipment
PPP	Prioritizing Public-private Partnership
PSD	Power System Department
PSS/E	Power Transmission System Planning Software
PTSCD	Power Transmission and System Control Department
RSSI	Received Signal Strength Indicator
S/N	Signal Noise Ratio
S/S	Substation
SCADA	Supervisory Control And Data Acquisition
SCF	Standard Conversion Factor
SDR	Software Definition Radio
SGP	Steel Gas Pipe
SOE(s)	State Owned Enterprise(s)
SPDC	State Peace and Development Council
SSG	Speed Signal Generator
SUS	Steel Use Stainless
T/L	Transmission Line
TOR	Terms of Reference
TPD	Thermal Power Department
TPP	Thermal Power Plant
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNHCR	United Nations High Commissioner for Refugees
UNIDO	United Nations Industrial Organization
UTM	Universal Transverse Mercator
VCB	Vacuum Circuit Breaker
VHF	Very High Frequency
VT	Voltage Transformer
YESB	Yangon City Electricity Supply Board
YESC	Yangon City Electricity Supply Corporation

CHAPTER 1

INTRODUCTION

Chapter 1 Introduction

1.1 Background of the Survey

As of November 2015, regarding power supply composition of existing power sources in the Republic of the Union of Myanmar (Myanmar), installed capacity of hydropower is 3,011 MW (including export amount to China of 521 MW), one of gas-fired thermal power is 1,520 MW and one of coal-fired thermal power is 120 MW. Installed capacity of hydropower occupied around 64.7% of total one. Because large-scale HPPs (Hydropower Plants) have operated since 2005, total installed capacity increased up to about 4,651 MW in 2015, which is approximately 1.3 times more than one in 2010. However due to output reduction during the dry season, aging (deteriorated) equipment and so on actual maximum power supply was only around 2,000 MW in 2014. On the other hand total power demand reached around 2,500 MW in 2014, power shortage of around 500 MW occurred and frequent planned power outage cannot be avoided. According to the scheme of the National Electricity Master Plan by MOEE (Ministry of Electricity and Energy) in Myanmar which JICA (Japan International Cooperation Agency) assisted to formulate, total power demand in 2030 is forecasted to increase up to around 14,500 MW at maximum, therefore enhancement of power supply is urgent issue.

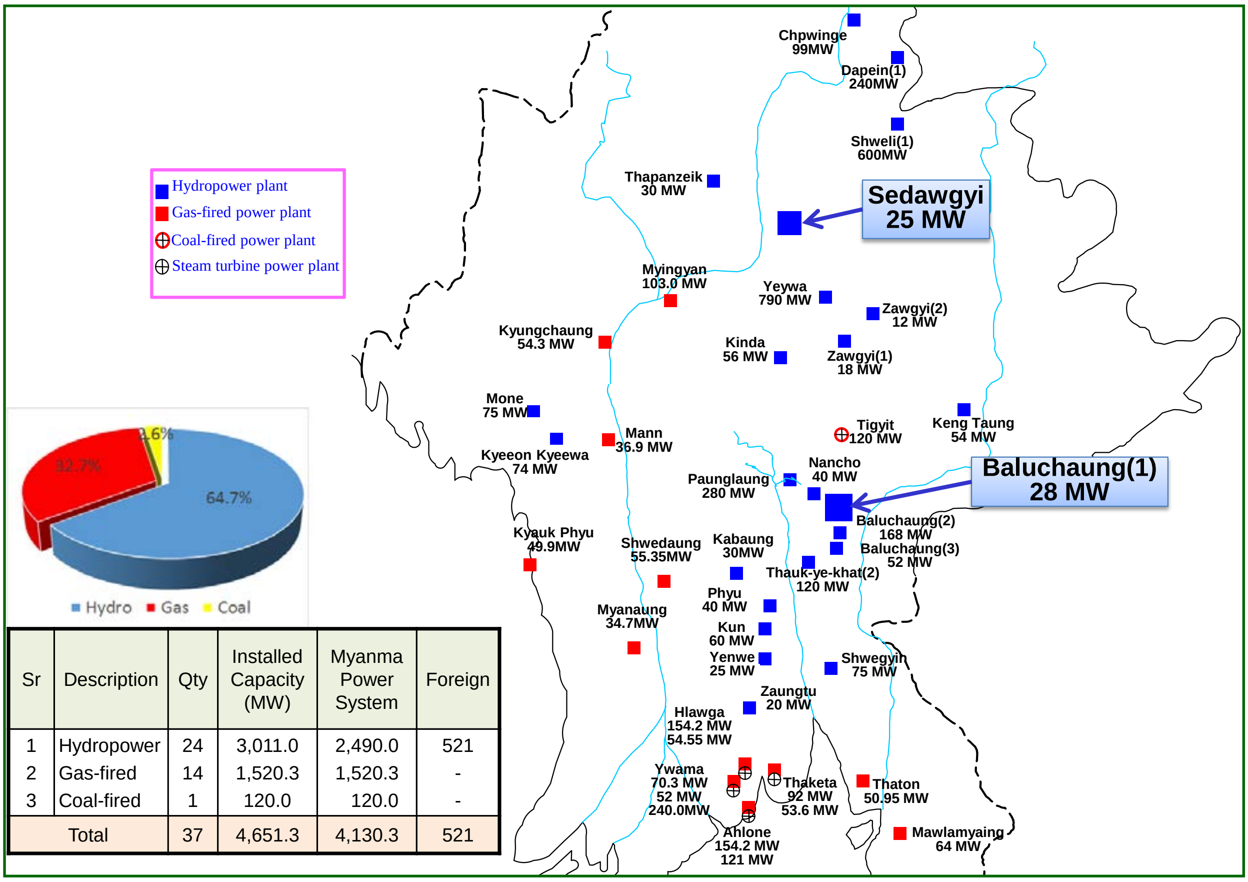
18 HPPs are of run-of-river type out of total 24 existing one, and total installed capacity of run-of-river type power plants is 1,082 MW, which is equivalent to around 36% of total hydropower output capacity. The run-of-river type HPPs especially which started commercial operation from 1970s to 1990s are aging without appropriate rehabilitation. Due to deterioration of facilities and failures of equipment, etc. as compared to rated power output of all existing HPPs actual power output decreased by approximately 30% in the rainy season and furthermore in the dry season actual one decreased by approximately 50% due to decrease of river flow.

In the speech by the President U Thein Sein in August 2013 power sector is considered to be the top priority of economic and social development. In the scheme of the National Electricity Master Plan, it is suggested that rehabilitation of these power plants is recommended from a standpoint of preventive measures against failures because deterioration of major equipment and parts of Sedawgyi HPP, Baluchaung No.1 HPP, etc. are progressing, also rehabilitation of existing power plants is regarded as the top priority measure from viewpoint of high economic efficiency, low environmental burden, no need of additional fuel and so on.

Considering above-mentioned situations, GOM (Government of Myanmar) requested the GOJ (Government of Japan) regarding the rehabilitation of Sedawgyi HPP and Baluchaung No.1 HPP to acquire further lifetime for power generation. In response to the request, JICA decided to conduct the “Preparatory Survey on Hydropower Plants Rehabilitation Project in the Republic of the Union of Myanmar” (the Survey).

1.2 Objectives of the Survey

The Survey aims to carry out the study for existing hydropower facilities by means of investigation of project outline, current conditions, required repair/replacement works, cost estimate, implementation structure, management, O&M (operation and maintenance) structure, environmental and social considerations and economic and financial evaluation of HPP rehabilitation project for Baluchaung No. 1 and Sedawgyi HPPs, which is required for validating the project feasibility.



Sr	Description	Qty	Installed Capacity (MW)	Myanma Power System	Foreign
1	Hydropower	24	3,011.0	2,490.0	521
2	Gas-fired	14	1,520.3	1,520.3	-
3	Coal-fired	1	120.0	120.0	-
	Total	37	4,651.3	4,130.3	521

Fig. 1.2-1 Location Map of Existing Power Plants and Objective Sites of the Study in Myanmar (as of November 2015)

1.3 Outline of the Survey

Item	Description	Special note / point of concern etc.
Objectives	The Survey aims to carry out the following study of HPP rehabilitation project required for validating project feasibility. 1) Objectives examination 2) Feasibility study 3) Procurement / construction method 4) Project implementation plan / schedule 5) Project cost estimate 6) Implementation structure and capability of the project implementation agency 7) Operation and management plan / O&M structure 8) Economic & financial analysis / Project evaluation 9) Environmental and social considerations	1) Selection of equipment / facilities required for rehabilitation 2) Utilization of prominent technologies of Japan 3) Design based on the concept of preventive maintenance
Objective area	Mandalay Region (Sedawgyi HPP) Kayah State (Baluchaung No.1 HPP)	Attention on security situation
Implementation agency	MOEE (Ministry of Electricity and Energy :former MOEP[*1]) EPGE (Electric Power Generation Enterprise, former HPGE[*2])	Correspondence to institutional reforms of MOEE Consideration for participation of MEPE[*3] depending on scope of the Project
Scope of Work	The Survey is to be implemented by the following 3 phases (1) Data Collection and Project Site Investigations (2) Selection of Rehabilitation Equipment / Facilities for the Future Project (3) Feasibility Study for the Future Rehabilitation Project ✓ Rehabilitation of existing HPP facilities (Sedawgyi HPP: 25MW, Baluchaung No.1 HPP: 28MW) ✓ Rehabilitation of relevant transmission and substation facilities (230kV, 132kV) ✓ Consulting services (preliminary design, bidding, construction supervision, technical facilitation for capacity building of O&M, etc.)	1) Site investigation in consideration of local conditions 2) Ensuring opportunity of discussion with MOEE

*1 MOEP: Ministry of Electric Power, currently reformed to MOEE (Ministry of Electricity and Energy)
*2 HPGE: Hydropower Generation Enterprise, currently reformed to EPGE (Electric Power Generation Enterprise)
*3 MEPE: Myanma Electric Power Enterprise, currently reformed to Power Transmission and System Control Department (PTSCD)

1.4 Work Flow of the Survey

Contents of the Survey is classified into three phases, “Phase 1: Data Collection and Project Site Investigations”, Phase 2: Selection of Rehabilitation Facilities for the Future Project” and “Phase 3: Feasibility Study for the Future Project”. Major study components in each phase and schedule is shown in Fig. 1.4-1 and the overall work flowchart is shown in Fig. 1.4-2. Actual survey results were described in Section 1.5.2.

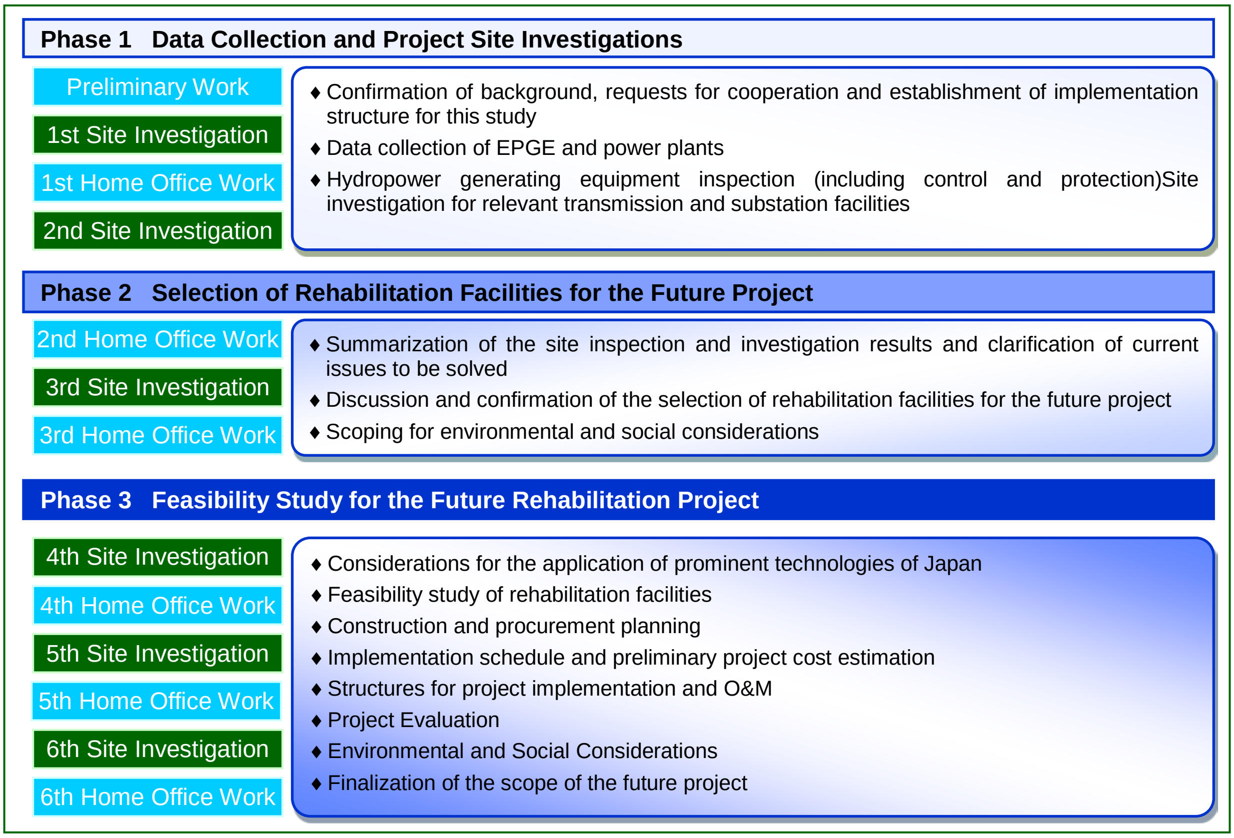


Fig. 1.4-1 Main Components of the Survey in each Phase

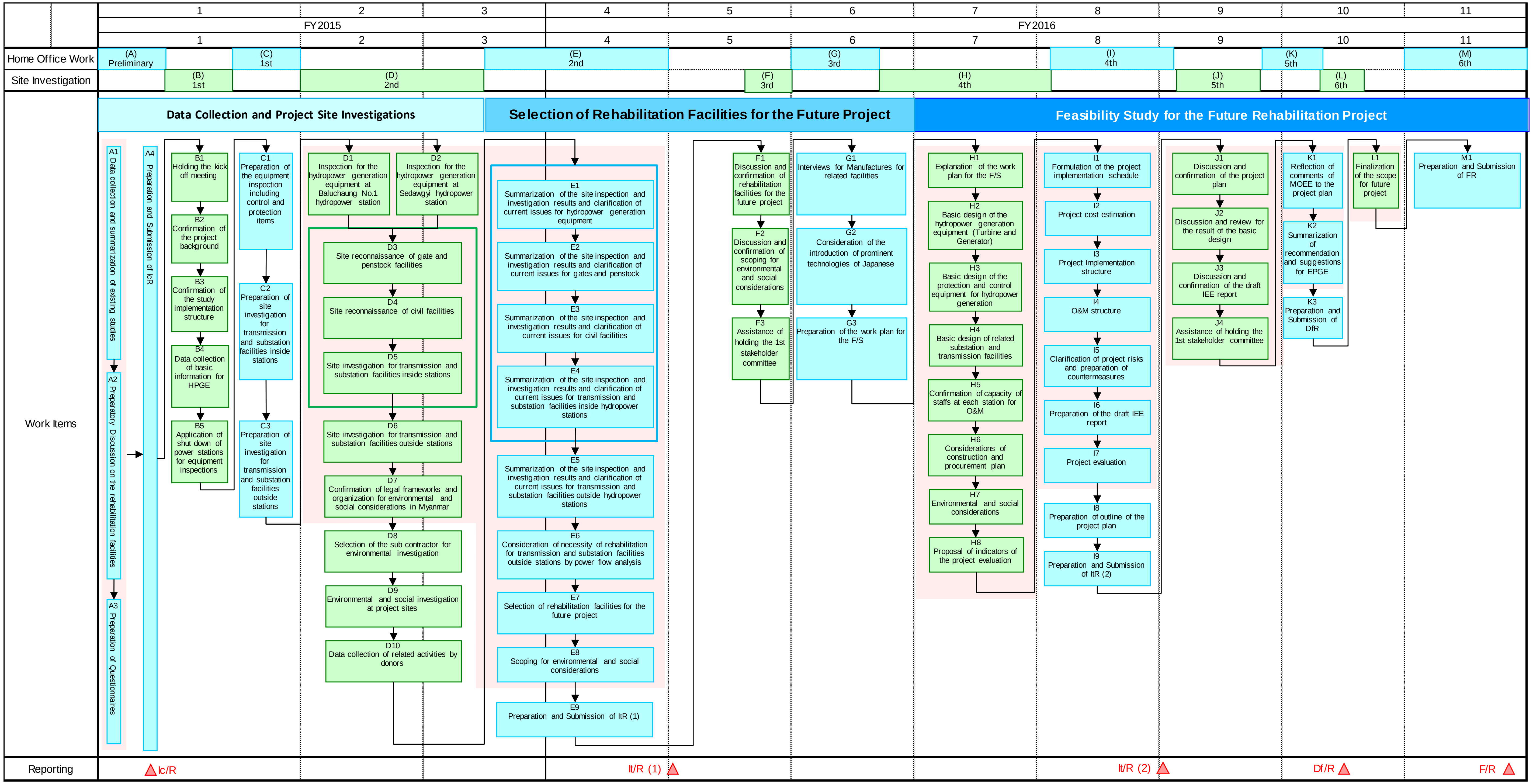


Fig. 1.4-2 Overall Workflow Chart of the Survey

1.5 Team Composition and Survey Schedule

1.5.1 Team Composition

JICA organized the consultant team for the Survey (JICA Survey Team). JICA Survey Team consists of the following experts and coordinator.

Table 1.5-1 Member of JICA Survey Team

Assignment	Name	Company
Team Leader/Hydropower Development Plan	Yuichi SANO	NEWJEC
Sub Team Leader /Civil Facilities	Taketoshi MATSUNAGA	NEWJEC
Hydropower Generating Equipment (Turbine)	Kimio TAKAHASHI	NEWJEC
Hydropower Generating Equipment (Generator)	Shoichi KUSHIMOTO	NEWJEC
Power System Planning and Analysis	Kiyotaka UENO	NEWJEC
Substation Facilities	Ryosuke TOKUNAGA	Nippon Koei
Transmission Line Facilities	Yuya UEHARA	Nippon Koei
Control and Protection Equipment	Tatsunobu SASAKI	KANSAI
Gate and Penstock	Taro UENO	Nippon Koei
Economic and Financial Analysis	Naoya AZEGAMI	Nippon Koei
Environmental and Social Consideration	Shinjiro OKUZAWA	Nippon Koei
Communication Facilities	Toshihiro KATSUMATA	Nippon Koei
Project Coordinator/Hydropower Development Plan	Sho SHIBATA	NEWJEC
Project Coordinator	Rika EBIHARA	NEWJEC

1.5.2 Survey Schedule

Site investigations were conducted six (6) times in Myanmar. A kick-off meeting was held on January 11th, 2016 with EPGE (Electric Power Generation Enterprise) at Naypyidaw.

- The 1st site investigation: January 10th to 16th, 2016
- The 2nd site investigation: January 30th to March 3rd, 2016
- The 3rd site investigation: May 22nd to 28th, 2016
- The 4th site investigation: June 19th to August 4th, 2016
- The 5th site investigation: September 6th to 24th, 2016
- The 6th site investigation: October 10th to 16th, 2016

(1) 1st Site Investigation

A kick-off meeting was held with EPGE during the 1st site investigation at Naypyidaw. JICA Survey Team explained the work plan, schedule, methodology and so on using Inception Report and both parties confirmed the contents and exchanged the memorandum. JICA Survey Team requested EPGE to arrange schedule, to make necessary preparation for the site inspection test of generating equipment at Baluchaung No.1 and Sedawgyi HPPs, which is planned to be carried out in the 2nd site investigation in February 2016.

Table 1.5-2 Member and Schedule of 1st Site Investigation

Position	Name	Period	Company
Team Leader/ Hydropower Development Plan	Yuichi SANO	from January 10th to 16th	NEWJEC
Sub Team Leader / Civil Facilities	Taketoshi MATSUNAGA	from January 10th to 16th	NEWJEC
Hydropower Generating Equipment (Turbine)	Kimio TAKAHASHI	from January 10th to 16th	NEWJEC
Power System Planning and Analysis	Kiyotaka UENO	from January 10th to 16th	NEWJEC
Substation Facilities	Ryosuke TOKUNAGA	from January 10th to 16th	Nippon Koei
Transmission Line Facilities	Yuya UEHARA	from January 10th to 16th	Nippon Koei
Project Coordinator/ Hydropower Development Plan	Sho SHIBATA	from January 10th to 16th	NEWJEC

Table 1.5-3 Activities during 1st Site Investigation

Date	Itinerary		
1	2016/1/10	Sun	Move to Yangon
2	2016/1/11	Mon	Move to Naypyidaw 10:00 Kick-off Meeting with EPGE
3	2016/1/12	Tue	09:20 U Htain Lwin, MD*1 of PTSCD 10:00 Dr. Win Myint, SE*2 of EPGE 17:00 U Khin Maung Win, DG*3 of DEPP*4 18:00 DyCE*5 of PTP*6-PTSCD
4	2016/1/13	Wed	10:30 U Tin Zaw, DyDG of ID*7-MOAI*8 14:00 U Zaw Moe Win, EE*9 of EPGE 15:00 U Thein Thura, CE*10 of PSD*11-PTSCD
5	2016/1/14	Thu	Site Visit to Shwemyo SS*12 10:00 Daw Mi Mi Khaing, DyDG*13 of DEPP 11:00 Dr. Win Myint, SE of EPGE 12:00 U Myo Win Zaw, AE*14 of PSD-PTSCD Data Collection Move to Yangon
6	2016/1/15	Fri	10:30 United Nations Information Managing Unit (Landmines) Move to Japan
7	2016/1/16	Sat	Return to Japan

*1 MD:	Managing Director	*8 MOAI:	Ministry of Agriculture and Irrigation, currently reformed to MOALI (Ministry of Agriculture, Livelihood and Irrigation)
*2 SE:	Superintending Engineer	*9 EE:	Executive Engineer
*3 DG:	Director General	*10 CE:	Chief Engineer
*4 DEPP:	Department of Electric Power Planning	*11 PSD:	Power System Department
*5 DyCE:	Deputy Chief Engineer	*12 SS:	Substation
*6 PTP:	Power Transmission Team	*13 DyDG:	Deputy Director General
*7 ID:	Irrigation Department	*14 AE:	Assistant Engineer

(2) 2nd Site Investigation

JICA Survey Team implemented the 2nd site investigation in Myanmar from January 30th to March 5th, 2016. Main contents of the 2nd site investigation are;

1) Inspection test of the hydropower generating equipment
2) Site investigation of the related transmission and substation facilities
3) Site investigation of the civil, penstock and gate facilities
4) Selection of sub consultants for environmental and social study

Members and stay period of JICA Survey Team are as shown below. Considering study components and schedule of each experts, Team is divided into three (3) groups, "Group 1: Team Leader", "Group 2: Hydropower Generation Equipment", and "Group 3: Transmission and Substation".

In order to check and grasp the current conditions of the generating equipment, it is necessary to stop the turbine and generator for the site inspection. The inspection was carried out for each unit in series to minimize the reduction of power generation. The site inspection of gates, penstock and civil structures can be carried out without shutdown of the unit. The first inspection was conducted at Baluchaung No.1 HPP and the next was conducted at Sedawgyi HPP.

The inspection schedule and procedure is basically as below.

Day	Work Procedures
1st to 2nd day	(1) Shutdown the unit (Close inlet valve or penstock gate, and/or draft tube gate or tailrace gate. Stop relevant auxiliary equipment. Stop power supply to control system. Attach to generator with earthing device.) (2) Drain water from spiral casing and draft tube (3) Open manholes of spiral casing and draft tube (4) Set up scaffolding for turbine inspection (5) Remove generator cover for generator inspection (6) Disconnect both neutral earth lead and power lead of generator for insulation resistance test of stator winding (7) Remove carbon brushes on collector ring for insulation resistance test of rotor winding
3rd to 5th day	(1) Inspect inside of the turbine (2) Inspect stator and rotor windings (3) Inspect cubicles, transformers, switchgears and other equipment (4) Measure insulation resistance of generator windings (5) Measure polarization index of stator winding
6th to 7th day	(1) Remove scaffolding for turbine inspection (2) Close manholes of spiral casing and draft tube (3) Reconnect both neutral earth lead and power lead of generator (4) Set up carbon brushes on collector ring (5) Attach generator cover (6) Remove earthing device (7) Restore power supply to the control system (8) Fill the turbine with water (9) Operate the unit

Table 1.5-4 Member and Schedule of 2nd Site Investigation

Position	Name	Period	Company
Group 1 (Team Leader)			
Team Leader/ Hydropower Development Plan	Yuichi SANO	from January 31st to February 13th	NEWJEC
Power System Planning and Analysis	Kiyotaka UENO	from January 31st to February 20th	NEWJEC
Environmental and Social Consideration	Shinjiro OKUZAWA	from January 30th to February 25th	Nippon Koei
Project Coordinator/ Hydropower Development Plan	Sho SHIBATA	from January 27th to March 4th	NEWJEC
Group 2 (Hydropower Generating Equipment)			
Sub Team Leader /Civil Facilities	Taketoshi MATSUNAGA	from January 30th to March 3rd	NEWJEC
Hydropower Generating Equipment (Turbine)	Kimio TAKAHASHI	from January 30th to March 3rd	NEWJEC
Hydropower Generating Equipment (Generator)	Shoichi KUSHIMOTO	from January 30th to March 4th	NEWJEC
Control and Protection Equipment	Tatsunobu SASAKI	from January 30th to February 29th	KANSAI
Gate and Penstock	Taro UENO	from January 30th to February 29th	Nippon Koei
Group 3 (Substation and Transmission Line)			
Substation Facilities	Ryosuke TOKUNAGA	from January 31st to February 12th	Nippon Koei
Transmission Line Facilities	Yuya UEHARA	from January 31st to February 19th	Nippon Koei

Table 1.5-5 Activities during 2nd Site Investigation

	Date	Day	Group 1 (Team Leader)	Group 2 (Power Generating Equipment)	Group 3 (Substation and Transmission Line)
1	2016/1/30	Sat		Move to Yangon	
2	2016/1/31	Sun	Move to Yangon	Move to Loikaw	Move to Yangon
3	2016/2/1	Mon	10:00 JICA 13:30 WB	Data Collcetion at BLC No.1 HPP	Move to Naypyidaw
4	2016/2/2	Tue	Move to Naypyidaw 11:30 EPGE, U Khin Maung Win (MD) 13:00 EPGE, Dr. Win Myint (SE) 15:00 PTSCD, U Kyi San Linh (SE)	Data Collcetion at BLC No.1 HPP	AM: Site Inspection at Taungoo SS PM: Move to Loikaw
5	2016/2/3	Wed	Move to Loikaw Site Investigation of BLC No.1 HPP	Site Inspection of Unit-1 at BLC No.1 HPP	Site Inspection at Baluchaung No.1 HPP
6	2016/2/4	Thu	Site Investigation of BLC No.1 HPP	Site Inspection of Unit-1 at BLC No.1 HPP	Site Inspection at Baluchaung No.1 HPP
7	2016/2/5	Fri	Site Investigation of BLC No.1 HPP	Site Inspection of Unit-1 at BLC No.1 HPP	Interview to Maintenance Staff of SS and TL
8	2016/2/6	Sat	Move to Heho	Reporting	Move to Heho
9	2016/2/7	Sun	Move to Mandalay	Reporting	Move to Mandalay
10	2016/2/8	Mon	Move to Sedaw gyi Site Investigation of Sedaw gyi HPP	Data Collcetion at BLC No.1 HPP	AM: Site Inspection at Aungpinlae SS PM: Site Inspection at Belin SS
11	2016/2/9	Tue	Site Investigation of Sedaw gyi HPP	Data Collcetion at BLC No.1 HPP	AM : Move to Sedaw gyi HPP PM: Site Inspection at Sedaw gyi HPP
12	2016/2/10	Wed	Site Investigation of Sedaw gyi HPP Move to Mandalay and NPT	Site Inspection of Unit-2 at BLC No.1 HPP	Site Inspection at Sedaw gyi HPP

Date		Day	Group 1 (Team Leader)	Group 2 (Power Generating Equipment)	Group 3 (Substation and Transmission Line)
13	2016/2/11	Thu	10:30 PTSCD, U Kyi San Linh (DyCE) 14:00 EPGE, Dr. Win Myint (SE) 16:00 PTSCD, U Htain Lw in (MD) Return to Yangon (Mr. SANO)	Site Inspection of Unit-2 at BLC No.1 HPP	Move to Mandalay Interview to Maintenance Staff of SS and TL
14	2016/2/12	Fri	Reporting	Reporting	Reporting / Interview to Maintenance Staff of SS and TL
15	2016/2/13	Sat	Reporting	Reporting	Move to NPT
16	2016/2/14	Sun	Reporting	Move to Mandalay	Reporting
17	2016/2/15	Mon	Data collection at NPT	Move to Sedaw gyi HPP Data Collcetion at Sedaw gyi HPP	Discussion w ith PTSCD
18	2016/2/16	Tue	Selection of Local consultant	Data Collcetion at Sedaw gyi HPP	Discussion w ith PTSCD
19	2016/2/17	Wed	Selection of Local consultant Move to Yangon	Site Inspection of Unit-2 at Sedaw gyi HPP	Reporting
20	2016/2/18	Thu	Contract negotiation	Site Inspection of Unit-2 at Sedaw gyi HPP	Return to Japan
21	2016/2/19	Fri	Contract signing	Site Inspection of Unit-2 at Sedaw gyi HPP Discussion w ith ID-MOALI	
22	2016/2/20	Sat	Reporting	Reporting	
23	2016/2/21	Sun	Reporting	Reporting	
24	2016/2/22	Mon	Data Collection at YGN	Data Collcetion at Sedaw gyi HPP	
25	2016/2/23	Tue	Data Collection at YGN	Data Collcetion at Sedaw gyi HPP	
26	2016/2/24	Wed	Data Collection at YGN Return to Japan	Site Inspection of Unit-1 at Sedaw gyi HPP	
27	2016/2/25	Thu		Site Inspection of Unit-1 at Sedaw gyi HPP	
28	2016/2/26	Fri		Site Inspection of Unit-1 at Sedaw gyi HPP Discussion w ith ID-MOALI	
29	2016/2/27	Sat		Move to Yangon Reporting	
30	2016/2/28	Sun		Reporting	
31	2016/2/29	Mon		Move to Naypyidaw Discussion w ith EPGE	
32	2016/3/1	Tue		Reporting to EPGE Return to Yangon	
33	2016/3/2	Wed		Reporting	
34	2016/3/3	Thu		Reporting to JICA Return to Japan	

(3) 3rd Site Investigation

JICA Survey Team implemented the 3rd site investigation in Myanmar from May 22nd to May 28th, 2016. Main contents of the 3rd site investigation are;

1) Explanation and discussion on Interim Report (1)
2) Discussion about objective rehabilitation equipment / facilities for future ODA (Official Development Assistance) Rehabilitation Project.
3) Discussion on relevant substation and transmission line facilities
4) Discussion on problems of Maintenance gates and Penstock gates of Sedawgyi Dam with ID, MOALI.
5) Scoping of environmental and social consideration and discussion and coordination of Stakeholder Meeting

Table 1.5-6 Member and Schedule of 3rd Site Investigation

Position	Name	Period	Company
Team Leader/ Hydropower Development Plan	Yuichi SANO	from May 22nd to 28th	NEWJEC
Sub Team Leader / Civil Facilities	Taketoshi MATSUNAGA	from May 22nd to 28th	NEWJEC
Hydropower Generating Equipment (Turbine)	Kimio TAKAHASHI	from May 22nd to 28th	NEWJEC
Power System Planning and Analysis	Kiyotaka UENO	from May 22nd to 28th	NEWJEC
Substation Facilities	Ryosuke TOKUNAGA	from May 22nd to 28th	Nippon Koei
Transmission Line Facilities	Yuya UEHARA	from May 22nd to 28th	Nippon Koei
Environmental and Social Consideration	Shinjiro OKUZAWA	from May 25th to June 4th	Nippon Koei
Project Coordinator/ Hydropower Development Plan	Sho SHIBATA	from May 22nd to 28th	NEWJEC

Table 1.5-7 Activities during 3rd Site Investigation

Date			Itinerary
1	2016/5/22	Sun	Move to Yangon
2	2016/5/23	Mon	Move to Naypyidaw 10:00 U Zaw Moe Win, EE of EPGE
3	2016/5/24	Tue	10:30 U Soe Myint Tun, DyDG of ID-MOALI 14:55 U Khin Maung Win, MD of EPGE 15:40 U Moe Theat, DyCE of PSD-PTSCD
4	2016/5/25	Wed	09:00~16:00 Dr. Win Myint, DyCE of EPGE 14:15 U Moe Theat, DyCE of PSD-PTSCD 18:00 U Kyi San Linh, DyCE of PTP-PTSCD
5	2016/5/26	Thu	09:00~12:00 Dr. Win Myint, DyCE of EPGE 14:00 U Kyi San Linh, DyCE of PTP-PTSCD Move to Yangon
6	2016/5/27	Fri	Reporting 15:00 Interview with Local Investigation Companies Move to Japan
7	2016/5/28	Sat	Return to Japan
8	2016/5/22	Sun	Reporting
9	2016/5/23	Mon	09:00 Dr. Win Myint, DyCE of EPGE Move to Yangon
10	2016/5/24	Tue	10:00 JICA
11	2016/5/25	Wed	Meeting with local consultant - 1
12	2016/5/26	Thu	Move to Naypyidaw Discussion with EPGE
13	2016/5/27	Fri	Discussion with MOECAF[*1] Move to Yangon
14	2016/5/28	Sat	Return to Japan

*1 MOECAF: Ministry of Environmental Conservation and Forest, currently reformed MONREC (Ministry of Natural Resources and Environmental Conservation)

(4) 4th Site Investigation

JICA Survey Team implemented the 4th site investigation in Myanmar from June 19th to August 3rd, 2016. Main contents of the 4th site investigation are;

1) Site Visits to Baluchaung No.1 HPP and Sedawgyi HPP
2) Design of hydropower generating equipment, control and protection system, substation and transmission line facilities, gates & penstock, civil facilities and communication system for the future Rehabilitation Projects
3) Discussion with EPGE on specifications of equipment
4) Discussion about measurement investigation for the penstock gate[s] and spillway gate[s] at Sedawgyi Dam
5) Assistance of holding 1st Stakeholder Meeting for IEE (Initial Environmental Examination) for both HPPs

Members and stay period of JICA Survey Team are as shown below. Considering survey components and schedule of each experts, Team is divided into three (3) groups, “Group 1: Team Leader)”, “Group 2: Hydropower Generating Equipment”, and “Group 3: Substation and Transmission line Facilities”.

Table 1.5-8 Member and Schedule of 4th Site Investigation

Position	Name	Period	Company
Group 1 (Team Leader)			
Team Leader/Hydropower Development Plan	Yuichi SANO	from June 22nd to July 14th	NEWJEC
Environmental and Social Consideration	Shinjiro OKUZAWA	from June 19th to July 9th	Nippon Koei
Economic and Financial Analysis	Naoya AZEGAMI	from June 22nd to July 6th	Nippon Koei
Project Coordinator/ Hydropower Development Plan	Sho SHIBATA	from July 3rd to July 16th	NEWJEC
Group 2 (Hydropower Generating Equipment)			
Sub Team Leader / Civil Facilities	Taketoshi MATSUNAGA	from June 19th to July 2nd from July 10th to July 23rd	NEWJEC
Hydropower Generating Equipment (Turbine)	Kimio TAKAHASHI	from June 22nd to July 14th	NEWJEC
Hydropower Generating Equipment (Generator)	Shoichi KUSHIMOTO	from June 22nd to July 10th	NEWJEC
Control and Protection Equipment	Tatsunobu SASAKI	from June 22nd to July 14th	KANSAI
Gate and Penstock	Taro UENO	from June 22nd to July 17th	Nippon Koei
Communication Design	Toshihiro KATSUMATA	from July 10th to July 23rd	Nippon Koei
Group 3 (Substation and Transmission Line Facilities)			
Substation Facilities	Ryosuke TOKUNAGA	from July 11th to August 4th	Nippon Koei

Table 1.5-9 Activities during 4th Site Investigation

	Date	Day	Group 1 (Team Leader)	Group 2 (Power Generating Equipment)	Group 3 (Substation and Transmission Line)
1	2016/6/18	Sat			
2	2016/6/19	Sun	Move to Yangon	Move to Yangon	
3	2016/6/20	Mon	Assistant agreement and data collection	Preparation of site investigations	
4	2016/6/21	Tue	Discussion w ith ECD-MONREC	Data Collcetion at Yangon	
5	2016/6/22	Wed	Discussion w ith ECD-MONREC Preparation of Stakeholder Meeting (SHM)	Data Collcetion at Yangon	
6	2016/6/23	Thu	Move to Naypyidaw Discussion w ith EPGE	Move to Naypyidaw Discussion w ith EPGE	
7	2016/6/24	Fri	Move to Mandalay Praparation of 1st SHM for Sedaw gyi HPP	Discussion w ith EPGE Discussion w ith ID-MOALI	
8	2016/6/25	Sat	1st SHM for Sedaw gyi HPP	Reporting	
9	2016/6/26	Sun	Reporting	Reporting Move to Mandalay	
10	2016/6/27	Mon	Move to Sedaw gyi Site Inspection at Sedaw gyi HPP	Discussion w ith ID-MOALI Move to Sedaw gyi Site Inspection at Sedaw gyi HPP	
11	2016/6/28	Tue	Site Inspection at Sedaw gyi HPP	Site Inspection at Sedaw gyi HPP	
12	2016/6/29	Wed	Site Inspection at Sedaw gyi HPP Move to Mandalay and YGN	Site Inspection at Sedaw gyi HPP	
13	2016/6/30	Thu	Meeting w ith JICA	Site Inspection at Sedaw gyi HPP Move to Mandalay	
14	2016/7/1	Fri	Move to Loikaw Data Collection at BLC No.1 HPP	Data Collection Move to Yangon	
15	2016/7/2	Sat	1st SHM for BLC No.1 HPP	Reporting	
16	2016/7/3	Sun	Reporting	Move to Loikaw	
17	2016/7/4	Mon	Site Inspection at BLC No.1 HPP	Site Inspection at BLC No.1 HPP	
18	2016/7/5	Tue	Site Inspection at BLC No.1 HPP	Site Inspection at BLC No.1 HPP	
19	2016/7/6	Wed	Move to Yangon and Naypyidaw	Site Inspection at BLC No.1 HPP	
20	2016/7/7	Thu	Discussion w ith EPGE	Site Inspection at BLC No.1 HPP	
21	2016/7/8	Fri	Discussion w ith EPGE	Site Inspection at BLC No.1 HPP	
22	2016/7/9	Sat	Reporting	Reporting	
23	2016/7/10	Sun	Reporting	Reporting	
24	2016/7/11	Mon	Discussion w ith EPGE	Site Inspection at BLC No.1 HPP	Move to Yangon
25	2016/7/12	Tue	Discussion w ith EPGE Move to Yangon	Site Inspection at BLC No.1 HPP	Move to Naypyidaw Discussion w ith EPGE
26	2016/7/13	Wed	Reporting Move to Bangkok	Site Inspection at BLC No.1 HPP	Discussion w ith EPGE
27	2016/7/14	Thu	Return to Japan	Site Inspection at BLC No.1 HPP	Discussion w ith EPGE
28	2016/7/15	Fri		Site Inspection at BLC No.1 HPP	Discussion w ith EPGE Move to Yangon
29	2016/7/16	Sat		Reporting	Reporting
30	2016/7/17	Sun		Reporting	Move to Loikaw
31	2016/7/18	Mon		Site Inspection at BLC No.1 HPP	Site Inspection at BLC No.1 HPP
32	2016/7/19	Tue		Site Inspection at BLC No.1 HPP	Site Inspection at BLC No.1 HPP
33	2016/7/20	Wed		Site Inspection at BLC No.1 HPP	Site Inspection at BLC No.1 HPP
34	2016/7/21	Thu		Site Inspection at BLC No.1 HPP	Site Inspection at BLC No.1 HPP
35	2016/7/22	Fri		Site Inspection at BLC No.1 HPP Move to Yangon and Japan	Move to Yangon
36	2016/7/23	Sat		Return to Japan	Reporting
37	2016/7/24	Sun			Move to Mandalay
38	2016/7/25	Mon			Move to Sedaw gyi Site Inspection at Sedaw gyi HPP
39	2016/7/26	Tue			Site Inspection at Sedaw gyi HPP
40	2016/7/27	Wed			Site Inspection at Sedaw gyi HPP
41	2016/7/28	Thu			Site Inspection at Sedaw gyi HPP
42	2016/7/29	Fri			Move to Yangon

Date		Day	Group 1 (Team Leader)	Group 2 (Power Generating Equipment)	Group 3 (Substation and Transmission Line)
43	2016/7/30	Sat			Reporting
44	2016/7/31	Sun			Reporting
45	2016/8/1	Mon			Move to Naypyidaw Discussion with EPGE
46	2016/8/2	Tue			Discussion with EPGE
47	2016/8/3	Wed			Discussion with EPGE Move to Yangon and Japan
48	2016/8/4	Thu			Return to Japan

* ECD: Environmental Conservation Department

(5) 5th Site Investigation

JICA Survey Team implemented the 5th site investigation in Myanmar from September 6th to 24th, 2016. Main contents of the 5th site investigation are;

1) Discussion with EPGE regarding the below issues
   a. Explanation and discussion on Interim Report (2)
   b. Final selection of equipment/facilities to be rehabilitated
   c. Construction Plan and Schedule
   d. Construction Cost estimate
   e. Implementation (Project) Schedule (from E/N to end of Defect Liability Period)
   f. Project Cost estimate
   g. Type of Bidding and Packaging

2) Assistance of holding 2nd Stakeholder Meeting for IEE for both HPPs

Table 1.5-10 Member and Schedule of 5th Site Investigation

Position	Name	Period	Company
Team Leader/ Hydropower Development Plan	Yuichi SANO	from September 11th to 24th	NEWJEC
Sub Team Leader / Civil Facilities	Taketoshi MATSUNAGA	from September 8th to 20th	NEWJEC
Hydropower Generating Equipment (Turbine)	Kimio TAKAHASHI	from September 11th to 24th	NEWJEC
Hydropower Generating Equipment (Generator)	Shoichi KUSHIMOTO	from September 11th to 24th	NEWJEC
Substation Facilities	Ryosuke TOKUNAGA	from September 11th to 24th	Nippon Koei
Control and Protection Equipment	Tatsunobu SASAKI	from September 11th to 24th	KANSAI
Economic and Financial Analysis	Naoya AZEGAMI	from September 11th to 24th	Nippon Koei
Environmental and Social Consideration	Shinjiro OKUZAWA	from September 6th to 24th	Nippon Koei
Communication Design	Toshihiro KATSUMATA	from September 11th to 24th	Nippon Koei
Project Coordinator	Rika EBIHARA	from September 11th to 18th	NEWJEC

(6) 6th Site Investigation

JICA Survey Team implemented the 6th site investigation in Myanmar from October 8th to 21st, 2016. Main contents of the 6th site investigation are;

1) Discussion with EPGE regarding the below issues
   a. Explanation and discussion on Draft Final Report
   b. Finalization of the Scope of Future Rehabilitation Project

2) Assistance of preparing Environmental Management Plan (EMP)

Table 1.5-11 Member and Schedule of 6th Site Investigation

Position	Name	Period	Company
Team Leader/ Hydropower Development Plan	Yuichi SANO	from October 10th to 16th	NEWJEC
Sub Team Leader / Civil Facilities	Taketoshi MATSUNAGA	from October 10th to 16th	NEWJEC
Hydropower Generating Equipment (Turbine)	Kimio TAKAHASHI	from October 10th to 15th	NEWJEC
Hydropower Generating Equipment (Generator)	Shoichi KUSHIMOTO	from October 12th to 16th	NEWJEC
Substation Facilities	Ryosuke TOKUNAGA	from October 10th to 15th	Nippon Koei
Control and Protection Equipment	Tatsunobu SASAKI	from October 10th to 16th	KANSAI
Economic and Financial Analysis	Naoya AZEGAMI	from October 10th to 15th	Nippon Koei
Environmental and Social Consideration	Shinjiro OKUZAWA	from October 8th to 21st	Nippon Koei

1.6 Counterparts

Counterparts of the Survey are as follows.

MOEE	U Htain Lwin	Permanent Secretary
EPGE Naypyidaw Head Office		
	U. Khin Maung Win	Managing Director
	U. Khin Maung Lay	Deputy Managing Director
	Dr. Maung Maung Kyaw	Chief Engineer
	Dr. Win Myint	Superintending Engineer
	U. Alyunt Aung	Assistant Superintending Engineer
	U. Mya Thein	Assistant Superintending Engineer
	U. Zaw Moe Win	Executive Engineer
	U. Myint Thu	Executive Engineer
	U. Hla Min Oo	Executive Engineer
	Daw Thida Myint	Executive Engineer
	U Aung Thant	Assistant Engineer
PTSCD	U Htain Lwin	Permanent Secretary, Managing Director
	U Kyi San Lin	Superintend Engineer
Baluchaung No.1 HPP		
	U Than Win	Factory Manager
	U Zaw Moe Win	Executive Engineer (EPGE)
	U Aung Ko Win	Executive Engineer (Deputy Factory Manager)
	U Min Thu Shein	Assistant Engineer (Head of Electric Department)
	U Chan Thar Min	Assistant Engineer (Mechanical)
	U Kyaw Thu Ko	Assistant Engineer (Electrical)
	U Kyaw Thu Ya	Junior Engineer Grade (2)
Sedawgyi HPP		
	U Nyi Nyi Aung	Factory Manager
	U Thein Tun	Superintending Engineer (Former Factory Manager)
	U Toe Naing Win	Head of Electrical
	U Myat Laung Hsat	Head of Mechanical
	U Moe Kyaw	
	U Hla Myint	Junior Engineer Grade (2)
	U Sai Kyaw Saya	Sub Assistant Computer Operator

1.7 Activities and Future Plans of Other Donors and International Agencies

JICA, ADB (Asian Development Bank), WB (the World Bank) Group, United Kingdom Government and Norway Government have implemented and prepare supporting projects to Myanmar power sector. Supporting activities to the power sector are being discussed and adjusted through donor's meeting, e.g., the Electric Power Sector Working Group.

(1) ADB

As of January 2016, ADB implements and plans supporting project to Myanmar power sector as shown in Table 1.7-1 and Table 1.7-2.

Table 1.7-1 Ongoing Projects on Myanmar Power Sector by ADB

Project Name	Type	Term	Amount (USD thousand)
Power Distribution Improvement Project	Loan	From 28-Jan-2014 to 31-Dec-2018	60,000
Power Transmission and Distribution Improvement Project (Supplementary)	Loan	From 29-Aug-2013 to 31-Dec-2017	150,000 (225)
Off-Grid Renewable Energy Demonstration Project	TA	From 23-July-2014 to 30-June-2017	2,000
Support for Public-Private Partnership Framework Development	TA	From 14-July-2014 to 31-Dec-2016	2,000

* TA: Technical Assistance Source: ADB HP

Table 1.7-2 Planned Projects on Myanmar Power Sector by ADB

Project Name	Type	State	Amount (USD thousand)
Power Transmission Improvement Project	Loan	Approved, but not yet signed Closing 31-Dec-2019	80,000

Source: ADB HP

1) Summary of ongoing projects

a) Power distribution improvement project

The project will help reduce system losses and subsequently increase the electricity supply to urban and rural consumers to support inclusive and sustainable economic development

To enhance MOEE capacity, ADB assistance includes (i) a power advisor to MOEE; (ii) international and national experts for preparing a transmission and distribution grid code, and electric standards and specifications; (iii) preparation of a financial management assessment of four enterprises within MOEE; and (iv) formulation of proper safeguard requirements and procedures. Also, to strengthen the legal framework, ADB provided assistance for drafting the revised electricity law and subsequent electricity regulation, and introducing the regulatory authority to enhance transparency and attract private sector participation. In addition, project preparatory TA conducted a feasibility study for transmission expansion.

Rehabilitation of distribution network in five townships Yangon Region (Hlaingtharyar, Insein, Kamayut, Mayangone, and Mingaladon), four (4) districts in Mandalay Region (Kyause, Meikhtila, Myin Gyan, and Yameethin), five (5) districts in Sagaing Region (Kalay, Katha, Monyawa, Sagaing and Shwebo) and two (2) townships in Magway Region (Aungland and Magway).

Project Outputs are as follows;

1. Renewable energy systems designed and installed in 25 villages to power community infrastructure and households.

2. Geospatial least-cost energy access and investment plans for select regions and states of the country developed.

3. Skills and abilities of staff in government entities and the private sector strengthened

b) Power transmission and distribution improvement project

This PPTA (Project Preparatory Technical Assistance) will focus on the rehabilitation of existing transmission and distribution network and expansion in next 5 years to increase supply of electricity and electrification ratio in the country.

The project will prepare a comprehensive investment plan for the improvement of the power transmission and distribution systems in Myanmar and prepare a feasibility study for rehabilitation and expansion of existing system. The PPTA would: (i) assess the power demand projections and suggest expansion plan with investment requirements; (ii) assess the losses of YESB (Yangon City Electricity Supply Board) and ESE (Electricity Supply Enterprise) and its loss reduction program, and identify measures for loss reduction; (iii) assess capacity and staff skills in the power sector, identify training needs, and prepare short and long term training plan; (iv) identify an urgent rehabilitation and expansion of transmission and distribution projects. For the identified projects, the PPTA will undertake a feasibility study to (i) propose the project scope; (ii) prepare detailed engineering design and bidding documents; (iii) undertake the procurement and implementation capacity assessment of executing agencies and implementing agencies; (iv) prepare cost estimates; (v) undertake economic and financial analyses; and (vi) complete social and environmental safeguards requirements. Expansion of transmission lines between (1) Kamarnat and Hlaingtharyar in Yangon, (2) Baluchaung-2 and Taungoo, (3) Taungoo and Shwedaung, (4) Thaketa and Ahlone in Yangon.

c) Off-grid renewable energy demonstration project

This capacity development TA (technical Assistance) aims to support the creation of rural infrastructure, including energy access projects and will have as its main objectives: (i) to support the installation of clean energy-based systems for providing energy access (mostly solar PV: Photovoltaic and biomass-based systems) to schools and other public infrastructure in at least 25 villages, (ii) develop geospatial least cost energy access plans and an investment plan for select states and regions in the country, and (iii) to strengthen the capacity of the government institutions and the private sector to manufacture, install, operate and maintain small-scale clean energy systems.

MLFRD (Ministry of Livestock, Fisheries, and Rural Development) will be the Executing Agency. The Department of Rural Development within MLFRD will be the implementing agency.

d) Support for PPP framework development

For the MOEE, the TA will help the GOM establish fair and balanced terms for private sector investment into power generation projects, establish principles for ICB (International Competitive Bidding), assist the GOM in PPP (Prioritizing Public-private Partnership) investment projects, and strengthen the design and management of future PPP procurements. The TA will provide recommendations on how to scale up the learning from MOEE's PPP experience to the national level, informing how to apply this framework to a broader cross-section of ministries. The TA will:

(1) Deliver to the GOM sound tendering processes and decision frameworks based on the principles of PPPs;

(2) Promote consistent, objective and transparent application of PPP project development criteria to an international standard; and

(3) Create recommendations for development of institutional management capacity for PPP, first within the MOEE and then at national level.

Project Outputs are:

(1) Institutional structure for managing PPP projects and financing proposed.

(2) Private sector investment management capacity in MOEE improved.

(3) Knowledge of and development in relation to PPPs shared

2) Summary of planned projects

a) Power Transmission Improvement Project

The project will (i) construct 8.4 kilometer (km) of 230 kilovolt (kV) transmission line between Thida and Thaketa substations, and 8.4 km of 230 kV transmission line between Thaketa and Kyaikasan substations; (ii) extend the switchyard of the existing 230 kV Thaketa substation to accommodate two new 230 kV transmission lines; (iii) upgrade the existing 66 kV Kyaikasan substation to 230 kV substation; (iv) build new 230 kV substations at South Okkalapa and West University; and (v) strengthen the capacity of the staff of PTSCD (Power Transmission and System Control Department). The project will help to complete the critically important 230 kV transmission ring supplying electricity for the Yangon region and ensure reliable electricity supply to support sustainable economic development for Myanmar.

Project output are

(1) A 230 kV power transmission ring including 230 kV transmission lines and substations

(2) Capacity of PTSCD staff implementing ADB financed projects strengthened

(2) WB Group

As of January 2016, WB Group implements and plans the following projects which are to enable poor rural communities to benefit from improved access, use of basic infrastructure and services, etc.

1) National Community Driven Development Project

Project term: from November 2012 to N/A

Amount: 400 million USD (addition)

Over View: The objective of the project is to enable poor rural communities to benefit from improved access to basic infrastructure services and enhance the government's capacity to promptly and effectively respond to emergencies. The program is implemented by the DRD (Department of Rural Development), with financing support from the GOM, the Governments of Italy and Japan, and the World Bank.

The program currently covers 27 townships and is in the process of scaling up, to ultimately provide funds for communities to improve access to basic services and essential infrastructure for an estimated 7 million people across 63 townships in Myanmar.

Since 2013, the NCDDP (National Community Driven Development Project) has delivered results by putting communities at the center of planning and managing development resources. Villagers decide how to use project funds, designing sub-projects including the rehabilitation and expansion of school buildings, health centers, water supply systems, footpaths, jetties and bridges. Now in its third cycle, over 5,000 sub-projects will be identified, designed and implemented by communities in 2016.

Source: WB HP

2) Electric Power Project

Project term: from January 2014 to April 2018
(Project signed between the GOM and WB in September 2013)

Amount: 140 million USD

Over View: The objective of the Project is to increase capacity and efficiency of gas-fired power generation and strengthen the institutional capacity of the MOEE and PTSCD. There are two components to the project. The first component of the project is supply and installation of a CCGT (Combined Cycle Gas Turbine) power plant at the existing Thaton gas turbine station. This is the main component of the project is the expansion of the Thaton gas turbine station into a new CCGT power plant. A modern, high-efficiency, low-emissions CCGT power plant will comprise two 40 MW gas turbines with inlet air chillers, one steam turbine of 26 (MW), a heat recovery steam generator and air-cooled steam condenser. The second component of the project is technical assistance component focused on institutional and capacity building support to MOEE and PTSCD. This component will provide technical assistance and advisory services to MOEE and PTSCD in two main areas. The first area of support is related to the capacity building for policy making and regulation in the power sector including Electricity Tariffs and Subsidies Mechanisms is also studied.

Source: WB HP

3) Support for the Corporatization of YESB

IFC (International Finance Corporation)'s technical support and assistance in transforming YESB (The mandate signing on 26th February 2014).

4) National Electrification Project

Project term: from September 2015 to September 2021
(Project approved by WB on 16th September 2015)

Amount: 400 million USD

Over View: The objective of the Project is to help increase access to electricity in Myanmar. There are four components to the project, the first component being grid extension. This component will support the distribution utilities to extend distribution networks and connect communities and households to the national power grid, including through the provision of goods and materials for the expansion of existing MV (medium voltage) substations and construction of new MV substations. The second component is the off-grid electrification. About 5.5 million households are estimated to remain without access to national grid by 2021. Of these, 1.3 million are in the remote Chin, Kachin, Kayin, Shan, Rakhine, Tanintharyi and Sagaing States and Regions. The project's off-grid component targets communities in these areas, located far beyond the existing national grid and unlikely to receive grid access in the next 10 or more years, and where private sector is not active due to relatively high operating costs and low ability to pay. The third component is the technical assistance and project management. This component provides support to MOEE and MLFRD to: (i) strengthen institutional capacity to implement the national electrification plan; (ii) improve the policy and regulatory framework related to electrification and renewable energy. Finally, the fourth component is the Contingent emergency response. This component, with an initial allocation of zero dollars, is part of IDA's support to an Immediate Response Mechanism in Myanmar

Source: WB HP

5) Sustainable Hydropower and Regional Cooperation in Myanmar

WB Group and the IHA (International Hydropower Association) held the workshop to take part in discussions on sustainable hydropower and regional cooperation in Myanmar.

The event aims to foster knowledge and encourage exchange between stakeholders in the energy and water sectors to develop good international industry practice for hydropower development in Myanmar. It builds on a series of previous events organized by IHA and IFC and addresses the important contribution that hydropower makes to regional cooperation and development.

Source: IFC HP

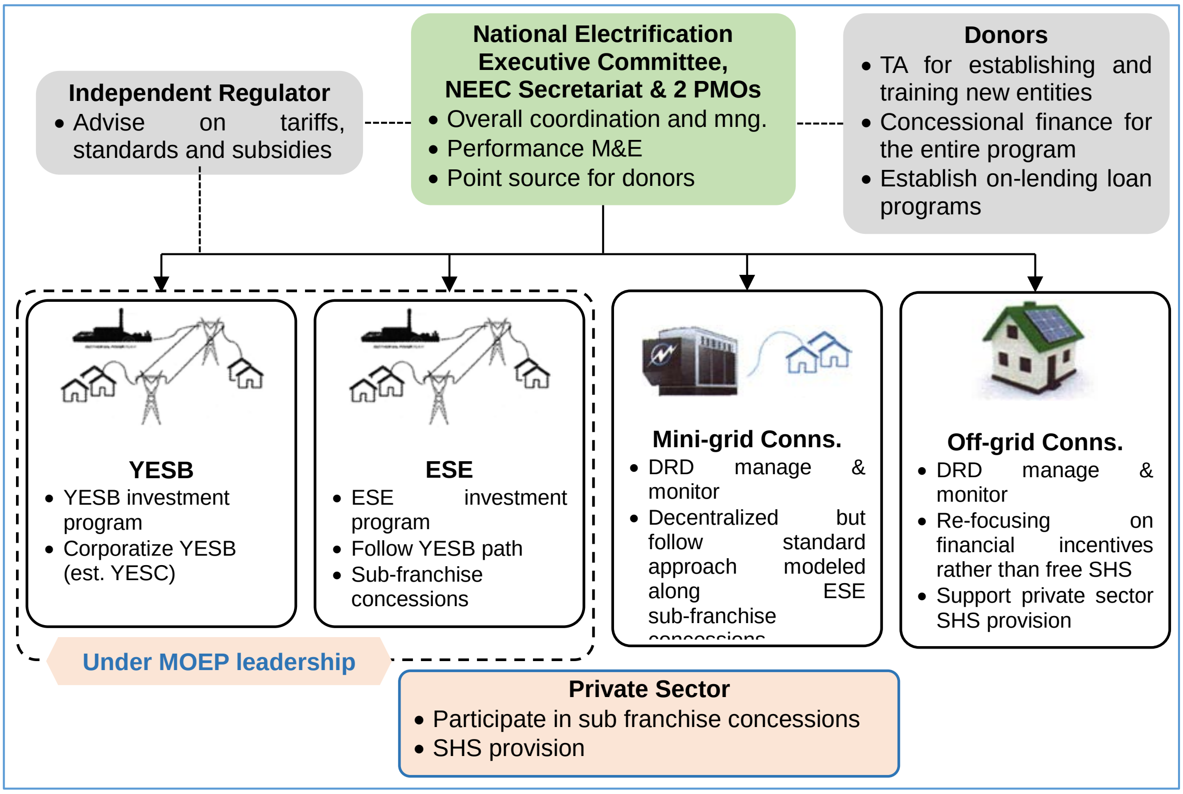


Fig. 1.7-1 Organization Change of MOEE and Electrification Program of Unenergized Area

CHAPTER 2

CURRENT STATUS OF POWER SECTOR IN MYANMAR

Chapter 2 Current Status of Power Sector in Myanmar

2.1 Current Status of Power Sector

2.1.1 Electricity Law, Regulation and Institution

The draft of the Electricity Law was publicized in November 2013. Deliberation of the law has been implemented through a committee of the Parliament and it will be enacted after the approval of the Parliament.

The objectives of the draft are shown as follows:

- Systematically manage electricity-related work in the country in order to satisfy the country's need for electric power;

- To develop the electric power sector of the country in order to contribute to the implementation of present policies of the GOM (Government of Myanmar) relating to economic, social and environmental conservation and development;

- To further encourage medium-scale and small-scale generation and distribution of electric power in the regions and the states to supplement large-scale power generation and distribution which is to be managed by the Union;

- To enable the wider use of electric power in a safe way in the urban and rural areas in the whole country;

- To ensure that electricity-related work in the country is performed in accordance with the stipulated standards and norms;

- To develop modern electrical technology and to increase the number of electrical technicians and professionals;

- To promote standards, norms and quality of electrical appliances;

- To control and supervise electricity-related work in conformity with the policies of the state;

- To prevent in advance the occurrence of electrical hazards and to implement effective penalties and specific rules in order to prevent losses to the public and the state when electricity-related work is performed;

- To increase foreign and local investments in electricity-related work;

- To write and promulgate equitable, transparent and reasonable rules and regulations for fixing electric power rates which are economically viable and sufficient to cover the investment costs;

- To respect and comply with, the international conventions on environmental conservation which were approved and signed by the Union.

In order to effectively and successfully perform electricity-related work the duties and responsibilities of the Electricity Regulatory Commission are as follows:

- To compile and write the National Electricity Policy after consultation with the relevant ministries and organizations;

- To compile and submit the matters relating to the electricity tariff policy in order to fix modern and systematic electricity power rates;

- To advise, as necessary, the relevant ministries according to the guidance of the GOM in order to systematically develop electricity-related work;

- To form, as necessary, electricity regulatory sub-commission in the regions, states and the respective self-administered zones and divisions and prescribe their duties and responsibilities;

- To survey, assess and review the status of the electricity sector in comparison to the international electricity standards and norms and communicate the findings to the relevant ministries for them to take necessary action;

- To form an inspection team comprising of suitable persons in order to check whether the production, import, export distribution and use of electrical appliances is done in conformity with the specified standards and norms;

- To perform other duties related to electricity as assigned by the GOM.

As for electricity-related work, the GOM will give authority to the relevant ministries, the relevant regions or state governments, and the relevant self-administered zones or self-administered divisions. Ministries continue to implement power development projects with large scale of more than 30MW, and regions or state governments will have the right to implement mid-sized projects of 10 to 30MW and small-scale projects of up to 10MW with prior approval from the relevant ministry.

2.1.2 Issues of Power Development

Regarding current situation of power generation development in Myanmar, HPPs (Hydropower Plants) have been delayed from their original schedule. Development of large hydropower and coal projects must be proceeded under the adequate environmental and social considerations including the consultation with local residents. As for gas, it is also difficult to increase supply capacity drastically due to the shortage of natural gas.

Therefore increasing supply capacity in short term is necessary to use expensive fossil fuel such as imported LNG (Liquid National Gas) and liquid fuel or to get back gas export from China and Thailand.

2.2 Institutional Reforms of Power Sector

2.2.1 Establishment of Ministry of Electricity and Energy

GOM announced on March 17th, 2016 that existing thirty six(36) ministries were reformed to twenty one (21) ministries and MOEP (Ministry of Electric Power) and MOE (Ministry of Energy) was merged into MOEE (Ministry of Electricity and Energy). Organization chart and mandate of each department are shown in Fig. 2.2-1 and Table 2.2-1 respectively.

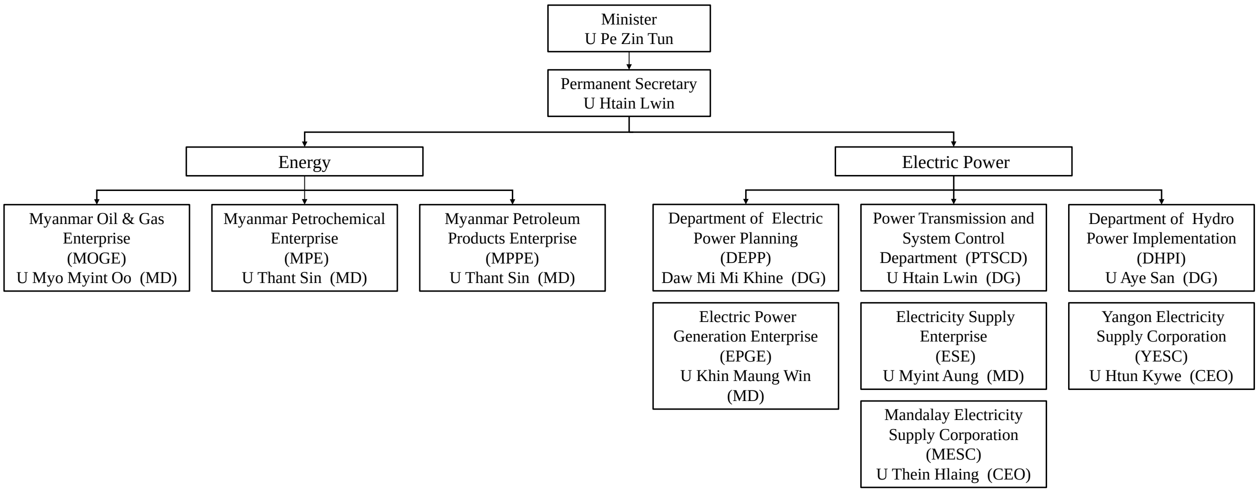


Fig. 2.2-1 Organization Chart of MOEE

Table 2.2-1 Mandate of each Organization in MOEE

Ministry		Remarks
Electric Power Sector (former MOEP)	DEPP (Department of Electric Power Planning)	Policy Planning, demand forecast, application of JV/IPP and power generation development planning
	PTSCD (Power Transmission and System Control Department)	Planning, design, construction and O&M of the national power system
	EPGE (Electric Power Generation Enterprise)	O&M of existing MOEE's power plants
	DHPI (Department of Hydropower Implementation)	Design and construction of MOEE's hydropower projects
	ESE (Electricity Supply Enterprise)	Planning, design, construction and O&M of the distribution network except Yangon and Mandalay Rural electrification
	YESC (Yangon Electricity Supply Corporation)	Planning, design, construction and O&M of the distribution network in Yangon
	MESC (Mandalay Electricity Supply Corporation)	Planning, design, construction and O&M of the distribution network in Mandalay
Energy Sector (former MOE)	MOGE (Myanma Oil & Gas Enterprise)	Planning, design, construction and O&M of oil and natural gas production
	MPE (Myanma Petrochemical Enterprise)	O&M of oil factory, production of petrochemical products, O&M of methanol factory
	MPPE (Myanma Petroleum Products Enterprise)	Transportation and market management of oil, petrochemical products and fossil fuel

2.2.2 Institutional Reforms of Former MOEP

Before the establishment of MOEE as described in Section 2.2.1, institutional reforms of MOEP was released on April 1st of 2015 as shown below. Change of institutions in MOEP is shown in Fig. 2.2-2.

1) Integration of Planning Department (DEP and DHPP) From June of 2015
2) Integration of Generation Section (HPGE and TPD of MEPE) From April of 2016
3) Corporatization of YESB and Mandalay Regional office of Electric Supply Division From April of 2015
4) Establishment of Permanent Secretary From April of 2015

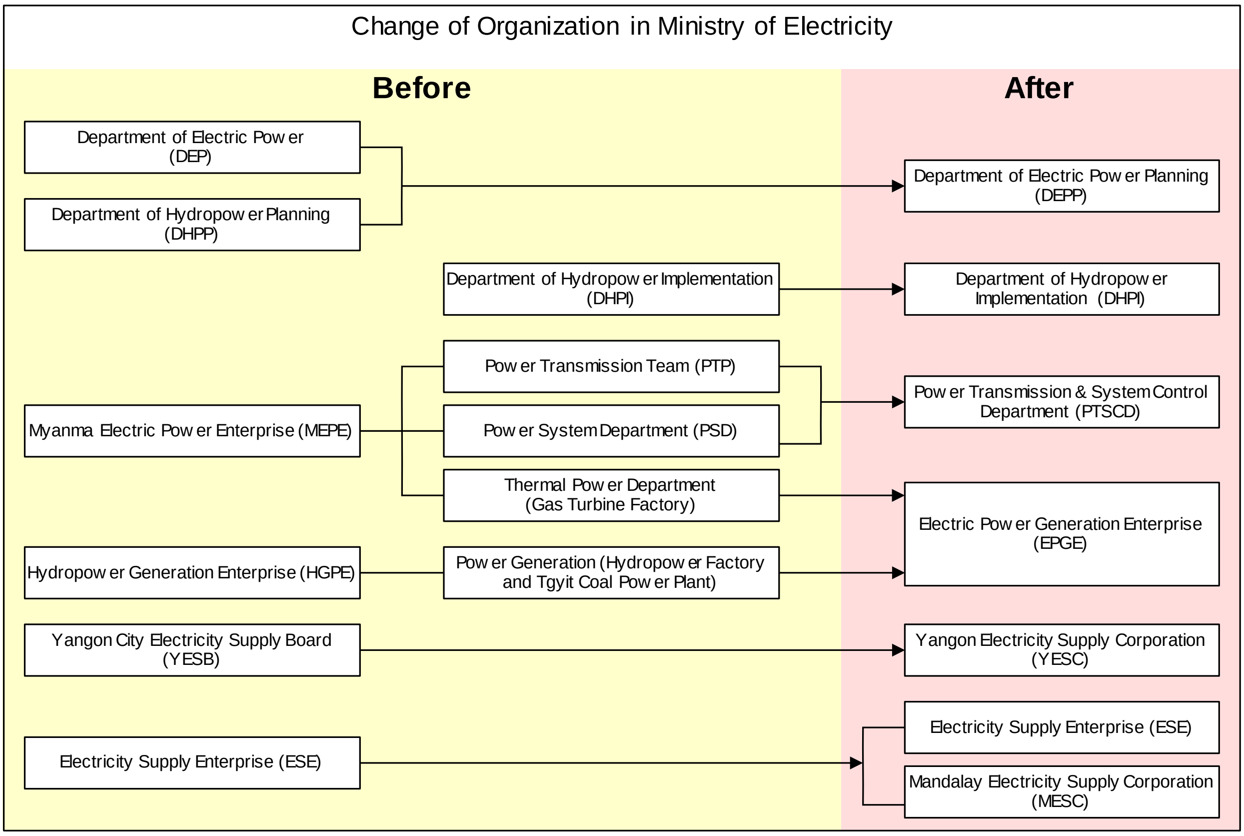
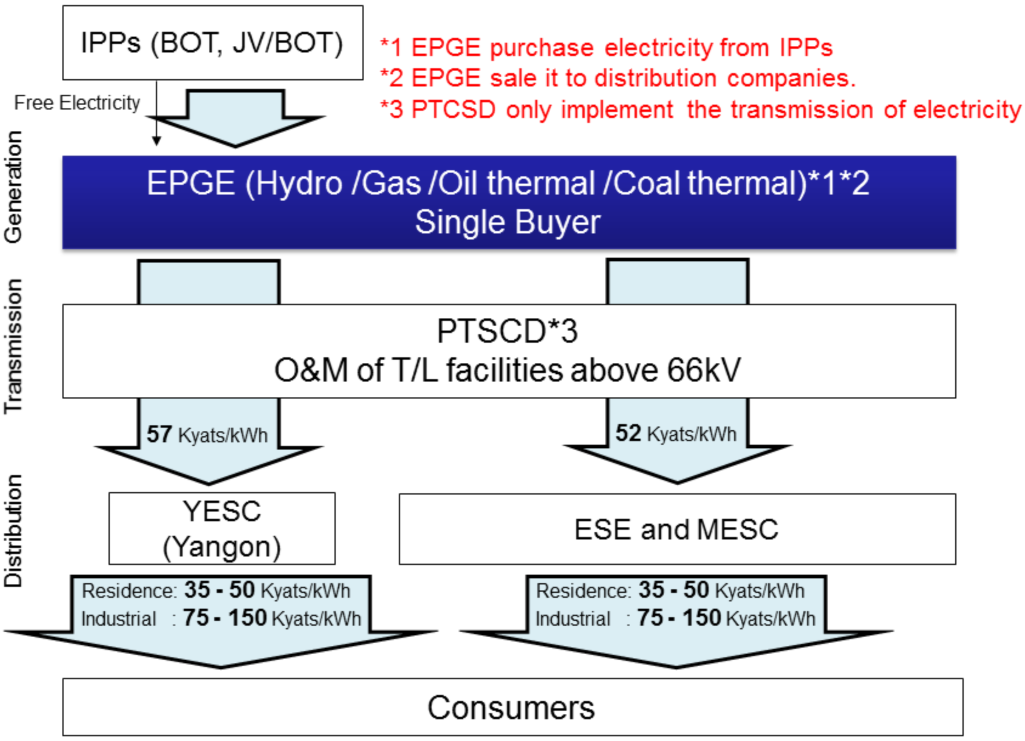


Fig. 2.2-2 Institutional Reforms of MOEP

Regarding 2), HPGE which is main C/P (counterparts) of the Survey was to be integrated with TPD-MEPE and reformed to EPGE in April of 2016. MEPE was reformed to PTSCD. These reforms had been already approved by GOM.

Electric power supply system after the institutional reforms of MOEE in April 2016 is as shown in Fig. 2.2-3.



Source: prepared by JICA Survey Team based on local newspaper and/or MOEE information

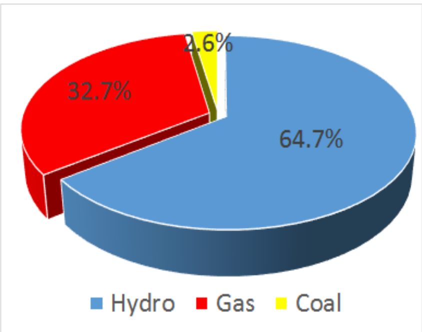
Fig. 2.2-3 Electric Power Supply System (as of April 2016)

2.3 Outline of Existing Generating and Transmission Line Facilities

2.3.1 Existing Generating Facilities

As of November 2015, total installed capacity of power generation increased up to about 4,651 MW in Myanmar as shown Fig. 2.3-1. Installed capacity of hydropower is 3,011 MW (including export amount to China of 521 MW), one of gas-field thermal power is 1,520 MW and one of coal-fired thermal power is 120 MW.

List of existing power plants in Myanmar is shown in Table 2.3-1.



Sr	Description	Qty	Installed Capacity (MW)	Myanma Power System	Foreign
1	Hydropower	24	3,011.0	2,490.0	521
2	Gas-fired	14	1,520.3	1,520.3	-
3	Coal-fired	1	120.0	120.0	-
	Total	37	4,651.3	4,130.3	521

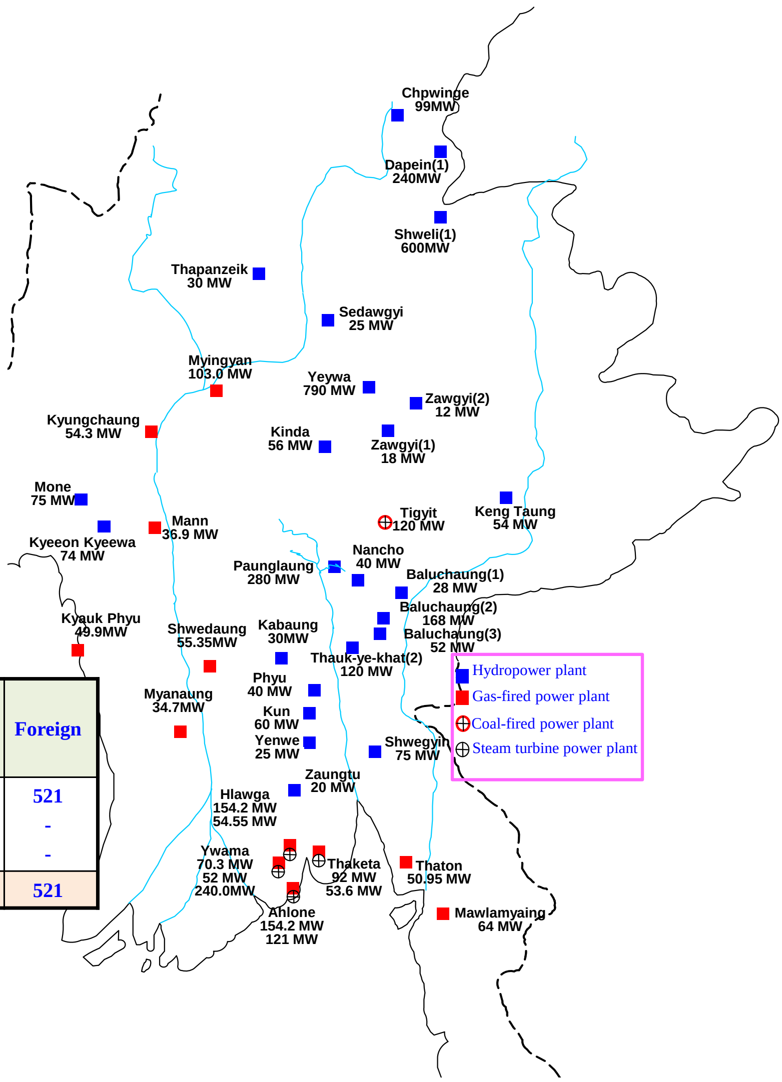


Fig. 2.3-1 Location of Existing Power Plants (as of November 2015)

Table 2.3-1 List of Existing Power Plants (as of August 2015)

Hydropower			Output (MW)	
1	Baluchaung -2	MOEP	168	
2	Kinda	MOEP	56	
3	Sedawgyi	MOEP	25	
4	Baluchaung – 1	MOEP	28	
5	Zawgyi -1	MOEP	18	
6	Zawgyi -2	MOEP	12	
7	Zaungtu	MOEP	20	
8	Thapanzeik	MOEP	30	
9	Mone	MOEP	75	
10	Paunglaung	MOEP	280	
11	Yenwe	MOEP	25	
12	Kabaung	MOEP	30	
13	Kengtawng	MOEP	54	
14	Shweli -1	JV/IPP	600	(300)
15	Yeywa	MOEP	790	
16	Dapein-1	JV/IPP	240	(221)
17	Shwegyin	MOEP	75	
18	Kun	MOEP	60	
19	Kyeeon Kyeewa	MOEP	74	
20	Thaukyegat 2	Local/IPP	120	
21	Nancho	MOEP	40	
22	Phyu	MOEP	40	
23	Baluchaung-3	MOEP	52	
24	Chipwinge	MOEP	99	
Subtotal			3011.0	(521)

Gas-fired			Output (MW)
1	Kyungchaung	MOEP	54.3
2	Mann	MOEP	36.9
3	Shwedaung	MOEP	55.4
4	Myanaung	MOEP	34.7
5	Thaton	MOEP	51.0
6	Mawlamyaing	IPP*2	65.0
7	Myingyan	Rental	103.0
8	Kanpouk	Local	6.0
9	Kyauk Phyu	Rental	49.9
10	Kyauk Se	Rental	100.3
11	Hlawga	MOEP	154.2
		IPP	26.7
12	Ywama	MOEP	70.3
		IPP	52.0
		IPP	240.0
13	Ahlone	MOEP	154.2
		IPP	121.0
14	Thaketa	MOEP	92.0
		IPP	53.6
Subtotal			1520.3
Coal-fired			**Output (MW)**
1	Tigyit	MOEP	120.0
Subtotal			120.0
Total			**4651.3**

*1 ( ) : export amount to China by JV Project
*2 Steam turbine of 35MWis not included because the plant is not yet operated.
*3 Operational contract of Rental thermal power plant is effective until operation of the new CCGT

2.3.2 Existing Transmission Line and Substation

Location of Baluchaung No.1, Sedawgyi HPPs and relevant transmission and substation facilities are indicated in latest power system diagram of Myanmar in August of 2015 as shown in Fig. 2.3-2. Scope of the study of transmission and substation facilities for rehabilitation covers relevant facilities in power plants and from plants to bulk power system.

MOEE has been introducing the SCADA (Supervisory Control And Data Acquisition) system and implementing some commissioning tests as Phase 1. Implementation structure for these tests is organized by PTSCD and EPGE staffs and they will be assigned to the system operation continuously after the commissioning.

According to interviews with MOEE, Phase 2 of SCADA introduction is not planned specifically. However it is assumed that remote control function of power plants and substation are introduced. SCADA system will be introduced to each power plants in the future and it is important to take account this matter into the selection of rehabilitation facilities and feasibility study.

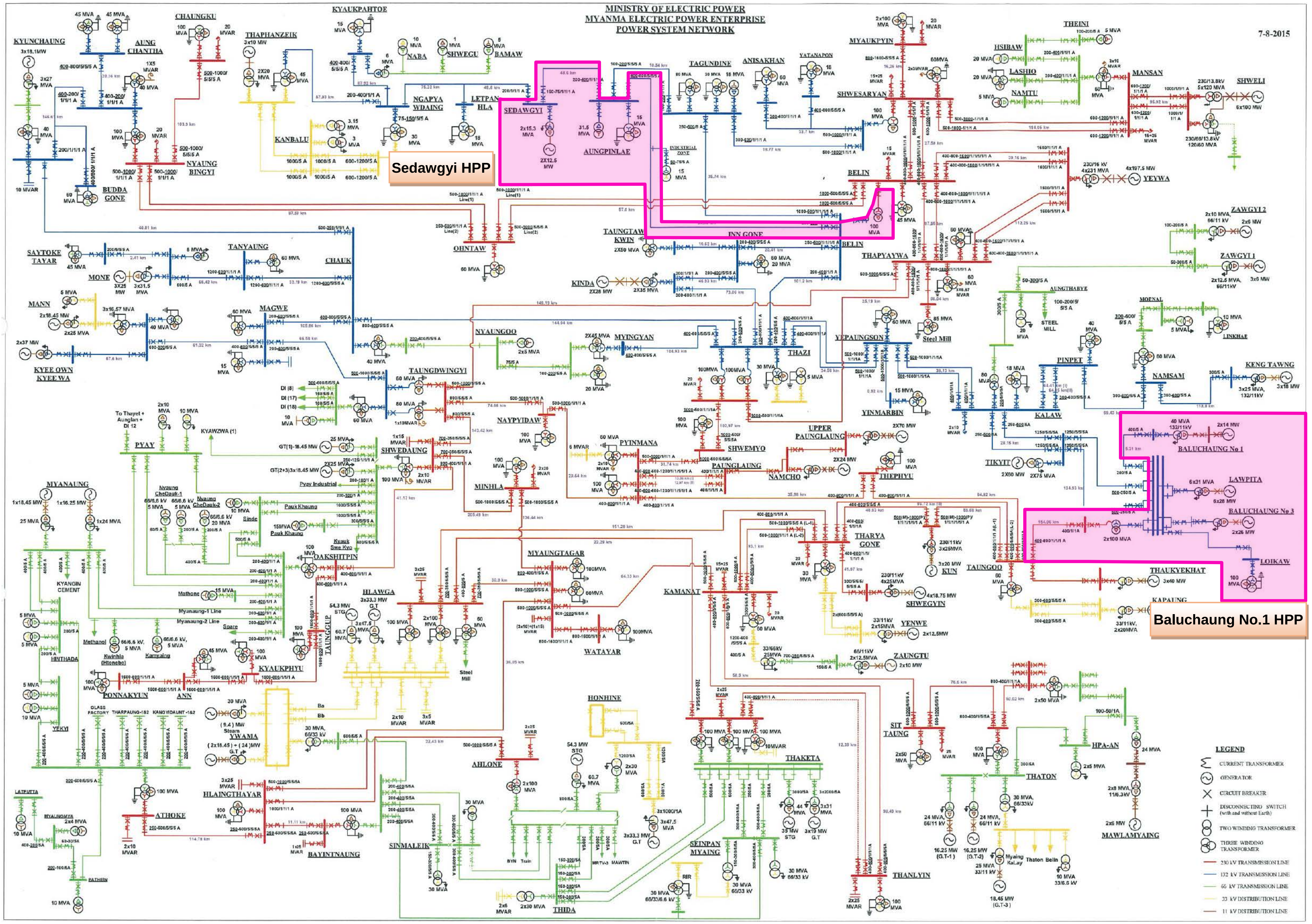


Fig. 2.3-2 Power System Diagram and Target Hydropower Plants (as of August 2015)

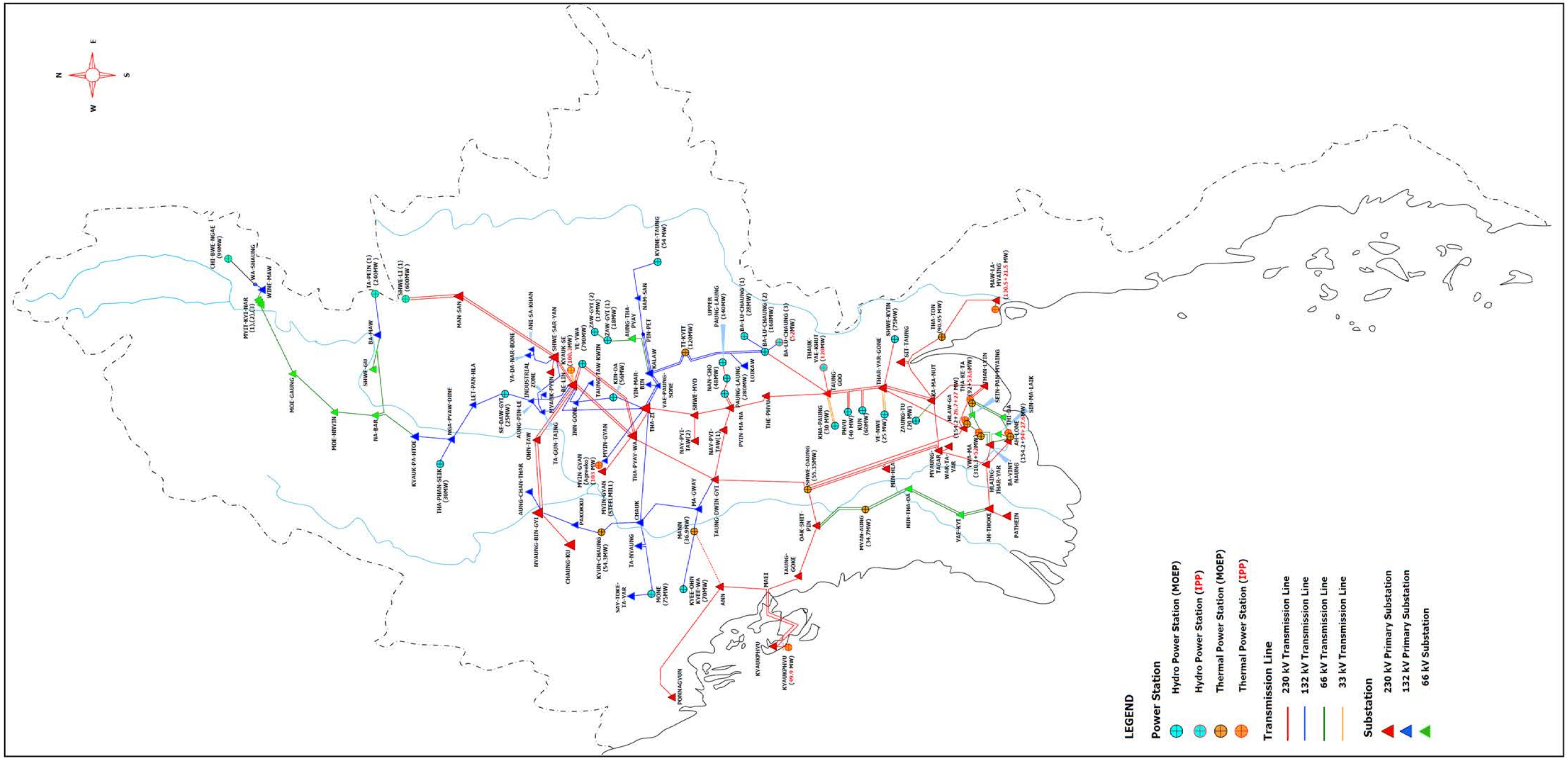


Fig. 2.3-3 Existing Transmission Lines and Substations in Myanmar (as of January 2016)

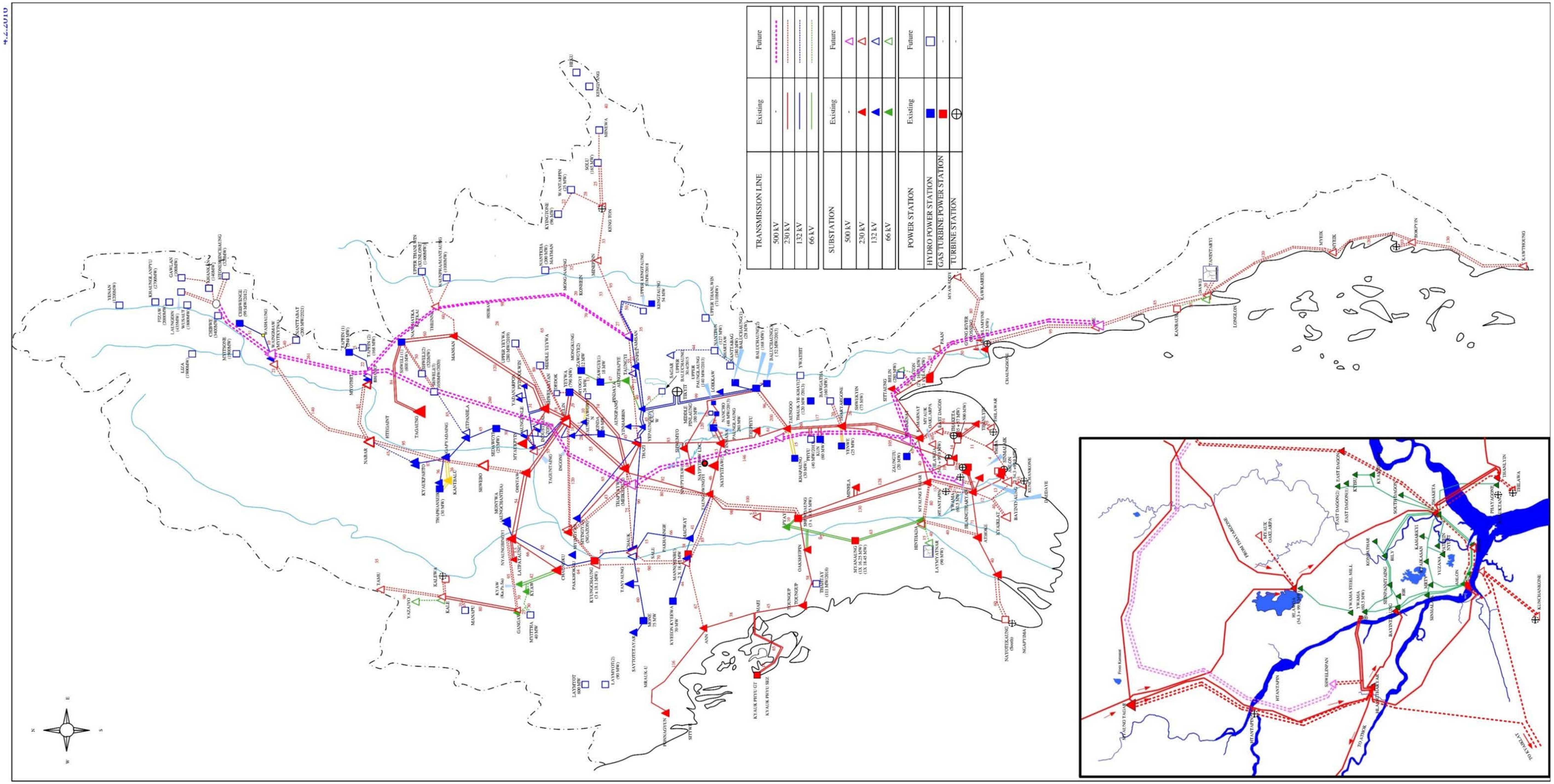


Fig. 2.3-4 Future Transmission Lines and Substations in Myanmar (as of January 2016)

2.4 Electricity Tariff System

Myanmar's electricity tariff is lowest among Southeast Asia's countries, which makes electricity affordable to residential and commercial end users. The GOM has raised tariffs several times over the years, most recent electricity tariff rates with effect from April 1st, 2014 are as follows:

Table 2.4-1 Current Electricity Tariff with Effect in April 2014

	consumption	For Local	For Foreigner
		Metered charge	Metered charge
households	< 100 kWh	Kyat 35/kWh	$0.036/kWh
	101–200 kWh	Kyat 40/kWh	$0.04 /kWh
	> 201 kWh	Kyat 50/kWh	$0.05 /kWh
industry	< 500 kWh	Kyat 75/kWh	$0.08 /kWh
	501–10,000 kWh	Kyat 100/kWh	$0.10 /kWh
	for 10,001–50,000 kWh	Kyat 125/kWh	$0.13 /kWh
	50,001–200,000 kWh	Kyat 150/kWh	$0.16 /kWh
	200,001–300,000 kWh	Kyat 125/kWh	$0.13 /kWh
	> 300,001 kWh	Kyat 100/kWh	$0.10 /kWh

Reference: Power Sector Development in Myanmar, October 2015, ADB

The GOM is implementing to corporatize SOE(s) (State Owned Enterprise(s)) and to make their management system more transparent and efficient. If accounts of SOEs in fiscal year are deficit, the GOM put government subsidies into them by maximum 20% of expenditure of purchasing raw materials including wholesale electricity. Other expenditure of SOE such as capital expenditure, financial expenditure, wage and salary, etc., is budgeted from government account.

Processes to decide electricity tariff rate are: (1) PTSCD, EPGE, ESE and YESC calculate cost per kWh based on all the expenses necessary to supply electricity corresponding to the demand and submit it to DEP (Department of Electric Power), (2) DEP makes a draft of tariff rate through discussion with each enterprise and submit it to Minister's office of MOEE, (3) Minister approves it and submits to the president office. The tariff rate is discussed and approved in the Cabinet.

MOEE has proceeded with a lot of IPP (Independent Power Producer) projects, and PTSCD had contracted six (6) PPAs (Power Purchase Agreement(s)) for two (2) HPPs of Shweli-1 and Thauk Ye Khat-2, three (3) gas engine projects of Zeya at Hlawga. Myan Shwe Pyi at Ywama and Central International Corporation at Thaketa and one (1) gas turbine project of Toyo-Thai at Ahlone as of April 2014. PTSCD has negotiated PPA including other ongoing IPP projects mostly from the nearly-completed time or after completion of project construction. PPAs for completed Baluchaung No.3 HPP project in 2014 were concluded between Future Energy and MOEE. PTSCD has set different terms of PPA contracts in each project, which effective term is one year and renewal negotiation is necessary every year or long period.

2.5 Balance of Power Demand and Supply

Sales of annual Generated Energy Power in 2014 are around 11,250 GWh/year. Power demand in Myanmar is increasing along with recent rapid economy growth.

Year	Annual Generated Energy (GWh/year)					Annual Growth (%)
	Total	General Purpose	Industrial Power	Bulk	Other	
1995-1996	2,262.37	972.29	875.67	340.21	74.20	
2000-2001	3,267.94	1,361.02	1,295.43	526.51	84.98	9%
2005-2006	4,352.66	1,811.97	1,756.42	695.41	88.86	7%
2010-2011	6,312.08	2,653.33	2,286.77	1,306.38	65.60	9%
2011-2012	7,716.86	3,380.97	2,727.37	1,531.71	76.81	22%
2012-2013	8,255.19	3,655.18	2,676.57	1,642.81	280.63	7%
2013-2014	9,612.64	3,764.00	2,699.00	1,692.12	1,457.52	16%
2014-2015	11,254.95	4,112.83	2,984.60	1,754.58	2,402.94	17%

Source: 2015 Myanmar Statistical Yearbook, Ministry of National Planning and Economic Development

Peak demand in 2012 is 1,874MW in total, 742MW in Yangon, 457MW in Mandalay, 131MW in Bago and so on.

At present, lack of power supply and power transmission capacity has been occurred, and faced to the frequent blackout because of transmission line faults.

2.6 Outline of Power Generation and Transmission Line Development Plan

The present condition of power development plan is as follows.

- On the whole, the hydropower development program gets delayed. At present 3 hydropower projects (2 projects by MOEE and 1 project by IPP) are under construction.

- At present, allocation of gas supply amount to future gas-fired thermal projects is studied and alternatives of rental gas engines supply to rapid increasing demand. If new gas-fired thermal plant will be operated, it is not expected to increase power supply by the plant significantly due to limited gas supply amount.

- Concerning the coal-fired thermal development, most of the recent projects are developing for the purpose of exporting energy to Thailand, therefore portion of domestic supply have to be considered. 2 coal thermal projects developed through JV (Joint Venture) / BOT (Build Operate and Transfer) schemes are developing energetically, however opposition movement by the residents is intensified.

- Regarding renewable energy such as PV (photovoltaic), wind, geothermal power, the development policy is under discussion in MOEE and purchase price is not yet fixed because it is under coordination.

Regarding the bulk transmission lines, it is crucial to install and reinforce the bulk power system connection from the northern to the southern areas of the country with the bulk power system in Yangon Area in order to achieve continuous economic growth and enable hydropower supply generation utilizing abundant available water resources.

Considering this situation, power development plan corresponding with an expansion plan of bulk transmission lines is required.

2.7 Rural Electrification

According to the Census Report, the 2014 Myanmar population and housing census, a sizeable proportion of households in Myanmar use electricity (32.4%) as the main source of energy for lighting, followed by candle (20.7%). However, there is a huge difference between urban (77.5%) and rural areas (14.9%) in the use of electricity as the main source of lighting. The proportion of households using battery, generator and solar systems as the main source of lighting is considerable. It is also evident that, four out of five households in Myanmar use wood or charcoal as main sources of energy for cooking. In urban areas, over half of households use wood or charcoal, while in rural areas up to 80 % use wood or charcoal for cooking. Overall, only 17 % of households use energy such as electricity and liquefied petroleum gas for cooking. The proportion is higher in urban areas (46%) but very low in rural areas (6%).

An expansion plan of the national grid should be coordinated with the National Electrification Plan on Rural Electrification presently supported by WB. DRD (Department of Rural Development) of MOALI (Ministry of Agriculture, Livestock and Irrigation) and ESE are in charge of making the Master Plan on Rural Electrification, showing the future electrification plan until 2030. GOM including MOEE and other relevant organizations cooperate and implement rural electrification effectively with assistance of international donors.

From an interview with DRD of MOALI in January 2014, the number of electrification village is 21,675 out of the total number of village of 64,917 as of 2012-2013, which is equivalent to 33.4%. Electrification includes not only access to grid-connected electricity but also access to mini-grid and off-grid ones.

2.8 Outline of Social and Economic Condition of Objective Areas

Baluchaung No.1 HPP is located at the Baluchaung River at Lawpita in Kayah State, about 16km away from southeast of Loikaw Township.

Kayah State is situated in the hilly eastern part of Myanmar, borders Thailand to the east, Shan State to the north, and Kayin State to the southwest. Kayah is a small but complex state, rich in natural resources, cultural heritage and natural beauty. But Kayah has also been in a state of conflict for more than 60 years, and over the years, the cost of the conflict has been extensive - impacting directly and indirectly, the lives and the livelihoods of most of the people in Kayah, and many thousands who have fled. Decades of conflict, broken ceasefires, and relocations have taken their toll on the people of Kayah, but at this time, there was a sense that things are improving and that genuine change may be forthcoming.

Sedawgyi HPP is located at the Chaungmagyi River at Madaya Township in Mandalay Region, around 130km away from north east of Mandalay city.

Mandalay Region is located in central Myanmar and bordered by Sagaing Region to the north, Sagaing and Magway Regions to the west, the Union Territory of Nay Pyi Taw to the south, and Shan State to the east.

One of the most developed among the states and regions of Myanmar, Mandalay Region fares fees as well as the national average on most social development indicators, and fares better than the national average on several social development indicators.

Contributing considerably to the Myanmar economy as a whole, Mandalay Region, and particularly the Mandalay metropolitan area, is also home to a large and growing community of economic immigrants from China.

Mandalay City and its surrounding Region have been always playing an important role in the political, economic and cultural history of Myanmar. After Yangon, Mandalay is the second most important economic hub in the country, contributing substantially to its National Product. Despite being one of the economic centers, Mandalay Region’s overall poverty incidence was 27 % in 2010 (14 % in urban and 32 % in rural areas), which was slightly above the national average of 26 %. This indicates that economic development is geographically rather unevenly spread over the Region with some parts benefiting more than others. On most of the social indicators Mandalay Region as a whole fares similar to the national average of Myanmar.

CHAPTER 3

NECESSITY OF THE PROJECT

Chapter 3 Necessity of the Project

3.1 Outline of the Project

3.1.1 Baluchaung No.1 Hydropower Plant

Baluchaung No.1 HPP (Hydropower Plant) is located in the Baluchaung River which is a tributary of the Nam Pawn River of the Thanlwin River system and was commenced in operation in August 1992 by Japan's ODA (Official Development Assistance) as one of cascade-type power generation scheme utilizing precipitous geography. In the same river system Baluchaung No.2 HPP (MOEE: Ministry of Electricity and Energy, 1960) and Baluchaung No.3 HPP (Future Energy, 2014) are operating, which are important HPP group for Myanmar and which can supply stable power all through the year by regulating river flow by the Mobye Lake in the upstream.

The electric power generated by Baluchaung No.1 HPP is transmitted to the S/S (Substation) located in Baluchaung No.2 HPP by 132 kV T/L (Transmission Line) and to Taungoo S/S by 230 kV T/L as shown in Fig. 3.1-1. The plant is located about 20 km far from Loikaw City, the capital of Kayah State and it takes about 30 minutes by vehicle. Pavement condition of the access road is good.

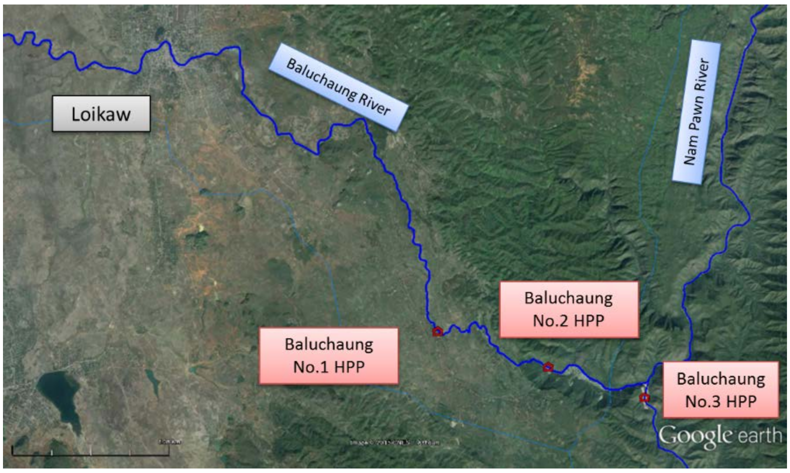
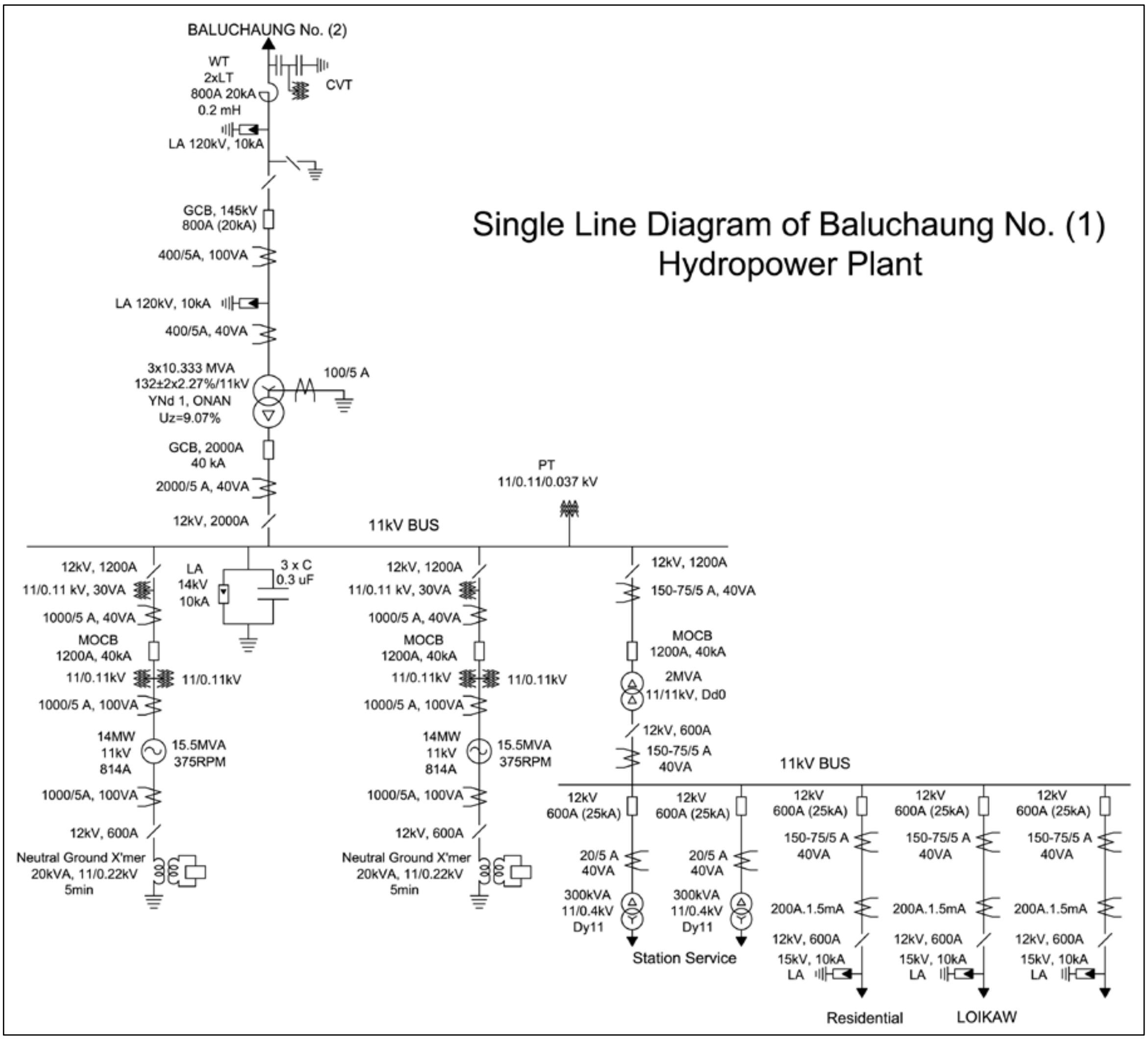


Fig. 3.1-1 Location Map

Table 3.1-1 Major Parameters of Baluchaung No.1 HPP

item	Baluchaung No.1 HPP
Max. power	28.0 MW
Annual generated energy	200 GWh (nominal) / 186 GWh (2013 actual)
Annual operation hour	8,104 hour (2012 actual)
Commencement of operation	August 1992
Power generation type	Dam and conduit type
Region/state	Kayah state
River	Thanlwin River system, Baluchaung River
Catchment area	7,960 km^2
Max. power discharge	47.6 m^3/s
Dam/weir	Concrete weir 11.0 m
Effective head	69.6 m
Turbine type	Francis turbine (Hitachi-Mitsubishi), 14.0 MW × 2 units



Source: JICA Survey Team

Fig. 3.1-2 Single Line Diagram of Baluchaung No.1 HPP

3.1.2 Sedawgyi Hydropower Plant

Sedawgyi HPP is located in the Chaungmagyi River of the Ayeyarwady River system, which is a HPP equipped with multi-purpose dam for irrigation and power generation was constructed by ADB's (Asian Development Bank) finance.

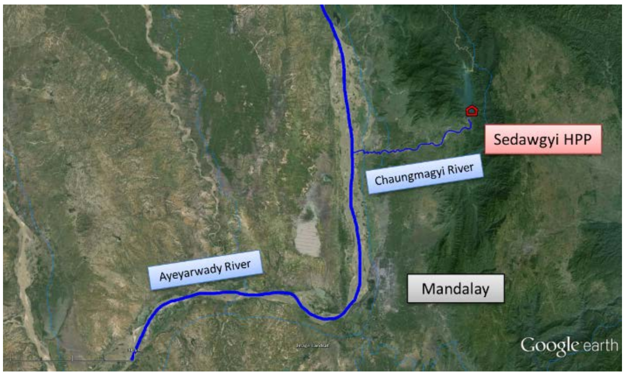


Fig. 3.1-3 Location Map

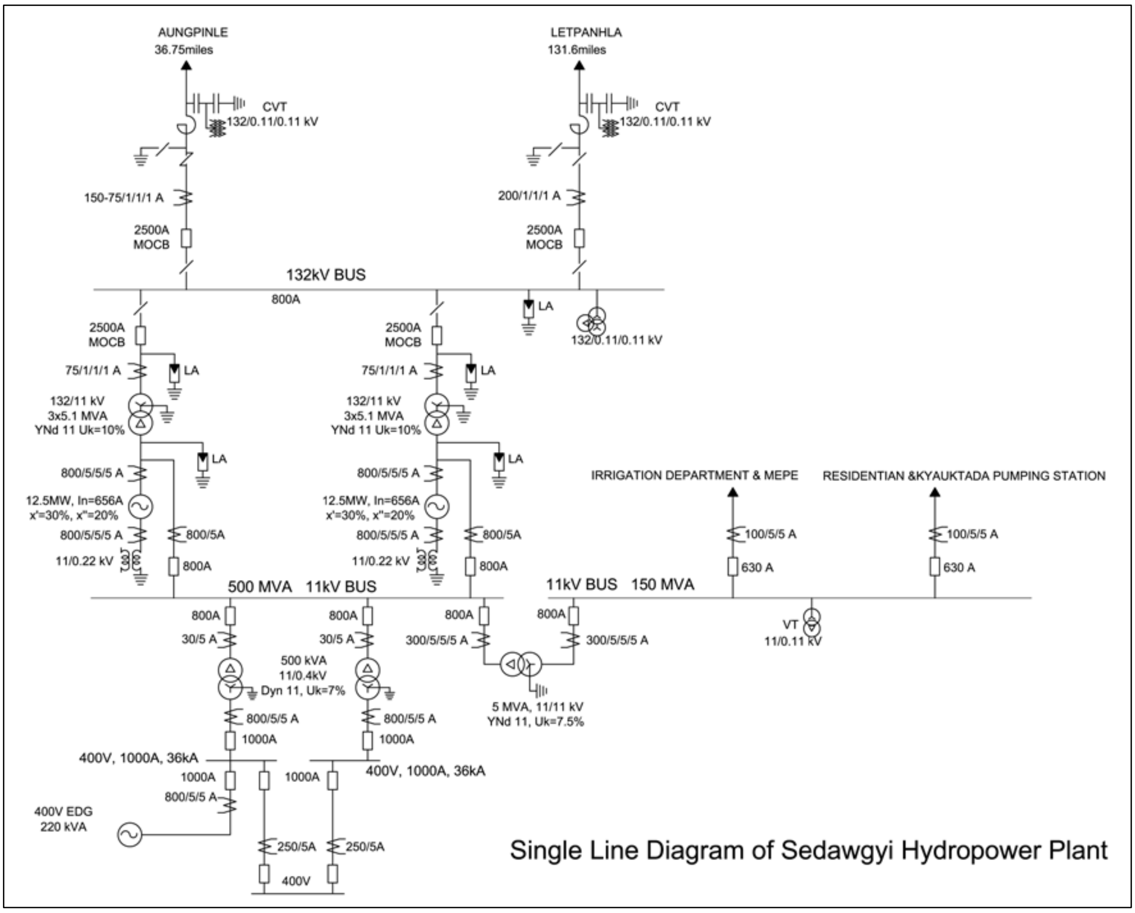
Upper Sedawgyi site in the upstream is selected as candidate development project, but it is under study stage and specific progress is not yet confirmed. MOALI (Ministry of Agriculture, Livelihood and Irrigation) has jurisdiction over the dam body and controls water utilization. MOALI operates the reservoir setting priority to irrigation usage.

The electric power generated by Sedawgyi

HPP is transmitted to Belin S/S by 132 kV T/L, which is connected to 230 kV bulk system as shown in Fig. 3.1-4. The plant is located about 60 km far from Mandalay. It takes about three and half hours by car in the rainy season because condition of access road pavement from main road to the power plant is bad at present. This access road is owned and managed by MOALI.

Table 3.1-2 Major Parameters of Sedawgyi HPP

item	Sedawgyi HPP
Max. power	25.0 MW
Annual generated energy	134 GWh (nominal) / 99.9 GWh (2013 actual)
Annual operation hour	6,919 hour (2012 actual)
Commencement of operation	May 1989
Power generation type	Dam type
Region/state	Mandalay region
River	Ayeyarwady River system, Chaungmagyi river
Catchment area	3,384 km^2
Max. power discharge	51.7 m^3/s × 2
Dam/weir	Rock-fill dam 40.6 m high
Effective head	28.2 m
Turbine type	Kaplan turbine (Toshiba), 12.5 MW × 2 units



Source: JICA Survey Team

Fig. 3.1-4 Single Line Diagram of Sedawgyi HPP

3.2 Current Operating Status of the Project

3.2.1 Baluchaung No.1 Hydropower Plant

(1) Hydropower Generating Equipment

The general specifications of Baluchaung No.1 HPP are as follows.

Turbine	Type:	Vertical Francis
	Capacity:	14 MW × 2 units
	Maximum Discharge:	23.8 m^3/sec
	Rotating Speed:	375 min^{-1}
Generator	Rated Output:	15,500 kVA
	Rated Output Voltage:	11 kV
	Rated Output Current:	814 A
Manufacturer	Hitachi-Mitsubishi Hydro Corporation, Japan	

(2) S/S and T/L

The S/S in Baluchaung No.1 HPP has a 132/11 kV main transformer which is of a three-phase bank of three single-phase transformers, 10.3 MVA per phase. (total 30.9 MVA) and manufactured by Mitsubishi Electric Corporation. This S/S is connected to the Baluchaung No.2 HPP through 132 kV T/L. And also, there are three (3) feeders of 11 kV medium voltage D/L (Distribution Line) in this S/S.

(3) Condition of Generation

Baluchaung No.1 HPP is base-load plant and operates for 24 hours. Annual and monthly generated energy of this plant for 10 years from 2006 to 2015 are shown in Fig. 3.2-1 and annual and monthly availability factor[1] of this Plant for 10 years are shown in Fig. 3.2-2. Annual generated energy, average capacity factor[2] and availability factor are shown in Table 3.2-1. Monthly average generated energy, average capacity factor and availability factor are shown in Table 3.2-2.

Monthly generated energy of this plant for 10 years are shown in Fig. 3.2-3.

1 Availability Factor (AF) = Annual generation hours / 8,760 hours
2 Capacity Factor (CF) = Annual generated energy / (rated output) × 8,760 hours

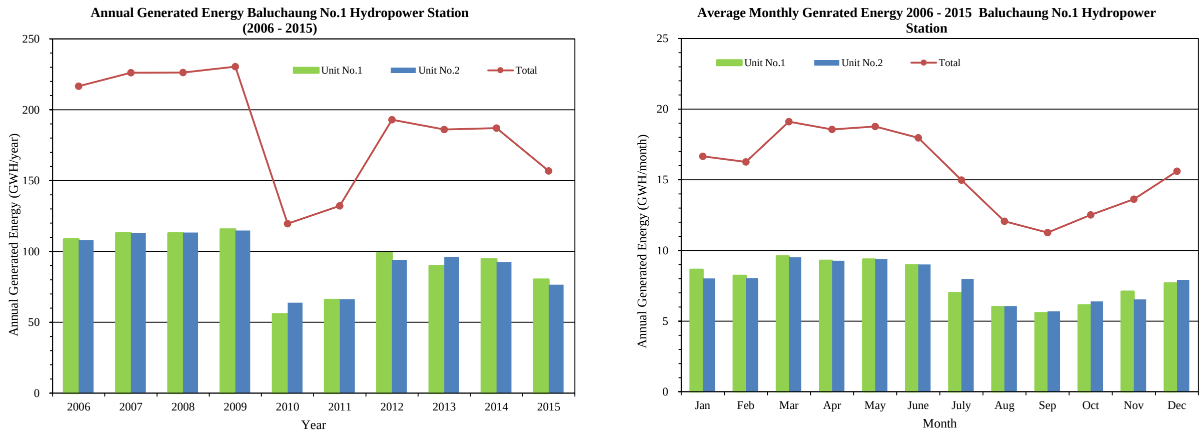


Fig. 3.2-1 Annual and Monthly Average Generated Energy of Baluchaung No.1 HPP (10 years from 2006 to 2015)

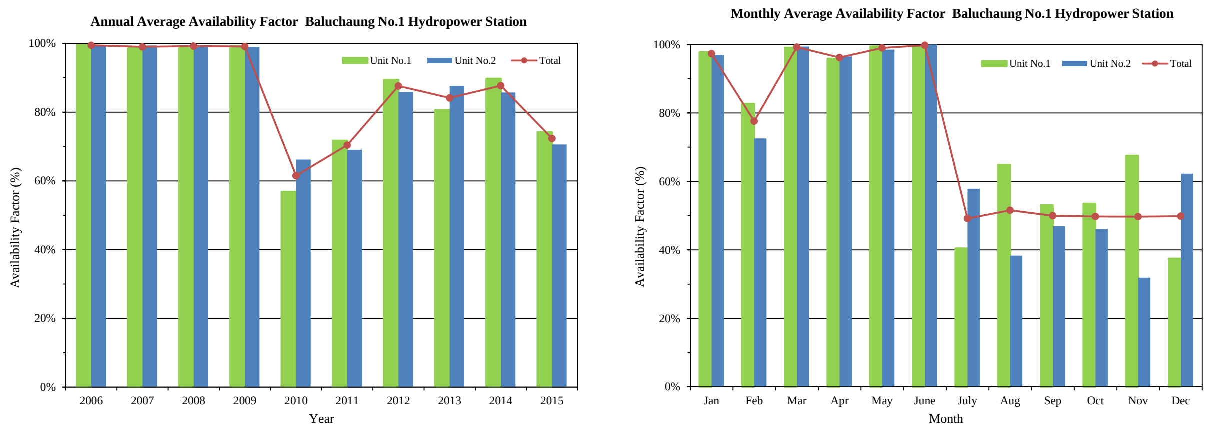


Fig. 3.2-2 Annual and Monthly Average Availability Factor of Baluchaung No.1 HPP (10 years from 2006 to 2015)

Table 3.2-1 Annual Generated Energy, Average Capacity Factor and Availability Factor of Baluchaung No.1 HPP (10 years from 2006 to 2015)

	Generated Energy (GWh)			Capacity Factor (%)			Availability Factor (%)		
year	Unit No.1	Unit No.2	Total	Unit No.1	Unit No.2	Total	Unit No.1	Unit No.2	Total
2006	108.649	107.997	216.645	88.6%	88.1%	88.3%	99.5%	99.4%	99.5%
2007	113.057	113.060	226.117	92.2%	92.2%	92.2%	98.6%	99.4%	99.0%
2008	112.899	113.346	226.245	92.1%	92.4%	92.2%	99.1%	99.3%	99.2%
2009	115.600	114.804	230.404	94.3%	93.6%	93.9%	99.2%	99.0%	99.1%
2010	55.802	63.796	119.597	45.5%	52.0%	48.8%	56.8%	66.2%	61.5%
2011	65.919	66.301	132.220	53.7%	54.1%	53.9%	71.7%	69.1%	70.4%
2012	98.876	94.103	192.980	80.6%	76.7%	78.7%	89.4%	85.9%	87.6%
2013	89.951	96.099	186.049	73.3%	78.4%	75.9%	80.6%	87.7%	84.1%
2014	94.591	92.496	187.087	77.1%	75.4%	76.3%	89.7%	85.7%	87.7%
2015	80.228	76.554	156.782	65.4%	62.4%	63.9%	74.2%	70.6%	72.4%
Average	**93.557**	**93.856**	**187.413**	**76.3%**	**76.5%**	**76.4%**	**85.9%**	**86.2%**	**86.1%**

Table 3.2-2 Monthly Average Generated Energy, Average Capacity Factor and Availability Factor of Baluchaung No.1 HPP (10 years from 2006 to 2015)

	Generated Energy (GWh)			Capacity Factor (%)			Availability Factor (%)		
Month	Unit No.1	Unit No.2	Total	Unit No.1	Unit No.2	Total	Unit No.1	Unit No.2	Total
January	8.642	8.024	16.667	83.0%	77.0%	80.0%	92.7%	87.2%	89.9%
February	8.221	8.045	16.266	87.4%	85.5%	86.4%	94.3%	93.6%	93.9%
March	9.594	9.516	19.109	92.1%	91.4%	91.7%	98.2%	97.8%	98.0%
April	9.289	9.276	18.564	92.1%	92.0%	92.1%	97.9%	98.1%	98.0%
May	9.372	9.399	18.772	90.0%	90.2%	90.1%	98.9%	98.9%	98.9%
June	8.960	9.009	17.969	88.9%	89.4%	89.1%	98.5%	98.6%	98.5%
July	6.997	7.987	14.984	67.2%	76.7%	71.9%	77.1%	86.5%	81.8%
August	6.005	6.065	12.070	57.7%	58.2%	57.9%	74.7%	77.8%	76.3%
September	5.574	5.685	11.259	55.3%	56.4%	55.8%	66.5%	67.0%	66.8%
October	6.125	6.391	12.516	58.8%	61.4%	60.1%	70.6%	73.7%	72.2%
November	7.093	6.532	13.625	70.4%	64.8%	67.6%	80.3%	74.0%	77.1%
December	7.684	7.926	15.611	73.8%	76.1%	74.9%	81.6%	82.0%	81.8%
Total	**93.557**	**93.856**	**187.413**	**76.3%**	**76.5%**	**76.4%**	**85.9%**	**86.3%**	**86.1%**

Fig. 3.2-3   Monthly Generated Energy Baluchaung No.1 HPP (10 years from 2006 to 2015)

Annual and monthly average generated energy of 132 kV T/L and 11 kV Feeder for 10 years from 2006 to 2015 is shown in Fig. 3.2-4 and Fig. 3.2-5 respectively.

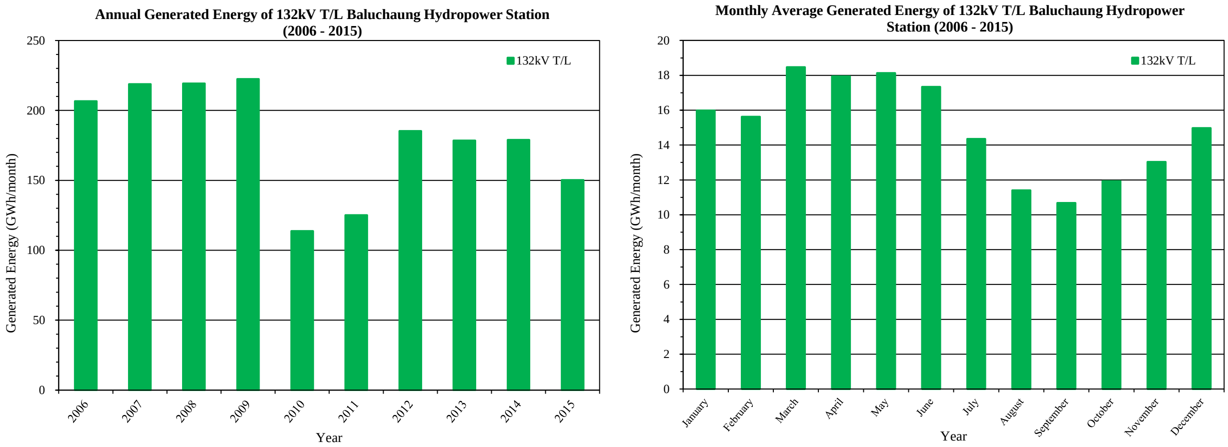


Fig. 3.2-4 Annual and Monthly Average Generated Energy of 132 kV T/L Baluchaung No.1 HPP (10 years from 2006 to 2015)

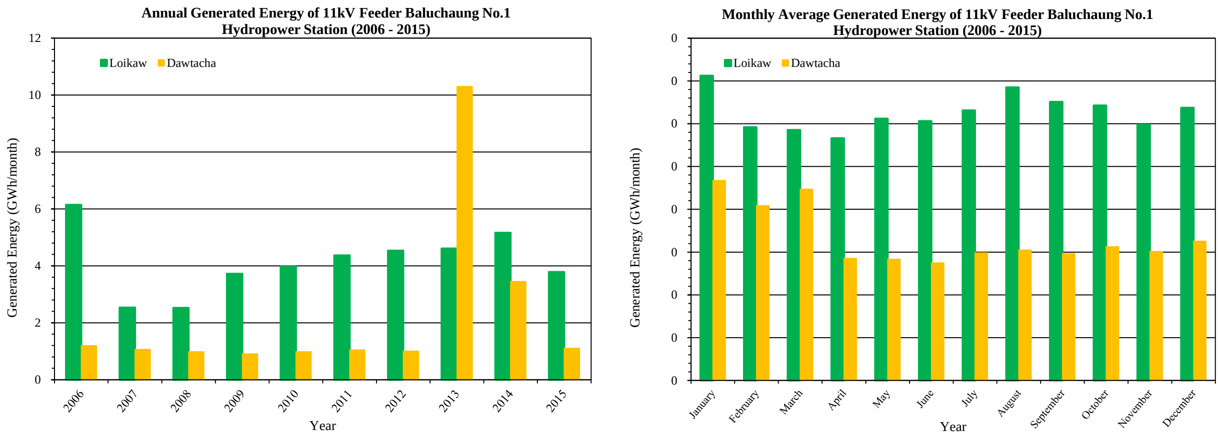


Fig. 3.2-5 Annual and Monthly Average Generated Energy of 11 kV Feeder Baluchaung No.1 HPP (10 years from 2006 to 2015)

Monthly Average Water Level of Mobye Dam and Power Discharge of Baluchaung No.1 HPP for 10 years from 2006 to 2015 are shown in Fig. 3.2-6.

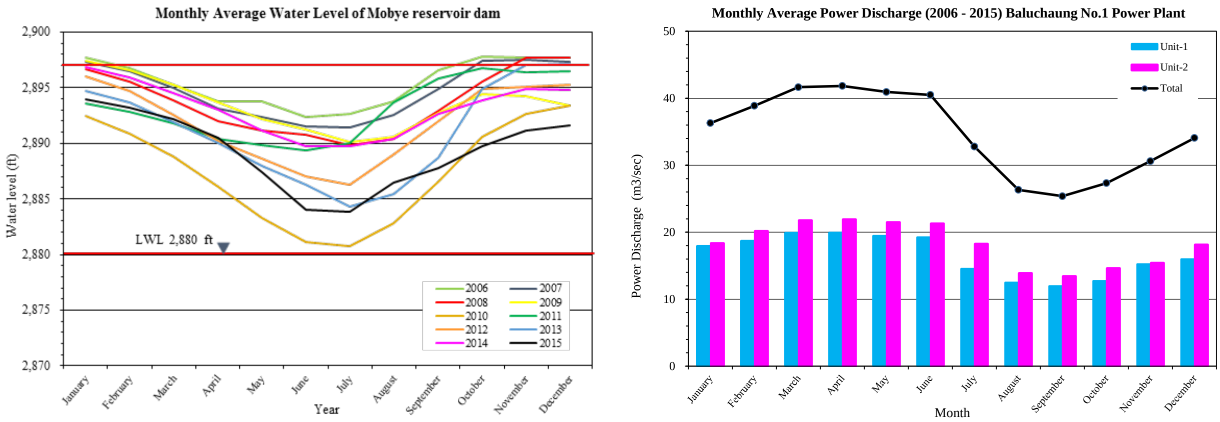


Fig. 3.2-6 Monthly Average Water Level of Mobye Dam and Power Discharge of Baluchaung No.1 HPP (10 years from 2006 to 2015)

The conditions of generation are summarized as follow:

- The annual average generated energy for latest 10 years from 2006 to 2015 is around 187 GWh/year and it is decreasing from 2010. Maximum one is about 230 GWh/year in 2009 and minimum one is about 120 GWh/year.
- The generated energy of each unit is almost same amount.
- The annual average capacity factor for latest 10 years from 2006 to 2015 is around 76% and it is decreasing from 2010.
- The annual average availability factor for latest 10 years from 2006 to 2015 is around 86% and it is decreasing from 2010.
- According to the monthly average generated energy for latest 10 years from 2006 to 2015, generated energy from August to November is smaller. Maximum one is about 19.1 GWh/month in March and minimum one is about 11.3 GWh/month in September.
- Regarding energy of 11 kV feeder, average annual generated energy evacuated to Loikaw is 4.1 GWh/year and one to Dawtacha is 2.2 GWh/year. One to Loikaw is increasing gradually and one to Dawtacha is almost same except 2013 and 2014.

3.2.2 Sedawgyi Hydropower Plant

(1) Hydropower Generating Equipment

The general specifications of Sedawgyi HPP are summarized as follows.

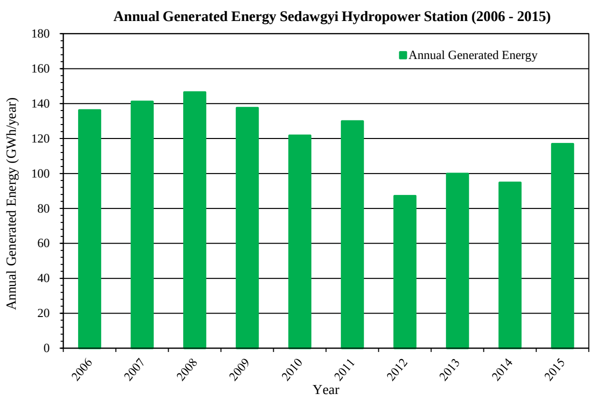
Turbine	Type:	Vertical Kaplan
	Capacity:	12.5 MW × 2 units
	Maximum Discharge:	51.7 m³/sec
	Rotating Speed:	250 min^{-1}
	Manufacturer:	Toshiba Corporation, Japan
Generator	Rated Output:	13,888 kVA
	Rated Output Voltage:	11 kV
	Rated Output Current:	814 A
Manufacturer:	Meidensha Corporation, Japan	

(2) S/S and T/L

The S/S in Sedawgyi HPP has two (2) 132/11 kV main transformers which are of a three-phase bank of three single-phase transformers for each unit, 5.1 MVA per phase (total 30.6 MVA) and manufactured by ABB. This S/S is connected to the Aungpinle S/S (incoming feeder) and Letpanhla S/S (outgoing feeder) through 132 kV T/Ls. And also, there are two feeders of 11 kV medium voltage D/L. This S/S has a role as a switching plant for power supply to west area of Madaya Township in Mandalay District.

(3) Condition of Generation

Sedawgyi HPP is base-load plant and operates for 24 hours. Annual generated energy and monthly average generated energy of this plant for 10 years from 2006 to 2015 are shown in Fig. 3.2-7 and annual and monthly average availability factor of this plant for 10 years are shown in Fig. 3.2-8. Monthly generated energy of this plant for 10 years are shown in Fig. 3.2-9. Annual generated energy, capacity factor and availability factor are shown in Table 3.2-3. Monthly average generated energy, capacity factor and availability factor are shown in Table 3.2-4.



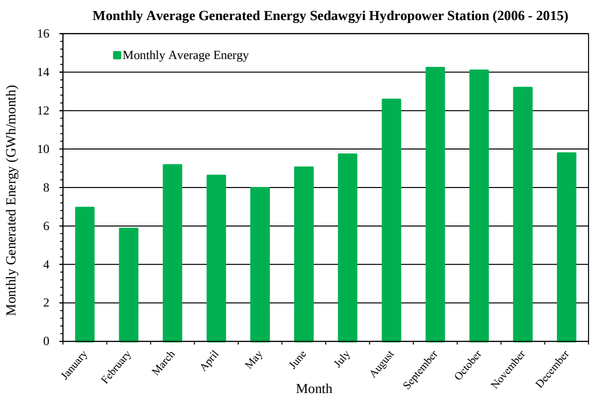


Fig. 3.2-7 Annual and Monthly Average Generated Energy of Sedawgyi HPP (10 years from 2006 to 2015)

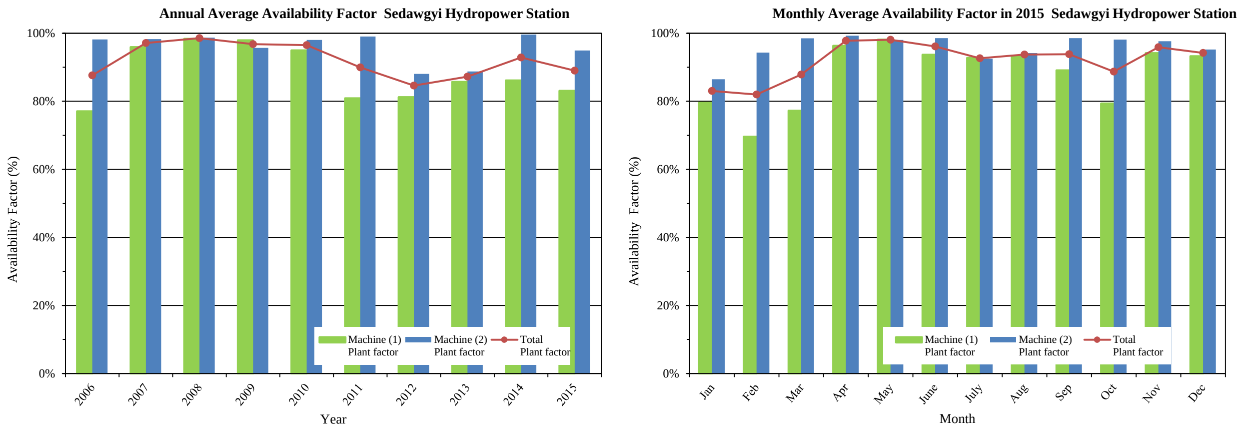


Fig. 3.2-8 Annual and Monthly Average Availability Factor of Sedawgyi HPP (10 years from 2006 to 2015)

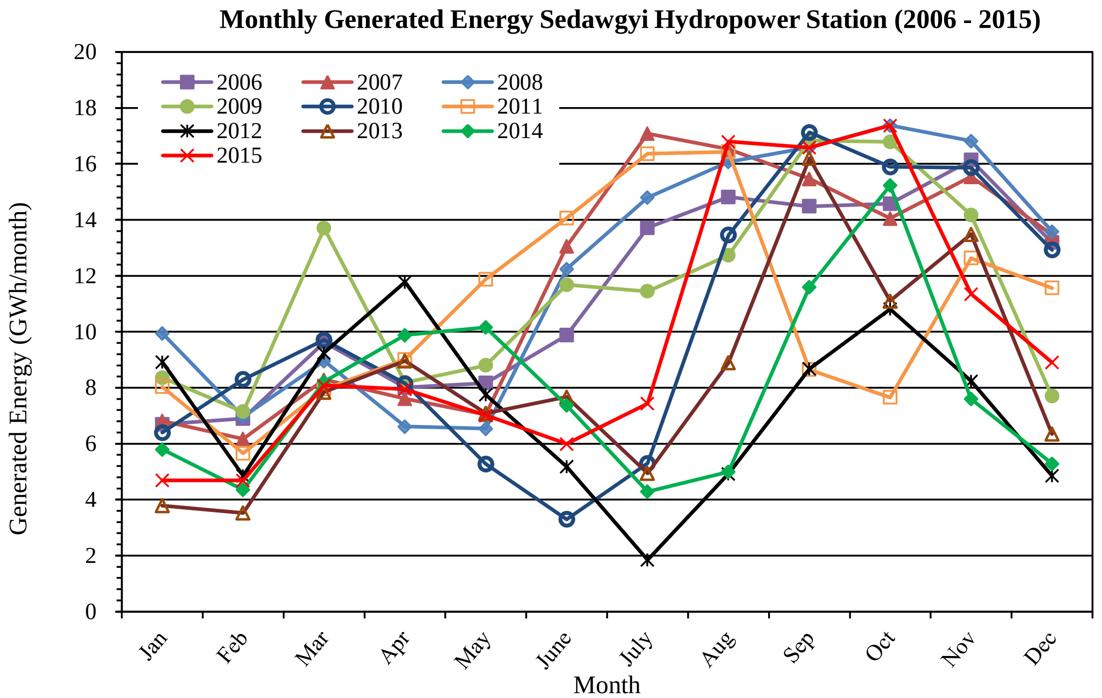


Fig. 3.2-9 Monthly Average Generated Energy Sedawgyi HPP (10 years from 2006 to 2015)

Table 3.2-3 Annual Generated Energy Average Capacity Factor and Availability Factor of Sedawgyi HPP (10 years from 2006 to 2015)

	Generated Energy (GWh)			Capacity Factor (%)			Availability Factor (%)		
year	Unit No.1	Unit No.2	Total	Unit No.1	Unit No.2	Total	Unit No.1	Unit No.2	Total
2006			136.179			62.2%	77.1%	98.2%	87.6%
2007			141.135			64.4%	95.9%	98.3%	97.1%
2008			146.516			66.9%	98.4%	98.7%	98.5%
2009			137.533			62.8%	97.9%	95.7%	96.8%
2010			121.693			55.6%	95.0%	98.0%	96.5%
2011			129.873			59.3%	80.9%	99.0%	90.0%
2012			87.102			39.8%	81.2%	88.0%	84.6%
2013			99.860			45.6%	85.7%	88.8%	87.2%
2014			94.784			43.3%	86.1%	99.6%	92.9%
2015			116.879			53.4%	83.1%	94.9%	89.0%
Average			**121.155**			**55.3%**	**88.1%**	**95.9%**	**92.0%**

Table 3.2-4 Monthly Average Generated Energy, Average Capacity Factor and Availability Factor of Sedawgyi HPP (10 years from 2006 to 2015)

	Generated Energy (GWh)			Capacity Factor (%)			Availability Factor (%)		
Month	Unit No.1	Unit No.2	Total	Unit No.1	Unit No.2	Total	Unit No.1	Unit No.2	Total
January			6.945			37.3%	79.6%	86.5%	83.0%
February			5.856			34.9%	69.6%	94.3%	82.0%
March			9.162			49.3%	77.2%	98.5%	87.9%
April			8.614			47.9%	96.3%	99.3%	97.8%
May			7.971			42.9%	98.1%	98.0%	98.0%
June			9.043			50.2%	93.7%	98.6%	96.1%
July			9.721			52.3%	92.8%	92.5%	92.6%
August			12.567			67.6%	93.2%	94.2%	93.7%
September			14.221			79.0%	89.1%	98.6%	93.8%
October			14.087			75.7%	79.3%	98.1%	88.7%
November			13.185			73.2%	94.1%	97.6%	95.9%
December			9.783			52.6%	93.2%	95.2%	94.2%
Total			**121.155**			**55.2%**	**88.0%**	**95.9%**	**92.0%**

Monthly generated energy evacuated to 132 kV T/L to Mandalay and Kyaukpahtoe for 10 years from 2006 to 2015 is shown in Fig. 3.2-10. Negative value means incoming energy from such T/L.

Annual and monthly generated energy evacuated to 11 kV Feeder for 10 years is shown in Fig. 3.2-11.

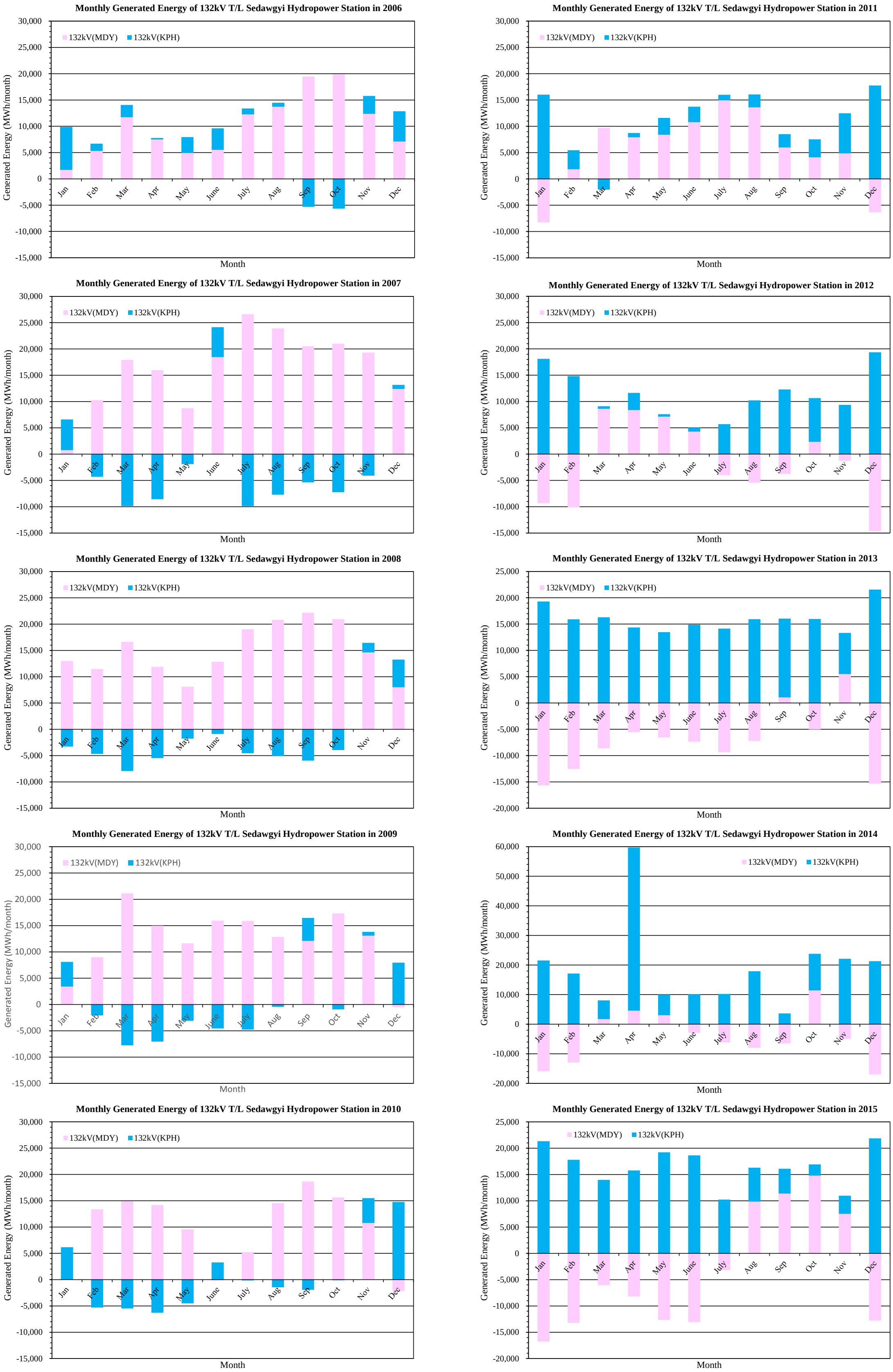
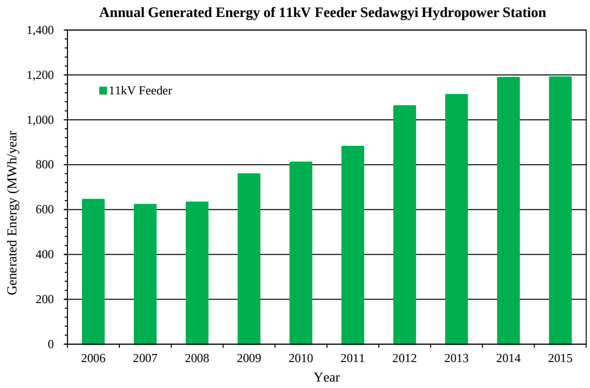


Fig. 3.2-10 Monthly Generated Energy of 132 kV T/L Sedawgyi HPP (10 years from 2006 to 2015)



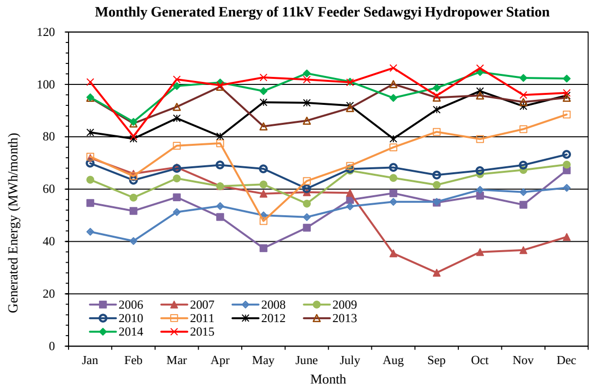


Fig. 3.2-11 Annual and Monthly Generated Energy of 11kV Feeder Sedawgyi HPP (10 years from 2006 to 2015)

The conditions of generation are summarized as follow:

- The annual average generated energy for latest 10 years from 2006 to 2015 is around 122 GWh/year and it seems to be decreasing from 2012 (except 2015). Maximum one is about 146 GWh/year in 2008 and minimum one is about 87 GWh/year in 2012.
- The annual average capacity factor for latest 10 years from 2006 to 2015 is around 55 % and it is decreasing from 2012.
- The annual average availability factor for latest 10 years from 2006 to 2015 is around 91% and they are not so different.
- According to the monthly average generated energy for latest 10 years from 2006 to 2015, generated energy from January to May is smaller. Maximum one is about 14.2 GWh/month in September
- Regarding 132 kV T/L, generated energy was sent to Mandalay and from Kyaukpahtoe until 2011, but since 2012 generated energy has been sent to Kyaukpahtoe
- Regarding evacuated energy to 11 kV Feeder, annual energy to near-by villages for latest 10 years from 2006 to 2015 is 0.9 GWh/year and in 2015 annual evacuated energy is increasing up to 1.2 GWh/year.

3.3 Current Maintenance Condition of the Project

3.3.1 Baluchaung No.1 Hydropower Plant

The summary of the maintenance work records of Baluchaung No.1 HPP provided by EPGE (Electric Power Generation Enterprise) is shown in Table 3.3-1 and details are given in Table 3.3-2.

(1) Hydropower Generating Equipment

The generating equipment is assumed to be aged and deteriorated. No overhaul works have been carried out since the commercial operation in 1992, even though actual damages such as the cavitation inside the turbine runner have not been identified through the visual inspection.

Eventually various defective points such as frequent water leakages in the air cooling units, water leakage of guide vanes and soil accumulations inside the turbine pit were identified through the visual check.

Also, the operation control units have some difficulties in temperature monitoring, the control cables behind the control panel are aged to some extent, and EDG (Emergency Diesel Generator) is practically functioning but has no automatic starting functions.

(2) S/S and T/L

This S/S has been operated for 23 years since the operation started in 1992 and deteriorations caused by aging of the equipment are commonly found. In particular, 11 kV indoor switchgear which is installed on the secondary side of the S/S cannot be repaired because the type of switchgear is old and the spare parts are not able to be procured. In addition, only one of two switchgears can operate normally due to the lack of spare parts and it is concerned that if any troubles would occur in the switchgear, it might lead to the blackout of plant service loads. Furthermore, one of two 11 kV insulating transformers (2 MVA × 2 units), which are installed for lightning surge protection, is not operating for several years and cannot be repaired due to the lack of spare parts. Therefore, it is also concerned that if any troubles would occur in this transformer, it might lead to the same blackout situation.

Table 3.3-1 Summary on Maintenance Records of Baluchaung No.1 HPP

Equipment	Content	Times
Turbine	Repair of Shear Pin	1
	Repair of Guide Bearing Water Supply Pipe	2
	Repair of Drainage Pipe of Spiral Case	1
Generator	Repair of Lower Guide Bearing Cooling Coil	29
	Repair of Upper Guide Bearing Cooling Coil	3
	Exchange of Air Coolers	14
Control and Protection System	Replacement of Frequency Changer	1
	Replacement of DC/DC Converter Module	2
	Repair of Automatic Synchronizing Control System	2
	Repair of Load Limiter Control System	1
	Repair of Status and Annunciator System	2
Power Service Equipment	Repair of LOCCB (Low Oil Content Circuit Breaker)	2
	Repair of Power House Transformer	1
Excitation System	Replacement of FCB (Field Circuit Breaker)	2
	Repair of Thyristor Cooling Fan Motor	1
132kV Equipment	Repair of GCB (Gas Circuit Breaker)	1
Others	Repair of Pressure Reducing Valve of Cooling System	2
	Repair of Cooling Water Supply Valve	2
	Repair of Joint of Oil Supply Pipe	1
	Repair of Air Blow off Valve of Oil Pressure Tank	2

Note: Records are since 1998 for generating equipment and since 2004 for electrical equipment

Table 3.3-2 Maintenance Record of Baluchaung No.1 HPP

	Date	Description	Cause
Mechanical			
1	22/06/1998	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
2	27/10/1998	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
3	29/10/1998	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
4	21/10/1999	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
5	13/04/2000	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
6	02/06/2001	Repaired cooling system, pressure reducing valve (Unit-1)	
7	05/07/2001	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
8	12/12/2002	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
9	13/12/2002	Repaired, joint of oil supply pipe (Unit-1)	
10	15/01/2003	Repaired, Air blow off valve of oil pressure tank (Unit-1)	
11	15/01/2003	Repaired, Air blow off valve of oil pressure tank (Unit-2)	
12	28/02/2004	Repaired, Pressure reducing valve (Unit-2)	
13	12/06/2004	Headrace channel, repair break hole	
14	25/07/2004	Repaired cooling water discharge pipe joint of turbine guide bearing (Unit-1)	
15	15/01/2005	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
16	29/11/2005	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
17	14/08/2005	Repaired spiral case drain valve (Unit-2)	

	Date	Description	Cause
18	10/2005	The spillway gate No.5 are rain forced by shot pin	Crack No.3 and No.4
19	23/04/2006	Changed new substitute No.1 air cooler (Unit-1)	leakage
20	28/04/2006	Changed new substitute No.3 air cooler (Unit-2)	leakage
21	05/08/2006	Repaired due to leakage cooling water discharge pipe of turbine guide bearing and cleaning actuating oil strainer from governor panel (Unit-1)	
22	07/08/2006	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
23	12/11/2006	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
24	12/11/2006	Changing substitute No.5 air cooler (Unit-2)	leakage
25	26/12/2006	Changing substitute No.3 air cooler (Unit-1)	leakage
26	26/12/2006	Changing substitute No.4 air cooler (Unit-1)	leakage
27	03/01/2007	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
28	07/02/2007	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
29	07/02/2007	Changing substitute No.2 air cooler (Unit-1)	leakage
30	25/03/2007	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
31	26/04/2007	Repaired (20 PM), Cooling water supply valve (Unit-1)	
32	14/05/2007	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
33	13/09/2007	Changing substitute No.5 air cooler (Unit-1)	leakage
34	13/09/2007	Changing substitute No.6 air cooler (Unit-1)	leakage
35	23/10/2007	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
36	21/03/2008	Repaired (20 PM), Cooling water supply valve (Unit-1)	
37	30/04/2008	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
38	02/06/2008	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
39	11/08/2008	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
40	31/08/2008	Changing substitute No.6 air cooler (Unit-2)	leakage
41	17/09/2008	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
42	27/10/2008	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
43	22/03/2009	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
44	30/05/2009	Changing substitute No.4 air cooler (Unit-2)	leakage
45	4/06/2009	Changing substitute No.4 air cooler (Unit-1)	leakage
46	30/07/2009	EDO main valve pressure supply pipe, welding with argon gas	
47	06/08/2009	Changing substitute air cooler (Unit-2)	leakage
48	06/08/2009	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
49	06/08/2009	Repaired, Generator upper guide bearing cooling coil (Unit-2)	leakage
50	25/08/2009	EDO main valve pressure supply pipe, welding with argon gas	
51	19/10/2009	Repaired, Generator lower guide bearing cooling coil (Unit-1)	
52	02/12/2009	Alignment control to raking equipment trash car at Dawtacha Intake Dam	
53	19/12/2009	Guide vane alignment test and repaired shear pin (Unit-1)	
54	03/02/2011	Alignment control to raking equipment trash car at Dawtacha Intake Dam	
55	07/02/2012	Changing substitute No.3 air cooler (Unit-2)	leakage
56	11/05/2012	Repaired, Generator lower guide bearing cooling coil (Unit-1)	leakage
57	30/07/2012	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
58	22/11/2012	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
59	03/09/2013	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
60	03/09/2013	Changing substitute No.2 air cooler (Unit-2)	leakage

	Date	Description	Cause
61	08/08/2014	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
62	11/01/2015	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
63	14/05/2015	Repaired, Generator lower guide bearing cooling coil (Unit-2)	leakage
(Electrical)			
1	1998	Replace LOCCB (Unit-1)	flash over
2	1999	Modified 11kV main bus bar	red hot
3	2000	Replace 2000kVA local transformer	flash over
4	04/09/2004	Replacing frequency changer (Unit-1)	burning internal circuit
5	12/10/2005	Replacing spring and fingers in low oil content circuit (Unit-2)	burning
6	31/10/2008	Repairing local transformer	burning bushing
7	25/09/2011	Replacing DC/DC converter module from AVR (Unit-2)	burning
8	19/01/2011	Replacing main shaft of field circuit breaker	burning
9	14/08/2012	Repairing LOCCB-1200A (Unit-1)	damaged mechanism
10	16/08/2012	Repairing automatic synchronizing control system (Unit-1)	Burning synchronizing contactor (25)
11	18/08/2012	Repairing DC/DC convertor (230V/24V) for status & annunciator system (Unit-1)	burning
12	09/10/2012	Repairing load limiter control system (Unit-2)	damage load limiter switch (77)
13	15/12/2013	Repairing status & annunciator system (Unit-1)	burning DC/DC convertor
14	15/03/2014	Repairing synchronizing control system (Unit-2)	burning synchronizing contact
15	16/03/2014	Repairing thyristor cooling fan motor and control system	burning fan motor and control
16	01/07/2014	Repairing status & annunciator system (Unit-2)	burning DC/DC convertor
17	13/01/2015	Replacing field circuit breaker (Unit-2)	burning
18	08/07/2015	Repairing GCB (R,S,T) and control system	burning spring charge motor contactor and over load

3.3.2 Sedawgyi Hydropower Pant

The summary of the maintenance work records of Sedawgyi HPP provided by EPGE is shown in Table 3.3-3.

(1) Hydropower Generating Equipment

The main equipment in this HPP are also assumed to be aged and this judgement is derived from the fact that no overhaul works have been conducted since 1989.

Many technical problems are recorded such as water leakage from the guide vane, soil accumulations inside the turbine pit, oil leakage from the hydraulic equipment for turbine governor control, and water leakage from cooling water pump seals.

(2) S/S and T/L

This S/S has been operated for 26 years since the operation started in 1989 and deteriorations caused by aging of the equipment are commonly found. In particular, the repair work of the main transformers (Units 1 & 2) is required as soon as possible because oil leakage of the main transformers (Units 1 & 2) is being found. In addition, it is also required to replace the power cable between the generators and main transformers because the troubles by insulation deterioration have been occurred in several times. Further, although 11kV outdoor switchgears were designed as one circuit is for operation and another one is circuit for standby, oil filled circuit breaker of one circuit is out of order from a few years ago. Therefore it is concerned that if any troubles would occur in current operating line, it might lead to situation at which cannot supply the power to external demands such as irrigation, local residents and pump plant, etc. and to the plant service loads.

Moreover, 132 kV circuit breaker, 2,500A of rated normal current and manufactured in Yugoslavia on the T/L side is in a situation at which spring charge and change over mechanism between remote and local are not working due to the aging of the equipment.

Table 3.3-3 Summary on Maintenance Records of Sedawgyi HPP

Equipment	Content	Times
Turbine	Inspection of Runner	1
	Inspection/Repair of Wicket Gates	2
	Check of Shaft Alignment	1
	Inspection of Oil Head	1
	Check of Guide Bearing	1
	Check of Governor System	2
	Check of Head Cover Drainage System	1
Generator	Check/Repair/Replacement of Thrust Bearing	2
	Replacement of Slip Ring	1
	Check of Oil Cooler	1
	Replacement of Carbon Brush	1
	Check of Air Cooler	1
Control and Protection System	Repair of AVR (Automatic Voltage Regulator) System	1
	Installation of Energy Meter	1
	Installation of T/L Protection Relay	1
	Repair of Speed Relay and Sensor	1
House Service Equipment	Check/Repair/replacement of 11kV Circuit Breaker	2
	Replacement of 230V DC Battery Bank	1
	Repair of 11kV Power Cable	2
	Check of 5MVA Transformer	1
	Check of 500kVA Transformer	1
132kV Equipment	Check of 5.1 MVA Transformer	2
	Replacement of Current Transformer	1
	Check/Repair of MOCB (Minimum Oil Circuit Breaker)	4
Others	Repair of Emergency Standby Diesel Generator	1
	Repair of Cooling Water Pump Inlet Valve	1

Note: Records are since 2008

Table 3.3-4 Maintenance Record of Sedawgyi HPP

	Date	Description	Cause
(Station service)			
1	17/12/1994	Repairing of station source CB NF-6	tripping coil burnt
2	06/03/1995	Repairing of 11kV power cable termination	Cable L-3 fault
3	15/08/1995	Detail inspection of 11kV/11kV isolation transformer and cable	fault
4	08/05/1997	Repairing of starter motor of EDG	starter motor defect
5	08/11/1999	Repairing of starter motor of EDG	starter motor defect
6	07/08/2006	Change from No.1 station transformer to No.2	cable fault
7	14/08/2006	Installation of new termination of 11kV L-1 for No.1 station transformer	cable L-1 terminal connection failure
8	08/12/206	Change from No.2 station transformer to No.1	cable L-1 termination failure

	Date	Description	Cause
9	05/03/2007	Repairing of 11kV cable for station transformer	failure
10	27/02/2009	Repairing of exciter on EDG	non excitation
11	16/04/2009	Repairing of termination kit for station transformer	cable L-2 termination kit flash over
12	03/09/2013	Repairing of cylinder head No.3 gasket of Diesel generator	Gasket defect
13	03/02/2015	Repairing of termination of 11kV/11kV (5MVA) isolation transformer	Incoming cable fault
14	14/06/2015	Repairing of termination of 11kV kA2 (500kVA) station transformer	11kV cable burning
15	12/07/2015	Replacement of CT of 11kV kA2 (500kVA) CT (30/5A)	CT flash over
16	16/10/2015	Replacement of termination kit of 11kV kA2 (500kVA) CT	CT flash over
(Mandalay T/L and 132kV bus)			
1	10/01/1995	Replacement of Mandalay MOCB trip coil	trip coil burnt
2	09/03/2003	Replacement of Mandalay MOCB trip coil	trip coil burnt
3	09/03/2003	Repairing of Mandalay MOCB mechanism	mechanism failure
4	21/04/2003	Replacement of Mandalay OCB trip coil	Trip coil burnt
5	08/09/2003	Repairing of Mandalay OCB	Flash over
6	11/09/2003	Replacement of Mandalay MOCB (C)	Mechanism housing damage
7	21/11/2005	Repairing of operating insulator cease on Mandalay feeder OCB	failure
8	07/12/2005	Repairing of inter lock connection on Mandalay feeder D/S	Inter lock connection failure
9	11/11/2008	Replacement of Mandalay feeder trip coil	Trip coil burnt
10	08/04/2015	Replacement energy meter from analog to bidirectional	
(Kyaukpahtoe T/L)			
1	27/5/1997	Replacement of Kyaukpahtoe CB (R)	burnt
2	26/06/2002	Changing of Mandalay feeder and Kyaukpahtoe feeder CT	
3	01/05/2003	Repairing of Kyaukpahtoe OCB mechanism	Mechanism failure
4	05/04/2007	Replacement of Kyaukpahtoe line CT (B)	burnt
5	03/08/2008	Repairing of Kyaukpahtoe feeder CB	Mechanism coil leaf spring taper shaft broken motor and bearing housing damage
6	11/09/2009	Repairing of Kyaukpahtoe feeder CB	Mechanism failure
7	29/08/2014	Replacement of MOC DC breaker	damage
8	08/04/2015	Replacement energy meter from analog to bidirectional	
(11kV Feeder)			
1	27/04/1995	Replacement of 11kV CB (kB3)	Mechanism damage
2	24/05/2006	Replacement of contact rod in combustion chamber on 11kV OCB (kB4) (A)	Combustion chamber burnt
3	04/05/2011	Replacement of 11kV OCB (kB3) with VCB	OCB (B) burnt
4	30/08/2011	Repairing of cable connection on kB3 feeder	Insulation failure
(230V DC power supply)			
1	20/01/2010	Replacement of No.1 battery bank	
(Turbine)			
1	27/02/2015	Replacement of turbine bearing oil	Water contamination
2	31/07/2014	Replacement of turbine bearing oil	Water contamination
3	10/09/2015	Replacement of turbine bearing oil	Water contamination
(Generator)			
1	10/08/2013	Repairing of air cooler discharge pipe	Water leakage
2	24/07/2015	Replacement of lower guide bearing dial thermometer	Thermometer damage

	Date	Description	Cause
3	06/08/2015	Changing of operation mode from AVR MVR	AVR (auto card) damage
4	26/10/2015	Repairing of DC/DC (230V/110V) converter	Converter damage
5	27/07/2015	Installation of new termination kit on transformer 11kV bus bar (incoming side)	Cable fault
(MOCB)			
1	03/12/2012	Repairing of MOCB	Mechanism box damage
2	17/04/2013	Repairing of spring chain in MOCB	damage
3	17/04/2013	Repairing of chain link in MOCB	Chain link defect
4	14/05/2013	Repairing of MOCB	Mechanism box catch bar damage
5	02/06/2014	Repairing of chain link in MOCB	Chain link defect
6	03/06/2014	Replacement of MOCB mechanism box latch pin and chain link	Latch pin and chain link defect
7	07/08/2014	Repairing of MOCB	Chain pin defect
8	26/11/2014	Repairing of chain link and lock key and replacement of main closing operating rod pin in MOCB	Mechanism box damage
(Transformer)			
1	23/09/2014	Repairing of Transformer Line-3	Oil leakage from conservator flange
(General)			
1	04/05/2011	Replacement of vacuum circuit breaker for 11kV irrigation feeder	
2	04/05/2011	Repairing of 132kV MOCB (Unit-1)	
3	13/09/2011	Inspection of single phase transformer (5.1MVA) (Unit-1)	
4	13/10/2011	Repairing of AVR system (Unit-1)	
5	12/03/2012	Checking turbine runner (Unit-1)	
6	01/07/2012	Replacement of 230V DC battery bank (Unit-1)	
7	26/07/2012	Replacement of guide van seal (Unit-2)	
8	26/07/2012	Checking and cleaning of thrust bearing pad and line check valve (Unit-2)	
9	14/08/2012	Checking shaft alignment (Unit-2)	
10	20/02/2013	Replacement of current transformer for 132kV Sedawgyi-Kyaukpahtoe line from 150/1/1/1(A) to 500/1/1/1(A)	
11	20/02/2013	Installation of energy meter for 132kV Sedawgyi-Kyaukpahtoe line	
12	20/02/2013	Installation of protection relay for 132kV Sedawgyi-Kyaukpahtoe line	
13	20/02/2013	Repairing of emergency standby diesel generator (200kVA)	
14	06/10/2013	Replacement of slip ring (Unit-1)	
15	06/10/2013	Disassemble of oil head and mechanical seal (Unit-1)	
16	02/06/2014	Repairing of drive chain and stabling chain of oil circuit breaker (Unit-1)	
17	04/06/2014	Filling oil into turbine bearing and cleaning GOV oil duplex strainers (Unit-1)	
18	09/06/2014	Checking and cleaning lubricating oil cooler (Unit-1)	
19	06/06/2014	Inspection and repairing of shear pin sensor (Unit-1)	
20	01/08/2014	Replacement of carbon brush (Unit-1)	
21	11/07/2014	Repairing of speed relay and speed sensor (Unit-1)	
22	03/06/2015	Repairing of cooling water pump inlet valve	
23	27/06/2015	Checking and cleaning of generator air cooler	
23	14/06/2015	Repairing of 500kVA station transformer No.2 incoming cable	

3.4 Myanmar Government's Applications of Rehabilitation for the Power Plants

Based on above understandings, GOM (Government of Myanmar) submitted a grant project proposal for Baluchaung No.1 HPP in 2012 and a loan one for Sedawgyi HPP in 2012. However, comparing the scope of rehabilitation works officially applied by the GOM for the two (2) HPPs, Baluchaung No.1 HPP requires mainly the overhaul work for the generating system as shown in Table 3.4-1 while Sedawgyi HPP requires more rehabilitation works including the replacement works for the main equipment Table 3.4-2.

Sedawgyi HPP started its commercial operation in 1989 and Baluchaung No.1 HPP started in 1992. JICA (Japan International Cooperation Agency) Survey Team implemented the site inspection at both HPPs and confirmed that two (2) HPPs have almost the same operation years to date, high operation rate and deterioration of equipment. The predicted degrees of the deterioration and the necessary rehabilitation works for the main equipment have no particular differences between the two (2) HPPs.

Therefore JICA Survey Team have discussed with MOEE to update the scope of works for the rehabilitation project. Finally MOEE decided to submit the loan project proposal for Baluchaung No.1 HPP to GOM again in order to implement adequate rehabilitation works.

Table 3.4-1 Components of Rehabilitation Request for Baluchaung No.1 HPP

Equipment	Action	Remarks
➢Overhaul Parts	R	including consumable material
➢Turbine		
Non Destructive Test	I	
Turbine Runner	R	replacement (depends on damage), efficiency improvement
Guide Vane	R	replacement (depends on damage), efficiency improvement
Guide Vane Bearing and Stem Bush	R	oil-less type, overhaul works
Shear Pin	R	overhaul works
Gate Servomotor	P	replacement of consumable parts
Turbine Guide Bearing	R	
Shaft Sleeve	R	overhaul works
Shaft Seal Box	R	water leakage, overhaul works
Head Cover	P	replacement of facing plate/wearing ring
Stay Ring	P	replacement of facing plate/wearing ring
Inlet Valve	P	replacement of consumable parts
Inlet Valve Servomotor	P	replacement of consumable parts
➢Generator		
Non Destructive Test	I	
Stator Coil	R	
Rotor Coil	R	insulation renewal
Generator Guide Bearing	R	upper and lower
Generator Thrust Bearing	R	plastic bearing
Oil Lifter	R	replacement of pump set
Oil Cooler	R	
Air Cooler	R	water leakage
➢Control and Protection System		
Operation Board	R	SCADA (Supervisory Control And Data Acquisition)
Speed Governor System	R	digital type

Equipment	Action	Remarks
Automatic Voltage Regulator	R	digital type
Protection Relay (Analog Type)	R	non-maintenance correspondence
SSG Speed Monitor	R	non-maintenance correspondence
Sequencer for Water Level Control	R	non-maintenance correspondence
➢Generator Transformer	I	detailed inspection
➢132kV Circuit Breaker	I	detailed Inspection
➢Lightning Arrestor	I	all of arrestors

R : Replacement P : Repair I : Inspection Source: JICA Survey Team

Table 3.4-2 Components of Rehabilitation Request for Sedawgyi HPP

Equipment	Action	Remarks
➢Overhaul Parts	R	including consumable material
➢Re-Centering and Alignment	I	shaft deflection, damaged turbine discharge ring and generator slip ring
➢Turbine		
Turbine Runner Vane	R	cavitation, efficiency improvement, existing runner to spare
Turbine Runner Hub	R	cavitation, oil-less runner hub
Guide Vane	R	cavitation, efficiency improvement
Guide Vane Stem Bush	R	water leakage, oil-less type
Inner Head Cover	R	with runner replacement, existing cover to spare
Outer Head Cover	P	overhaul works
Turbine Guide Bearing	R	oil leakage, segment type
Shaft Sleeve	R	overhaul works
Shaft Sealing Box	R	overhaul works
Vacuum Breaker Valve	R	overhaul works
Runner Vane Return Mechanism	R	deterioration, wireless type, including oil head repair
Pressure Oil Supply Pipe for Runner Vane Servomotor	R	with runner vane return mechanism work
Speed Governor System	R	deterioration, digital type
Cooling Water Supply System,	R	leakage, replacement of pump/strainer
Water Drainage System	R	defects, draft tube/drainage pit/head cover
Pressure Oil Supply System	R	leakage
➢Generator		
Non Destructive Test	I	
Stator Coil	R	deterioration
Rotor Coil	R	deterioration, insulation renewal
Generator Guide Bearing	R	leakage, upper and lower, two sets of spare
Generator Thrust Bearing	R	leakage, two sets of spare
Oil Lifter	R	clogging of choke valve
Speed Relay	R	defected, digital type
Air Cooler	R	
Excitation System	R	deterioration, brushless type, defects on field discharge CB and ventilation fan
➢Control and Protection System		deterioration, non-maintenance correspondence
Operation Board	R	Programmable Logic Controller (PLC)
Automatic Voltage regulator	R	digital type
Vibration Monitor	R	
Generator Gauge Board (G22)	R	

Equipment	Action	Remarks
Indication Lamp	R	
➢Cable		deterioration
Power Cable	R	b/w generator and each panel/cubicle
Control Cable	R	
➢Ventilation	R	defects, turbine and generator room
➢Electro-Mechanical and Static Relay	R	deterioration
➢11kV Vacuum Circuit Breaker	R	deterioration
➢Plant DC Battery Bank	R	deterioration
➢Generator transformer	R	deterioration
➢11kV Phase Shift Transformer	R	deterioration
➢Powerhouse Service Transformer	R	deterioration
➢EDG	R	deterioration, higher rating capacity, with automatic starting function
➢400V House Service Equipment	R	deterioration
➢Switchyard Equipment (All)	R	defects, GIS with 31.5kA capacity,
➢132/11kV Powerhouse Service Transformer	A	reliability improvement
➢Shunt Reactor	A	voltage regulation for grid

R : Replacement P : Repair I : Inspection A : Addition Source: JICA Survey Team

3.5 Necessity of the Project

As mentioned above, both plants are valuated as the important facilities fulfilling the energy demand of Myanmar and have been operated all through the year since their commercial operations. Meanwhile maintenance works including equipment repair works have been performed through the consecutive efforts provided by plant staffs and consequently generating abilities are kept constant so far.

According to the official rehabilitation applications submitted by the GOM to the GOJ (Government of Japan), the current situations of the two (2) HPPs show the necessity for prompt rehabilitation works due to the deterioration in the quality of the equipment. Some equipment should be rehabilitated under compulsory operation suspension.

Especially the HPP staffs strongly recognize that the repair works are urgent. Possible risks of the facility defects and power outages will not be avoided, even though they have performed maintenance works so far as much as possible.

Therefore it is remarkably important for Myanmar to operate and maintenance existing power plants and sustain stable power supply capacity by appropriate rehabilitation of equipment / facilities.

Both Baluchaung No. 1 and Sedawgyi HPPs are very important power plants to supply the electricity to the national grid.

Therefore viability of the future rehabilitation project studied and proposed in this Survey is evaluated by economic and financial analysis described in Chapter 15.

3.6 Basic Design Concept

The rehabilitation of Sedawgyi and Baluchaung No.1 HPPs, not only the rehabilitation but also the equipment supply and management system should be improved in consideration of the future rehabilitation of other existing HPP s in Myanmar. In this Survey, JICA Survey Team proposed the sustainable equipment supply and management plans based on the concept of preventative maintenance adapted in power plants in Japan and other developed countries.

Overhaul of turbine and generator is usually recommended around every decade. JICA Survey Team studied equipment, wear parts and consumable materials to be replaced or repaired, taking into account of the future overhaul as well.

Generally, insulation diagnosis should be periodically performed to check the operating condition of the equipment. The deterioration tendency can be used to plan the replacement at proper time before the insulation fault might happen. The plan was determined in consideration of the reliability improvement of the power plant and restraint of the stoppage time in every rehabilitation work of each equipment. The plan may include the rehabilitation works which will be carried out in the near future.

When a trouble on the exiting equipment occurs, it is important what kind of countermeasures should be conducted from the viewpoint of reliability of the power plant. As for the spare parts, it is necessary to evaluate and analyze from a viewpoint whether they are necessarily secured or maintained to fulfill the required function as well.

It is hoped that more reliable and advanced technology with labor saving and efficient maintenance should be employed considering adoption of possible Japanese technology in the equipment to be rehabilitated.

The advantageous prominent technologies of Japan for hydropower and power transmission/ transformation equipment are verified. And, possibilities of the adoption of Japanese technologies/equipment are examined.

Furthermore, the concept of life cycle cost evaluation is introduced for the selection of cited equipment, and advantageous plans and specifications of Japan are examined not only on individual element technologies but also on the rehabilitation and maintenance of power plants and S/Ss.

CHAPTER 4

REHABILITATION OF TURBINE AND AUXILIARY EQUIPMENT

Chapter 4 Rehabilitation of Turbine and Auxiliary Equipment

4.1 Method, Results of Site Inspection and Issues

4.1.1 Baluchaung No.1 Hydropower Plant

(1) Inside of the Turbine (after dewatering)

To inspect the inside of the turbine, the water in the spiral casing was dewatered from the dewatering pipe at the bottom of turbine casing after the inlet valve was fully closed under the standstill condition of corresponding unit. Both unit #1 and unit #2 were inspected successfully. Succinct observations were recorded in the sheets of check-list for the inspection previously prepared during the inspection.

Detail explanations on the inspection results for each major components/systems are provided as follows.

Generally speaking, the inside of turbine including the surfaces of the spiral casing and the stay ring is fairly in good condition. However, some specific issues to be considered are described in details in following clauses. The difference of inspection results is very small, considerably same results in other words, between unit #1 and unit #2.

1) Guide Vane

Gaps between the upper and lower portion of guide vanes are measured as samples. The measured gap is averagely 0.6 - 0.7mm. This value clearly exceeds the design value of 0.3mm. (Photo 4.1-1 (1)).

Some guide vanes tuck down small floating foreign materials at the gap portions. But it is not an irregular issue. (Photo 4.1-1 (2)).


(1) Gap measurement


(2) Foreign materials at the side gap

Photo 4.1-1 Guide Vane Conditions

2) Inlet of Runners (Inspected from the spiral casing side), for reference

Usually, guide vanes are in fully closing position under unit standstill condition, thus the inspection on the inlet portion of runner is impossible. On the other hand, the guide vanes only of unit #2 were opened by manual operation exceptionally for the inspection this time, thanks to the station manager.

The inside portions of the guide vane pitch circle and runner vane surfaces (only pressure side) are in good condition and no apparent problems. (Photo 4.1-2 (1))

(1) from the out-side of Guide Vanes

(2) Runner Inlet (bottom side)

Photo 4.1-2 Runner Inlet Portion

Results of the sampling measurement of the gap between outer edge of the runner inlet and inner edge of the wearing ring of the lower cover at unit-#2 are 2.8mm and 2.5mm which are within 3±0.6mm of the design criteria. That means the sand erosion and/or special damages including secular change were very small. (Photo 4.1-2 (2))

3) Outlet of Runners (Inspected from the draft tube side)

The inspection on the outlet portion of the runner was carried out on the scaffold specially installed for the inspection after dewatering of turbine inside under unit standstill condition.

a) Runners of both units are eroded by the cavitation at the outlet portions of the runner vane on the suction surface. There are partially deeply eroded portions (the maximum depth of 3 - 5mm) and countermeasures such as replace or repair work are necessary in the near future. (Photo 4.1-3 (1))

b) Near the connection point with runner band (shroud) on the suction surface of runner vane root and the adjacent area of runner band (shroud), there are eroded portions by cavitation on every runner vanes of both units of #1 and #2. There are partially deeply damaged portions (the maximum depth of 5 - 8mm) and countermeasures such as replace or repair work are necessary in the near future. (Photo 4.1-3 (2))
The eroded portions at the runner inlet were impossible to check from the turbine

(1) Runner outlet portion

(2) Runner inlet portion

Photo 4.1-3 Cavitation Erosion on Runner Surface

casing, because the portions are on the back side of vanes.

c) (Reference) Gaps between the bottom end of runner and the wearing ring of the lower cover are measured. Gaps are 15mm at unit-1 and 14mm at unit-2. As the design value is 13 mm, these are within the acceptable level. (Photo 4.1-4 (1))

4) Air Supply Pipe (Upper Draft Tube)

The air supply pipes in the upper draft tube, tripod type, to prevent large water pressure fluctuation during turbine partial load operation had no apparent damage. (Photo 4.1-4 (2))
There are portions slightly eroded by cavitation on the inner face of draft tube downstream side of the connecting portion with the air supply pipes. It is expected to be repaired by grinding off the rough surfaces in the future. (Photo 4.1-4 (1))

(1) Runner bottom and air pipe

(2) Air pipes (tripod type)

Photo 4.1-4 Conditions in the Upper Draft Tube

(2) Outside of Turbine

1) Guide Vane Servomotor and Related Components

The guide vane servomotors themselves and related components, including the guide ring and the connecting link, etc., have no apparent defect. But, oil leakage was found from the flange connections of pressure oil piping near the servomotor. The oil leakage was found at both unit of #1 and #2. (Photo 4.1-5)

(1) Left side servomotor

(2) Right side servomotor

Photo 4.1-5 Around Guide Vane Servomotors (Unit-#2)

2) Guide Vane Operating Mechanism

The upper surface of the head cover and guide vane operating mechanism, etc. are covered by a film of mud which was contained in water from the penstock. That condition is unfavorable for long satisfactory turbine operation. (Photo 4.1-6 (1))

There was no experience of shear pin breakage at unit #1 and #2, according to the plant staff. On the other hand, although limit switches of the alarm for the shear-pin breakage have often troubles, there are no spare parts at present. (Photo 4.1-6 (1))

3) Water Distribution Pipes inside the Turbine Pit

There are deeply rusted portions on the surface of water distribution pipes of each unit. It may become the cause of eroded holes and water leakage in the future. (Photo 4.1-6 (2))

(1) Guide vane operating mechanism

(2) Eroded water piping

Photo 4.1-6 Conditions in the Turbine Pit

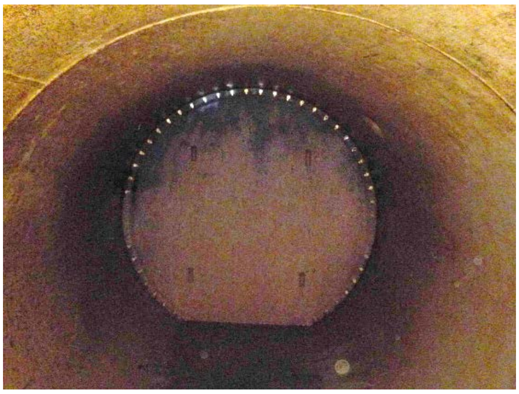
(3) Inlet Valve

Generally speaking, the inlet valves are in good condition. However, some issues to be considered are pointed out in as follows.

1) Inside of Inlet Valve (after dewatering)

In general, the water seal is in good condition. However, there are slight water leakage points due to the partial damage of sealing packing. Water is leaked splashing at unit-#1 and dropping at unit-#2. (Photo 4.1-7)

(1) Splashing water leakage (unit #1)



(2) Drop-like water leakage (unit #2)

Photo 4.1-7 Water Leakage from the Seal Packing of Inlet Valve

2) Outside of Inlet Valve

(Reference) The inlet valve body, bypass valve and manually operated valve are apparently in good condition and there are no water and oil leakage.

(4) Auxiliary Equipment

There are many issues, both for unit #1 and #2, to be solved due to damages by the aging deterioration.

1) Pressure Oil System

a) Pressure Oil Pump

(a) Sludge is observed around the motor coupling. It is supposed that damage and abrasion of the devices such as a bearing are developed.

(b) Aging deterioration of the motors is predicted.

b) Oil Sump Tank (Photo 4.1-8 (1))

(a) There are symptoms of the deterioration at unloader valves, one of very important components.

(b) There is slight oil leakage from the flange connection with pressure oil pipe at unit-#2.

(c) Aging deterioration of relays, meters, gauges and the local control panels is predicted.

(1) Oil sump tank and related components

(2) Oil pressure tank set

Photo 4.1-8 Pressure Oil System

c) Oil Pressure Tank Set (Photo 4.1-8 (2))

(a) A pressure relay is operated manually as a results, not operated automatically, due to its breakdown.

(b) It is supposed that reliability of the function of safety valve is decreased due to the aging deterioration.

(c) The aging deterioration of relays, meters, gauges and the local control panels is predicted.

2) Cooling Water System

a) Cooling Water Pump (Common usage for both Units)

The deterioration of insulation of the motors for cooling water pumps is predicted. And the reliability of the pumping system including electrical devices such as a local control panel is seemed to decrease. (ref. the lower left of Photo 4.1-9 (1))

(1) Automatic water strainers
(Regular use and backup)

(2) Hand-operated water strainers
(Regular use and backup)

Photo 4.1-9 Water Strainers

b) Automatic Strainer (3 units in total) (Photo 4.1-9 (1))

It is predicted that reliability of motor-driven automatic water strainers is decreased due to the aging deterioration at "motor and gear box"s.
The inside of strainers was cleaned and maintained periodically, once two months, by station staff by dismantling the major components. No damage of internal components/parts was confirmed by the staff.

c) Hand-operated Strainer (4 units in total, 2 units for each unit) (Photo 4.1-9 (2))

Although foreign materials is tended to be deposited at the water filter in the strainer, it is impossible to remove it manually and easily due to its mechanical structure. Thus, cleaning the inside of the strainers was carried out frequently by the staff after dismantling the strainer components. It is necessary to improve the strainer construction.

d) General Issues on Cooling Water Piping

(a) The internal inspection for the water piping near a manual strainer was implemented by dismounting a pipe piece. As a result, the mixing layer of rust and mud of approx. 5- 6mm thickness was deposited at the pipe wall. Thus, the rust and mud layer is predicted to be deposited in all water piping. (Photo 4.1-10 (1))

(b) Troubles by the deposit of foreign materials at the intake of cooling water pipe often interrupt water supply and are the obstacles to the stable operation of the power plant. (Photo 4.1-10 (2)).
The accumulation of foreign materials was removed by station staff once a few months after dewatering the penstock and dismantling the inlet components of cooling water piping. Thus, strong request for the improvement of the intake configuration (or piping configuration) was transmitted to the JICA (Japan International Cooperation Agency) Survey Team by EPGE (Electric Power Generation Enterprise).

(1) Rust and mud accumulation in the water piping (near strainers)

(2) Foreign Materials at the intake of cooling water piping

Photo 4.1-10 Water Pipe Internal Conditions

3) Dewatering System

a) Dewatering Pump (2 units, regular use and back-up) (Photo 4.1-11 (1))

The deterioration of the insulation of motors for dewatering is predicted. Reliability of the system including all electrical devices/components such as the local control panel is seemed to decrease.

(1) Water drainage pumps for the drainage pit (regular use and backup)

(2) Water level gauge/detector for the drainage pit

Photo 4.1-11 Water Drainage System

b) Water Level Gauge/Detector at Dewatering Pit

(a) Water level gauging equipment, a gauge and a detector, has not been functioned due to the troubles. The damaged detector was removed already by station staff. (Photo 4.1-11 (2))

(b) Due to these troubles, as a result the dewatering pumps are operated manually, not automatically, at present.

4) Compressed Air System

a) Air Compressor (2 units, regular use and back) (Photo 4.1-12 (1))

Deterioration of insulation of the motors for the air compressors is supposed. Reliability of the system including gauges and electrical devices such as the local control panel is seemed to decrease. The air compressors are located near the inlet valve where is in humid condition. Thus, the redesign of arrangement of the system and the replacement of all related components is needed.

b) Air-pressure Tank (Photo 4.1-12 (2))

Aging deterioration of safety valve, gauges and accessories is predicted.
The location of the tank set is to be redesigned according to the new location of the air compressor sets

(1) Air compressor set (regular use and backup)

(2) Pressure air tank set

Photo 4.1-12 Components of Pressure Air System

5) Governor Panel (Mechanical equipment)

a) The mechanical portion of the actuator are covered with deteriorated grease and oil and it is predicted to cause operational failures. (Photo 4.1-13 (1))

b) Metal ablation powder is around Cam mechanism portion. It will cause troubles in the function of position detection of the governor system.

6) Control Panel of Turbine (Mechanical equipment)

(1) Governor actuator portion in governor control panel

(2) Solenoid valves in turbine control panel

Photo 4.1-13 Components of Control System (Mechanical)

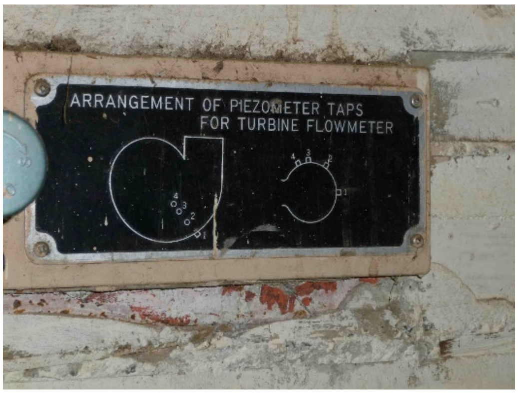
a) Solenoid valves are deteriorated by aging and it will cause troubles in the control of oil pressure. (Photo 4.1-13 (2))

b) The display function of each meter in the panel is considered to be deteriorated by aging.

7) Turbine Flow Meter (Photo 4.1-14)

The turbine flowmeters, using piezometer taps, of both units are broken and out of use.

Monitoring system of turbine flow rate by alternative method was requested to the JICA Survey Team by the station manager.



(1) Name plate for piezometer taps

(2) Turbine flow meter transducer

Photo 4.1-14 Turbine Flow Meter

8) Main Crane (Photo 4.1-15 (1))

Concerning the mechanical portions of the main crane, bridge, trolley, wires, etc., no apparent damage was found.

On the other hand, it is predicted that function of electrical equipment such as motor, relay, breaker, etc. is decreased due to the aging deterioration. (Photo 4.1-15 (2))

(1) Overview of main crane

(2) Electrical parts in the control panel of main crane

Photo 4.1-15 Main Crane

4.1.2 Sedawgyi Hydropower Plant

(1) Inside of the Turbine (after dewatering)

Sedawgyi HPP (Hydropower Plant) has no inlet valve for each turbine originally. Thus, to inspect the inside of the turbine, the water in the spiral casing and the penstock is to be dewatered from the dewatering pipe at the bottom of turbine casing after the intake penstock gate was fully closed under the standstill condition of corresponding unit.

Because the closing condition of the penstock gate was unsatisfied, the maintenance gate (stoplogs) were used for the closure of water flow instead, though the water leakage from the maintenance gate was predicted to flow down to the turbine.

Eventually, the inside of the turbine of "unit #2" was inspected successfully, though the amount of water leakage was not so small. The leakage water of unit #2 was blocked by sandbags in the turbine casing and was dewatered from its dewatering piping. (Photo 4.1-16 (1)) Repair works of the penstock and maintenance gate are described in Chapter 9.

(1) Water leakage of unit #2

(2) Water leakage of unit #1

Photo 4.1-16 Conditions of the Leakage Water from the Intake

On the other hand, because the amount of water leakage from concrete crack in the upper side of the stoplog maintenance gate was very large (over 7 m^3/min was estimated), the internal inspection of the turbine of "unit #1" was impossible. Photo 4.1-16 (2) shows the water leakage from the flange of manhole at the turbine casing after loosening the fastening bolts.

JICA Survey Team discussed with EPGE staff on the issue and decided to postpone the internal inspection of unit #1 until the implementation of repair work of concrete crack by ID (Irrigation Department) to prevent large leakage. Thus, as a result only the external inspection on the turbine of unit #1 was carried out this time.

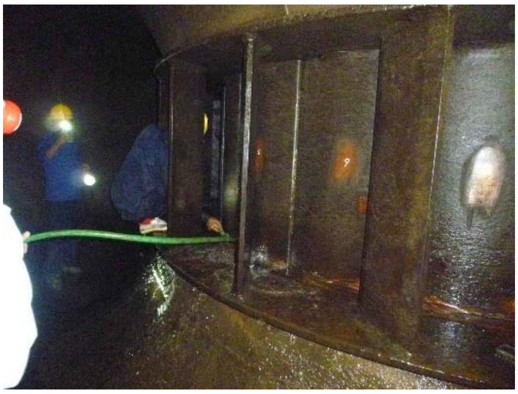
Succinct observations were recorded in the sheets of check-list for the inspection, previously prepared, during the inspection. Detail explanations on the inspection results for each major components/systems are provided as follows.

Generally speaking, it is stated that there are no serious damages in major equipment of turbines. However, deterioration and erosion have been partially developed at individual components/parts in details. Some issues to be considered are pointed out as described in following clauses. The difference of inspection results was very small, considerably same results in other words, between unit #1 and unit #2.

1) Guide Vane

The surface of guide vanes had no apparent damage. (Photo 4.1-17)

Gaps at the upper and lower portion of guide vanes are measured. The measured gaps are averagely 2.0 - 3.0mm. This value extremely exceeds the design value of 0.5mm. There are much less sand abrasions at the surface of facing plates of upper and lower cover portion. It is necessary to adjust the guide vane gaps at the upper and lower portion during future overhaul work.

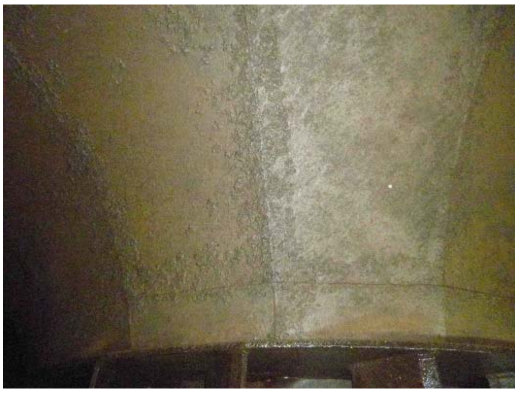

(1) External view of Guide vanes


(2) Bottom portion of guide vane

Photo 4.1-17 Guide Vane Inspection

2) Inner Surface of Casing

There are many blisters due to the rusty knobs on the inner surface of casing. It is necessary to execute scouring rust, cleaning and coating the surface (Photo 4.1-18).


(1) Blisters on casing surface


(2) Hammering check of rusty portion

Photo 4.1-18 Casing Internal Surface

3) Runner Vanes (Inspected from the draft tube side)

a) There were obvious portions eroded by cavitation at the outer periphery of inlet portions of all runner vanes on the suction side (6 vanes in total). There are also partially deeply eroded portions (the maximum depth of 10 - 12mm) and countermeasures such as replace or repair works are necessary in the near future. (Photo 4.1-19 (1))

b) There were portions slightly eroded by cavitation on the root disk of runner vane, on the suction surfaces in upstream side. The portions have the pear skin surface, but the damage is not serious. (Photo 4.1-19 (2))

c) Gaps between the outer periphery of runner vanes and the inner surface of the discharge ring are measured. Gaps of the vane have the values of minimum 0.6mm and maximum 5.3mm. This variation is remarkably large. It is supposed that aging of overall equipment has been developed. It is necessary to adjust these gaps in the future. (Photo 4.1-19 (3)).

d) Circumferential abrasion signatures are observed at a portion of the inner face of the discharge ring. However the relation with the large variation of runner vane gaps mentioned in 3) is not clear. (Photo 4.1-19 (4)).

(1) Portions eroded by cavitation

(2) Root disk of runner vane

(3) Gap at runner vane periphery

(4) Abrasion signatures

Photo 4.1-19 Inspection on Runner Condition

(2) Outside of the Turbine

The conditions in the turbine pit including the upper surface of head cover were relatively clear in general in spite of the long turbine operation of about 30 years. No oil leakage was found around the guide vane servomotors and its pressure oil piping. (Photo 4.1-20 (1))

1) Guide Vane Operating Mechanism

According to the interviews with station staffs, shear pin breakage detectors had some malfunctions up to now. (Photo 4.1-20 (2))

(1) Overview in the turbine pit

(2) Shear pin breakage detector

Photo 4.1-20 Conditions in Turbine Pit (1)

2) Guide Vane Stem Seal Packing

Relatively much water leakage from the water seal packings of the guide vane stem is observed at some guide vanes (Both unit).

3) Rotating Oil Tanks on Turbine Shaft

Indication of the oil gauge (sight glass) of the rotating oil tank equipped at the upper turbine shaft cannot be checked due to the grim of deteriorated oil by aging (both unit). (Photo 4.1-21 (1))

(1) Oil tank on turbine shaft

(2) Oil level detector and devices

Photo 4.1-21 Conditions in Turbine Pit (2)

4) Equipment inside Turbine Pits

a) The oil level detection relay at the turbine bearing has sometimes troubles (unit-2). (Photo 4.1-21 (2))

b) Generally speaking, it is predicted that aging deterioration of relays, gauges and other electrical devices have been developed. (Photo 4.1-22)


(1) Temperature indicators/relays


(2) Water pressure gauges/relays

Photo 4.1-22 Conditions in Turbine Pit (3)

(3) Auxiliary Equipment

Generally speaking, there are many issues to be solved such as damages and the decrease of function due to the aging deterioration. It is difficult for staffs to repair them due to the lack of appropriate spare parts. Although the system of one-man operation and control of power plant had been planned originally, but it is impossible in current situation. Results of the inspection for each unit are almost similar.

1) Pressure Oil System (one set for each unit)

a) Pressure Oil Pump (4 units in total, 2 units per one unit for regular use and back-up)

(a) Two oil pumps are installed on the oil sump tank. Regarding unit-2, the oil pressure output is decreased due to the deterioration of the oil-pump.

(b) Aging deterioration of the bearings and insulation of all motors is predicted.

b) Oil Sump Tank (Photo 4.1-23 (1))

Total function of the oil sump tank set is decreased due to the deterioration of unloader valves on the tank and all electrical components/devices including the local control panel.


(1) Oil sump tank set


(2) Pressure oil tank set

Photo 4.1-23 Condition of Pressure Oil System

c) Oil Pressure Tank (Photo 4.1-23 (2))

(a) It is predicted that reliability of the function of all electrical/mechanical components including pressure relay and the safety valve is decreased due to the aging deterioration.

(b) It is difficult to read the value of the oil gauge (sight glass) of oil tank due to the grim of deteriorated oil.

d) Electrical Parts at Operation Panel

It is predicted that reliability of the function of electric parts is decreased due to the aging deterioration. There is no spare part.

2) Leakage Oil System (1 unit, common usage for both Units)

a) Oil Feeding Pump (1 unit) (Photo 4.1-24 (1))

The oil feeding pump is on the leakage oil tank. Aging deterioration of insulation for motors is predicted.

b) Instrumentation Equipment

It is predicted that reliability of the function of instrumentation equipment such as the flow relay is decreased.

c) Electrical Parts at Operation Panel (Photo 4.1-24 (2))

It is predicted that reliability of the function of electric parts is decreased due to the aging deterioration.

(1) Leakage oil tank set

(2) Local control panel

Photo 4.1-24 Leakage Oil System

3) Cooling Water System (common use for each unit)

a) Cooling Water Pump (2 units for regular use and back-up) (Photo 4.1-25 (1))

Deterioration of insulation of the motors for cooling water pumps is predicted. Reliability of the system is seemed to decrease.

b) Main Strainer of Cooling Water System (2 units for regular use and back-up)

It is impossible to remove foreign materials at the inner water filter easily due to its mechanical structure and is necessary to dismantle the strainer parts to remove the foreign materials currently. The motor-driven system by the automatic control is expected to be installed for stable operation of the plant. (Photo 4.1-25 (2))

(1) Cooling water pumps

(2) Main water strainers

Photo 4.1-25 Cooling Water System

c) Instrumentation Equipment

(a) Generally speaking, it is supposed that reliability of the function of instrumentation equipment is decreased. There are no spare parts.

(b) Flow meters of air cooling equipment for generators of each unit are broken.

(c) Turbine flow meter of unit-1 inside the transmitter box sometimes has troubles. (The flow meter is equipped in the local panel shown in Photo 4.1-26 (1))

(d) Flow meters at the main pipe of cooling water system for oil cooling equipment of Unit-1 are broken. (Photo 4.1-26 (2))

Meanwhile, the readings of these meters can be observed only on site and the additional remote monitoring system is requested to be installed by the plant manager.

(1) Turbine flow meter

(2) Flowmeter at cooling water pipe

Photo 4.1-26 Flow Meters in Auxiliary System

d) Electrical Parts at Operation Panel

It is predicted that the reliability of the function of electrical parts is decreased due to the aging deterioration.

e) General Issues on Cooling Water Piping

(a) Internal inspection for water piping at the outlet of cooling water pump and at air cooling equipment for generators is implemented by dismantling the pipe pieces. As a result, mixing layer of rust and mud of approx. 5.0 - 6.0 mm thickness is deposited on the pipe wall. Thus, the rust and mud layer is surely supposed to be deposited in all water piping. (Photo 4.1-27 (1))

(b) Photo 4.1-27 (2) shows a piece of small pipes used for water pressure meters/relays in the turbine pit after dismantling for the inspection. Thick rust layer was deposited on the internal surface and the outer surface of the pipe was corroded.


(1) Internal condition of the cooling pipe just after a water pump


(2) Condition of a small water pipe piece in the turbine pit

Photo 4.1-27 Condition of Water Piping

4) Dewatering System (one common set for each unit)


(1) Drainage pumps for powerhouse water leakage pit


(2) Drainage pumps for draft tube dewatering pit

Photo 4.1-28 Dewatering Pumps for Drainage Pits

a) **Dewatering Pump for Powerhouse Water Leakage Pits (2 units, regular use and back-up)** (Photo 4.1-28 (1))

One of two units is damaged (the shaft vibration due to the damage of the bearings). Reliability of another unit is seemed to be decreased due to the deterioration of the insulation of motors and the deterioration of mechanical parts of the pump.

b) **Dewatering Pump for the Draft Tube Dewatering Pits (2 units, regular use and back-up)** (Photo 4.1-28 (2))

Regarding all pumps, decrease of the reliability of the function due to the deterioration of insulation of the aging motors is predicted.

c) **Dewatering Pump at the Inner Head Cover of the Turbines (2 units for each unit, regular use and back-up)** (Photo 4.1-29 (1))

One of two pumps is in trouble at both units. The remaining pump is predicted to be in aging and deteriorated conditions.

(1) Drainage pump on head cover (2 pumps/unit)

(2) Water level detector for drainage pit

Photo 4.1-29 Drainage Components

d) **Water Level Gauge/Detector at Dewatering Pits (1 unit for each dewatering pit)**

Currently, the detectors of water level for dewatering pits are not in troubles.
However, these are also predicted to be in aging and deteriorated conditions. (Photo 4.1-29 (2))

e) **Electrical Parts at Operation Panel**

It is supposed that reliability of the function of electrical parts is decreased due to the aging deterioration.

5) **Compressed Air System (one common set for each unit)** (Photo 4.1-30 (1))

a) **Air Compressor (2 units, regular use and back)**

Deterioration of insulation of the motor for the air compressor is supposed. Reliability of the system is seemed to decrease. (Photo 4.1-30 (2))


(1) Compressed air equipment


(2) Air compressor

Photo 4.1-30 Compressed Air System

b) Air-pressure Tank (1 unit, common usage for both Units)

Aging deterioration of safety valve for the pressure tank is predicted.

c) Electrical Parts at Operation Panel

It is predicted that reliability of the function of electrical parts is decreased due to the aging deterioration.

6) Governor Panel (Mechanical equipment) (Photo 4.1-31 (1))

a) Mechanical portions of the actuator are covered with deteriorated grease and oil and it is predicted to prevent smooth movement of mechanical parts and cause operational failures. (Photo 4.1-31 (2))


(1) Governor actuator panel


(2) Governor actuator portion

Photo 4.1-31 Turbine Control System

b) Solenoid valves inside the panel are aged and deteriorated by aging and it may cause troubles in the control of oil pressure.

c) Indicators are predicted to be not functioned due to the aging deterioration of mechanical and electrical parts. Watt meters of governor actuator panels are lacking due to troubles. The revolution meter for unit-1 is also not functioned.

7) Control Panel of Turbine (Mechanical equipment)

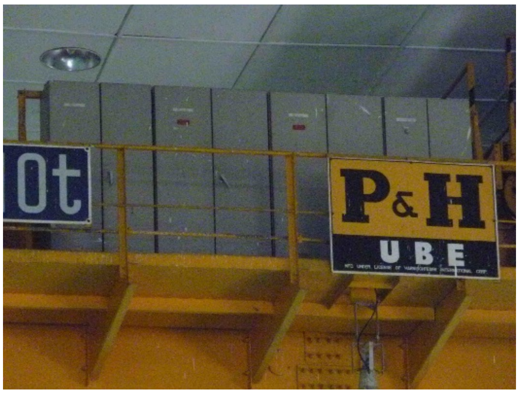
Indicators are supposed to be not functioned due to the aging deterioration of meters and electrical parts. All monitoring recorders of mechanical type are not functioned.

8) Main Crane (Photo 4.1-32)

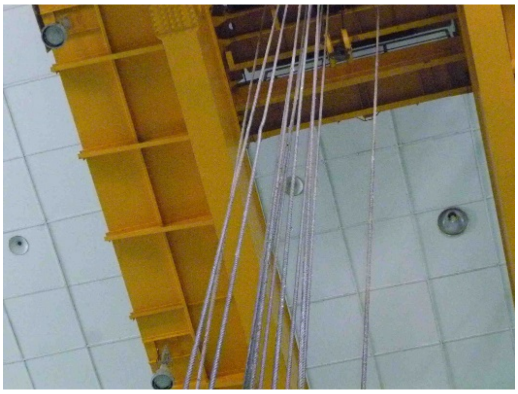
a) It is predicted that function of electrical equipment such as (motor, relay and breaker) is decreased due to the aging deterioration. During the inspection, there was a trouble of related electrical control system for the main 50 ton hook and the operation for hoisting up/down was implemented manually using the local panel. Although this trouble was already repaired tentatively by the change of wiring terminal location, similar troubles are surely predicted to occur in all electrical equipment.

b) Squeak mechanical noise sounded when the operation test of gantry, trolley and hooks were executed. Grease/oil lubrication for the mechanical parts such as reduction gears and the bearings may be insufficient for lack of maintenance.

(1) Overview of main crane



(2) Control panel of main crane



(3) Damage(kink) of main lifting wire

Photo 4.1-32 Condition of Main Crane

4.2 Identification of Rehabilitation Items and Spare Parts

4.2.1 Baluchaung No.1 Hydropower Plant

(1) Screening of existing facilities/equipment for the rehabilitation

Screening results of rehabilitation items for Baluchaung No.1 HPP in the original application and additionally proposed items based on the observations in the inspection are shown in the screening sheets as follows.

Table 4.2-1 Screening of Existing Facilities/Equipment for the Rehabilitation Project (Baluchaung No.1 HPP - Turbine)

Hydropower Plant **Baluchaung No.1**
Facilities/Equipment **Turbine**

*1 Check items
✓ :Problem
NA :Not available
blank: No problem

*2 Screening for the Rehabilitation Project
A :Required
B :Recommended
C :Not Required

*3 Measures
R :Replacement
P :Repair
A :Addition
I :Inspection

Components	Application	Check item*1				Screening*2	Measures*3	Remarks
		aged deterioration	apparent inspection	trouble record	availability of spare parts			
(1. Application Items)								
Non Destructive Test (NDT)	✓					B	I	NDT is preferable to be conducted during the overhaul
Turbine Runner	✓	✓	✓	NA	✓	A	R	Newly designed runner is needed, because of the unignorable cavitation erosion, and difficulties for welding repair
Guide Vane	✓	✓		NA	✓	B	I	No apparent defect was found. Non-destructive inspection is needed during overhaul period. Expectation of some turbine efficiency improvement.
Guide Vane Bearing and Stem Bush	✓	✓		NA	✓	A	R	Replacement of all the bearings/bushes and related consumable small parts
Shear Pin	✓	✓		✓	✓	A	R	Complete replacement of the shear pins and the breakage detecting device
Gate Servomotor	✓	✓	✓	✓	✓	A	P	Complete replacement of the consumable parts, packings and piston rings, etc.
Turbine Guide Bearing	✓	✓		NA	✓	A	P	Replacement of the bearing metal component to one designed using up-to-date technology.
Shaft Sleeve	✓	✓		NA	✓	A	R	Replacement of the sleeve itself to one designed using up-to-date technology.
Shaft Seal Box	✓	✓		NA	✓	A	P	Replacement of the seal packing
Head Cover	✓	✓		NA	✓	A	P	Replacement of its facing plates and wearing rings
Stay Ring	✓	✓		NA	✓	A	P	Replacement of its facing plates and wearing rings
Inlet Valve	✓	✓		NA	✓	A	P	replacement of all the consumable parts
Inlet Valve Servomotor	✓	✓		NA	✓	A	P	replacement of all the consumable parts, packings and piston rings, etc.
(2. Additional Items by the inspection)								
2.1 Speed Governor System		✓	✓	✓	✓	A	R	Redesign and replacement to newly designed digital governor system
2.2 Cooling Water Supply System		✓	✓	✓	✓	A	R	All electrical components including pumps, motor-operated valves and local control panels are needed to be replaced. The motors/gear boxes for main water strainers are needed to be replaced. Hand-operated strainers are needed to be redesigned and replaced. All small exposed water pipings (less than 100mm) should be replaced. The cooling water intake structure at penstock wall is needed to be redesigned and applied for preventing terrible accumulation of foreign materials.
2.3 Water Drainage System		✓	✓	✓	✓	A	R	Drainage pumps at drainage water pits, all related electrical components including local control panels and water level meters, etc.
2.4 Pressure Oil Supply System		✓	✓	✓	✓	A	R	The air-compressor set/system for the pressure oil supply system is needed to be replaced and its location is redesigned. Therefore, the pressure oil system is needed to be redesigned fundamentally. In the replacement, the oil-sump tank set and oil-pressure tank set are needed to be redesigned.
2.5 Turbine flow meter (by piezometer method)		✓	✓	✓	NA	B	A	The flow monitoring method is recommended to be changed to the method using turbine model test data by computation in the new control/monitoring system.
2.6 All wearing/ consumable parts of turbine components		✓		NA	✓	A	R	Ordinarily conducted during the overhaul
2.7 Small electrical/ mechanical components in turbine system		✓	✓	✓	✓	A	R	The small components such as motors, pressure meters, relays and flow meters/gauges, etc. are needed to be replaced.
2.8 Embedded pipings		✓	✓	NA	NA	A	P	Cleaning the inside of embedded pipings is needed. Rust-preventive coating for embedded water pipings should be carried out.
2.9 Station Overhead Crane		✓	✓	NA	✓	A	P	All electrical components/parts and damaged are needed to be replaced.

(2) Detail rehabilitation items

Below rehabilitation items for each equipment/components based on the results of the site inspection/study were suggested for further discussions. The close discussions with EPGE on the selection of rehabilitation items were conducted in the basic design stage.

1) Inevitable replace of consumable/wearing parts during overhaul work

- Packings, O-rings, gaskets,
- Bearing bushes, sliding liners, piston rings
- Facing plates, wearing rings for head and bottom covers
- Shear pins
- Turbine oil for pressure oil system, grease for mechanical parts
- etc.

2) Non-destructive test

- Turbine shaft
- Guide vanes
- Guide vane servomotor
- Guide ring
- Stay vane/(stay ring)
- Inlet valve (body, leaf and stem)
- Inlet valve servomotor
- etc.

3) Runner

- Replacing the runner to newly designed one is weighty because the welding repair for damaged portions having the depth over 3mm by cavitation is very difficult.
  But, the final countermeasure is decided after the discussion with EPGE.

4) Guide vane

- The replacement of the guide vanes is recommendable. But, the final countermeasure is decided after the discussion with EPGE.

5) Electrical and instrumental components/devices/parts

- All electrical/instrumental components/devices/parts such as motors, meters, gauges, relays, local control panels, etc. shall be replaced.

6) Compressed air system

- Air compressors including its air tank and local control panel shall be replaced.
  And its installing place shall be redesigned at the upper floor.

7) Pressure oil system

- The oil sump tank set including oil pumps and unloader valves shall be replaced.
- The pressure oil tank set shall be replaced according to the redesign of the related compressed air system.
- The pressure oil piping shall be redesigned and replaced.

8) Cooling water system

- The cooling water pump including its local control panel shall be replaced
- The motor-operated valves shall be replaced
- The motor operated automatic water strainer: The “motor+gear box”s shall be replaced
- The hand operated water strainer: the strainers shall be redesigned and replaced.

- The new device at the intake of cooling water pipe around the penstock shall be designed and equipped additionally for preventing foreign material accumulation.

9) Drainage system

- The drainage pumps and its local control panel shall be replaced.
- The water level detecting equipment for the drainage pit shall be replaced.

10) Water piping

- The small exposed water pipes, less than 100mm in diameter, shall be replaced.
  And the material of each pipe is to be re-examined.
- Cleaning and rust-preventive coating shall be conducted for all embedded pipes.

11) Turbine accessories in the turbine pit

- All shear pin breakage detectors and its electrical wires shall be replaced.
- All instrument such as meters/parts, electrical devices and exposed small pipes and related valves shall be replaced.

12) Turbine control panel/Governor panel

- The turbine control panel/Governor panel including the mechanical portions shall be replaced.

13) Turbine flow meter

- The original turbine flowmeter by piezometer method is to be scrapped.
- Instead, new turbine flow rate monitoring system using the turbine model test data shall be adopted in the system of the control panel newly installed in the control room.

14) Main crane

- All electrical components such as motors, relays, breakers, etc. shall be replaced.

15) Spare parts

The spare parts for the equipment/devices replaced and repaired in the rehabilitation work shall be supplied for future usual maintenance work by the station staff. The items and numbers of necessary spare parts will be examined in the design stage.

4.2.2 Sedawgyi Hydropower Plant

(1) Screening of existing facilities/equipment for the rehabilitation

Screening results of rehabilitation items foe Sedawgyi HPP in the original application and additionally proposed items based on the observations in the inspection are shown in the screening sheets as follows.

Table 4.2-2 Screening of Existing Facilities/Equipment for the Rehabilitation Project (Sedawgyi HPP - Turbine)

Hydropower Plant **Sedawgyi**
Facilities/Equipment **Turbine**

*1 Check items
✓ :Problem
NA :Not available
blank: No problem

*2 Screening for the Rehabilitation Project
A :Required
B :Recommended
C :Not Required

*3 Measures
R :Replacement
P :Repair
A :Addition
I :Inspection

Components	Application	Check item*1: aged deterioration	apparent inspection	trouble record	availability of spare parts	Screening*2	Measures*3	Remarks
(1. Application Items)								
1.1 Turbine Runner Vane	✓	✓	✓		✓	A	R	Newly designed runner vanes are needed, because of the unignorable cavitation erosion and difficulties for welding repair
1.2 Turbine Runner Hub	✓	✓		NA	✓	A	R	Newly designed hub and the inner mechanism are needed according to the introduction of water lubricated method in the hub.
1.3 Guide Vane	✓	✓		NA	✓	B	I	No apparent defect was found. Non-destructive inspection is needed during overhaul period. Expectation of some turbine efficiency improvement.
1.4 Guide Vane Stem Bush	✓	✓		NA	✓	A	R	Replacement of all the bush itself and related consumable small parts
1.5 Inner Head Cover	✓	✓		NA	✓	A	P	Repair of the cover itself and replacement of related consumable parts
1.6 Outer Head Cover	✓	✓		NA	✓	A	P	Repair of the cover itself and replacement of related consumable parts
1.7 Turbine Guide Bearing	✓	✓		NA	✓	A	R	Replacement of the bearing metal component designed using up-to-date technology
1.8 Shaft Sleeve	✓	✓		NA	✓	A	R	Replacement of the sleeve itself designed using up-to-date technology.
1.9 Shaft Sealing Box	✓	✓		NA	✓	A	P	Replacement of the packing using new material and related small parts
1.10 Vacuum Breaker Valve	✓	✓		NA	✓	A	P	Repair of the valve and replacement of small consumable parts
1.11 Runner Vane Return Mechanism	✓	✓		NA	✓	A	R	Replacement of the mechanism according to the replacement of the exciter and the governor system
1.12 Pressure Oil Supply Pipe for Runner Vane Servomotor	✓	✓		NA	✓	A	R	Replacement of the pipe according to the replacement of the exciter
1.13 Speed Governor System	✓	✓	✓	NA	✓	A	R	Redesign and replacement to newly designed digital governor system
1.14 Cooling Water Supply System	✓	✓	✓	✓	✓	A	R	All electrical components including pumps, motor-operated valves and local control panels are needed to be replaced. The main water strainers should be redesigned and replaced to motor-driven automatic strainers. All small exposed water pipings (less than 100mm) should be replaced
1.15 Water Drainage System	✓	✓	✓	✓	✓	A	R	Head cover drainage pumps, drainage pumps at drainage water pits and all related electrical components including local control panels and water level meters, etc. Corroded or damaged pipings should be replaced.
1.16 Pressure Oil Supply System	✓	✓	✓	✓	✓	A	R	The oil-sump tank set is needed to be replaced. All ancillary components and parts including local control panel of the pressure-oil tank are needed to be replaced. The air-compressor set including related electrical devices including the local control panel are needed to be replaced.
(2. Additional Items by the inspection)								
2.1 Small electrical/mechanical components in turbine system		✓		NA	✓	A	R	The small components such as motors, pressure meters, relays and flow meters/gauges, etc. are needed to be replaced.
2.2 Shear pins and its breakage detectors		✓		✓	✓	A	R	Shear pins which are one item of consumable parts and the breakage detectors are needed to be replaced.
2.3 Turbine flow meter (by piezometer method)		✓	✓	✓	NA	B	A	The flow monitoring method is recommended to be changed to the method using turbine model test data by computation in the new control/monitoring system.
2.4 All wearing/consumable parts of turbine components		✓		NA	✓	A	R	Ordinarily conducted during the overhaul
2.5 Embedded pipings		✓	✓	NA	NA	A	P	Cleaning the inside of embedded pipings is needed. Rust-preventive coating for embedded water pipings should be carried out.
2.6 Repair painting for the internal surface of turbine casing		✓	✓	NA	NA	B	P	Because of the deterioration of original painting inside the turbine casing. Usually, the thickness allowance of 2-3mm for steel plate corrosion is provided in the design.
2.7 Station Overhead Crane		✓	✓	✓	✓	A	P	All electrical components/parts and damaged lifting wires are needed to be replaced.

(2) Detail rehabilitation items

Below rehabilitation items for each equipment/components based on the results of the site inspection/study were suggested for further discussions. The close discussions with EPGE on the selection of rehabilitation items were conducted in the basic design stage.

As mentioned in Section 4.1.2, the condition of the inside of #1 turbine is considered to be almost same as one of #2 turbine because the accumulated operating hours of each unit is almost same and the difference of external inspection results of each unit was very small. Thus, the rehabilitation items described as follows are common for both unit #1 and #2.

1) Inevitable replace of consumable/wearing parts during overhaul work

- Packings, O-rings, gaskets,
- Bearing bushes, sliding liners, piston rings
- Facing plates, wearing rings for head and bottom covers
- Shear pins
- Turbine oil for pressure oil system, grease for mechanical parts etc.

2) Non-destructive test

- Turbine shaft
- Guide vanes
- Guide vane servomotor
- Guide ring
- Stay vane/(stay ring), etc.

3) Runner

- Replacing the runner including runner vanes and the runner hub to newly designed ones is weighty because the welding repair for damaged portions having the depth over 3mm by cavitation is very difficult.
  But, the final countermeasure is decided after the discussion with EPGE.

4) Guide vane

- The replacement of the guide vanes is recommendable. But, the final countermeasure is decided after the discussion with EPGE.

5) Electrical and instrumental components/devices/parts

- All electrical/instrumental components/devices/parts such as motors, meters, gauges, relays, local control panels, etc. shall be replaced.

6) Compressed air system

- Air compressors including its local control panel and electrical devices/parts shall be replaced.
  And its installing place shall be redesigned at the upper floor.

7) Pressure oil system

- The oil sump tank set including oil pumps and unloader valves shall be replaced.
- All accessories of pressure oil tank set shall including the local control panel shall be replaced.

8) Cooling water system

- The cooling water pump including its local control panel shall be replaced
- The motor-operated valves including the local control panel shall be replaced

- The main water strainer (hand operated) shall be replaced to motor-driven automatic strainers.

9) Drainage system

- The drainage pumps for drainage pits and its local control panels shall be replaced.
- The water level detectors for the drainage pit shall be replaced.
- The drainage pumps on the turbine head cover shall be replaced.

10) Water piping

- The small exposed water pipes made of normal steel, less than 100mm in diameter, shall be replaced. And the material of each pipe is to be re-examined.
- Cleaning (and rust-preventive coating if necessary) shall be conducted for all embedded pipes.

11) Turbine accessories in the turbine pit

- All shear pin breakage detectors and its electrical wires shall be replaced.
- All instrument such as meters/parts, electrical devices and exposed small pipes and related valves shall be replaced.

12) Oil head (above the generator exciter)

- The oil head shall be redesigned and replaced for new digital system and the replacement of the exciter.

13) Turbine control panel/Governor panel

- The turbine control panel/Governor panel including the mechanical portions shall be replaced.

14) Turbine flow meter

- The original turbine flowmeter by piezometer method is to be scrapped.
- Instead, new turbine flow rate monitoring system using the turbine model test data shall be adopted in the system of the control panel newly installed in the control room.

15) Refinish painting for the internal surfaces of the turbine casing

- Cleaning and refinish painting for the internal surfaces of the turbine casing shall be conducted.

16) Main crane

- All electrical components such as motors, relays, breakers, etc. and damaged lifting wires shall be replaced.

17) Spare parts

The spare parts for the equipment/devices replaced and repaired in the rehabilitation work shall be supplied for future usual maintenance work by the station staff. The items and numbers of necessary spare parts will be examined in the basic design stage.

4.3 Basic Design on Rehabilitation of Turbine and Auxiliary Equipment

4.3.1 Baluchaung No.1 Hydropower Plant

(1) General condition

Some items of the rehabilitation contents of the two turbines are not same each other.

To examine the rehabilitation design, the basic specification of the existing units is applied basically for the units rehabilitated.

Table 4.3-1 Turbine Basic Specification (Existing Unit)

	unit	Maximum	Design	Normal	Minimum
Net Head	m	75.1	69.9	69.1	66.9
Output	kW	14,400	14,400	14,400	13,750
Discharge	m^3/s	21.7	23.4	23.7	23.5
Speed	min^{-1}	375			

Among the corresponding parts/items for the rehabilitation, the details are described in the following clauses, consumable parts inevitably replaced during the overhaul work and replacement parts/components newly manufactured in this project are included. The new replacement parts/components will have the consistency on the dimensions, etc. with the existing components to be used successively.

The components/parts of the turbine main structure to be rehabilitated are shown in the drawing of “Sectional Assembly of Vertical Francis Turbine” in the Drawing No. BLC_001 by coloring.

(2) Turbine model test

The turbine model test for Baluchaung No.1 HPP is decided not to be carried out after the discussions with EPGE (Electric Power Generation Enterprise), because the runners of the existing design are to be applied for the rehabilitation.

At first, a newly designed runner was planned to be installed for one of the two units, in this case the turbine model test is inevitable to verify the turbine performance.

(3) Turbine runner

(a) The runner of the first unit out of the existing two units is to be replaced with the existing spare runner. The runner of the remaining unit is to be replaced with a new runner of the existing design. (ref. Section 4.3.1 (2))

In the original recommendation, the two existing runners were considered to be replaced to newly designed ones.

(b) The existing turbine shafts are to be connected to the new runners. (for two units)

(c) The existing coupling bolts for the connection to the turbine shaft are to be replaced to new ones.

(4) Guide vane & operating mechanism

1) Guide vane

In the original recommendation, the all guide vanes for two existing units were considered to be replaced to newly designed ones. After the discussion with EPGE, the rehabilitation concept was decided as follows.

(a) For the first unit to be rehabilitated, new guide vanes of the existing design are to be supplied to replace the existing twelve (12) ones in total. New guide vane arms are to be attached to the new guide vanes.

(b) For the following unit, if the existing guide vanes of the first unit are confirmed to be unsatisfactory, all twelve (12) guide vanes of the following unit will be replaced with new ones additionally ordered and manufactured.
If the conditions of existing guide vanes of the first unit are satisfactory, the existing guide vanes are to be used for the following unit successively.

(c) The dimensions of stems of a new guide vane supplied for the rehabilitation should be same as ones of the existing ones for the interchangeability.

2) Guide Vane Stem Bush

(a) All guide vane bearings and stem bushings are to be replaced to new ones. (for two units)

(b) The design dimensions should be same as ones of the existing parts. And, the materials should be equivalent to ones of the existing parts.

3) Shear pins and its breakage detectors

(a) The shear pins and shear pin breakage detecting devices (limit switches) for the existing two unit (24 pieces in total) are to be replaced with new ones.

(b) Twelve (12) sets, for one unit, of new shear pin breakage detecting devices (limit switches) are to be supplied as ones of spare parts.

(c) As for the new shear pin breakage detecting devices (limit switches), lead wires for the device having required length to corresponding adjacent terminal box are to be supplied.

4) Guide vane operating mechanism

(a) As for the guide vane operating mechanism including a gate operating ring, the consumable parts (bearing bushings, guide strips, etc.) and the parts needed for assembly adjustment including eccentric pins are to be replaced with new ones. The other existing parts are to be used successively. (for two units)

5) Guide vane servomotor

(a) The existing main parts are to be used successively.

(b) The consumable parts such as piston rings and O-rings, etc. are to be replaced with new ones. (for two units)

(5) Head cover/ Stay ring (for two units)

1) Head cover

(a) The existing main parts are to be used successively.

(b) The existing guide vane stem bushings and thrust bearings are to be replaced with new ones.

(c) The existing facing plates and a wearing ring are to be replaced with new ones.

2) Stay ring

(a) The existing main parts are to be used successively.

(b) The existing guide vane stem bushings are to be replaced with new ones.

(c) The existing facing plates and a wearing ring are to be replaced with new ones.

(6) Turbine guide bearing (for two units)

(a) The existing component is to be replaced with new one.

(b) The design dimensions should be same as ones of the existing one.

(7) Turbine shaft seal device (for two units)

(a) The existing main component is to be replaced with new one.

(b) The dimensions should be same as ones of the existing one.

(c) The material of new packing to be used should be one of the latest technology.

(d) The existing shaft sleeve is to be replaced with new one. The dimensions should be same as the existing one. The material should be equivalent to the existing one.

(e) The existing packing for maintenance seal are to be replaced with new one.

(8) Inlet valve (for two units)

1) Inlet valve body

(a) The existing main parts are to be used successively.

(b) The bushings for trunnion bearings are to be replaced with new ones.

(c) The consumable parts such as a packing for valve leaf and O-rings, etc. are to be replaced with new ones.

2) Inlet valve servomotor

(a) The existing main parts are to be used successively.

(b) The consumable parts such as piston rings, swivel joints and O-rings, etc. are to be replaced with new ones.

3) Bypass valve

(a) The existing main parts are to be used successively.

(b) The consumable parts such as bearing bushings and O-rings, etc. are to be replaced with new ones.

(9) Cooling water & air supply equipment

The components, noted below, applied for the cooling water supply system (turbine and generator) are to be replaced with new ones. (for one set)

As for this item, attached "Schematic Diagram for Water Supply and Drainage System" in the Drawing No. BLC_002 should be referred to. The drawing is based on the existing drawing of "Schematic diagram of water supply and drainage system, (WA-P4301)".

(a) Electrical equipment
All "local On-Off switch"es are to be replaced with new ones.

(b) Dusting screen structure for the inlet of cooling water pipe
1. The component of dusting screen device for the inlet of cooling water pipe on the penstock wall are to be designed and supplied/installed, for preventing the blockage at the inlet by the refuse in river water.
2. The material of the component should be stainless steel.

(10) Drainage system equipment

The components, noted below, applied for the water drainage system are to be replaced with new ones. (for one set)

As for this item, attached "Schematic Diagram for Water Supply and Drainage System" in the Drawing No. BLC_002 should be referred to.

(a) Electrical equipment

1. The dewatering pumps (2 units in total) in the drainage sump pit are to be used successively.
2. The local control panels for the dewatering pumps are to be replaced with new ones.
3. Specifications on the MCC (Machine Control Center) for the pumps are described in another chapter "protection & control system".
4. The "local On-Off switch"es in the dewatering system are to be replaced with new ones.

(b) Water level detector (for drainage sump pit)

- Water level switch (float type)
- Water level switch (immersion type)
- The lead wires of required length to the adjacent terminal boxes.

(11) Oil system equipment

The components, noted below, applied for the pressure oil supply system are to be replaced with new ones.

As for this item, attached "Schematic Diagram for Oil Control System" in the Drawing No. BLC_003 should be referred to. The drawing is based on the existing drawing of "Schematic diagram for control system, (WA-P4300)"

(a) Oil sump tank set including all related accessories, for 2 units

(b) Air compressor sets including all related accessories, for 2 units in total, common use

(c) Specifications on the MCC for above sub-sections (a), (b) are to be described in Chapter 6, "protection & control system"

(d) The "local On-Off switch"es in the oil system are to be replaced with new ones.

(e) The existing components of the body portions of the oil tank and air tanks are to be used successively.

(12) Electrical/mechanical small equipment (for turbine and generator)

As for this item, the existing drawings on the turbine and generator system and the attached drawings should be referred to. And, the small electrical and mechanical components except for the main items described above are described in this clause.

All monitoring and measuring components noted below by an example are to be replaced with new ones. (for one set)

(a) Water piping system

- Pressure gauges
- Pressure switches
- Differential pressure gauge
- Flow relays
- Others
- The lead wires of required length from each electrical components to adjacent terminal boxes

(b) Oil and air piping system

- Safety valves
- Pressure gauges
- Pressure relays
- Limit switches
- Solenoid valves
- Oil level relays
- Oil level gauges
- Oil level sight glasses
- Thermometers
- Thermal relays
- Others
- The lead wires of required length from each electrical components to adjacent terminal boxes

(c) Various valves

- The valves, including motor-driven valves for draft tube air-admission system, marked in red in the "Schematic Diagram for Water Supply and Drainage System" in the Drawing

No. BLC_002 are to be replaced with new ones
- The valves should be made in Japan.

(13) Wearing/consumable parts for overhaul work (for turbine and generator)

Required quantities of the wearing/consumable parts noted below for turbine and generator components, which are inevitably replaced with new ones for the overhaul work, are to be supplied for the rehabilitation. (for one set)

- O-rings
- Gasket
- Packings
- Others

(14) Special tools (for turbine and generator) (for one set)

(a) Among the special tools for existing turbine and generator supplied originally at the completion, the missing tools at present are to be supplied.

(b) Newly special tools required for newly designed components for the rehabilitation are to be supplied.

(c) On the other hand, the missing special tools unnecessary for the new design are not included in the tools to be supplied.

(15) Spare parts (for turbine and generator)

(a) The quantities of each spare part, except for the spare parts designated separately in the other clause, are to be same as ones in the spare parts list of the existing turbine/ generator.

(b) The spare parts required for the newly designed components for the rehabilitation are to be supplied.

(c) On the other hand, unnecessary spare parts for the new design are not included in the spare parts to be supplied.

(d) Special spare components are designated as follows.

- Runner; unnecessary (The existing runner removed after the rehabilitation will be a spare runner)
- Turbine guide bearing; unnecessary (Existing spare bearing is stored.)
- Newly designed guide vane; 3 pieces
- Shear pin; unnecessary (Existing spare shear pin are stored.)
- Shear pin breakage detecting device; designated in the clause of "(4) Guide vane & operating mechanism".

(16) Turbine governor

(a) This item is to be specified in Chapter 6.

(17) Turbine flow meter (piezometer type)

(a) The existing meter is to be scrapped, because of its ultimate trouble.

(b) As the best alternative, the method using a conversion chart (from generator output to turbine discharge) using the existing turbine model test data is to be introduced to find the current discharge easily. The chart will be prepared by the turbine supplier in the implementation stage.

(18) Nondestructive test (NDT)

NDT is to be conducted by EPGE. EPGE will prepare the materials and equipment needed for the NDT. The test results are to be reviewed by a supervisor dispatched by the contractor during the rehabilitation work.

(19) Embedded pipes & exposed pipes

The inside of the existing embedded pipes and exposed pipes is to be cleaned by EPGE.

(20) Station overhead crane

In the process of discussions with EPGE, the rehabilitation of the crane was to be conducted completely by EPGE. But, finally the rehabilitation concept was finalized as follows.

(a) A supervisor of the crane manufacture is to inspect and identify the components to be replaced and/or repaired, in the early stage after the contract.

(b) The crane manufacturer is to procure the necessary components for the rehabilitation immediately after the inspection.

(c) The crane rehabilitation work is to be carried out by EPGE workers, in time for the main rehabilitation work of the power plant, under the supervision of the crane supervisor.

(d) The crane supervisor is to check and confirm the final conditions of the crane after the rehabilitation.

(21) Paintings for rehabilitation work

Repair painting for the rehabilitation work, for inside/exposed surface of the casing, draft tube, etc., is to be conducted by EPGE. And, the paints and solvents, etc. will be prepared by EPGE. The contractor should provide the paint specifications, quantities, painting procedures, etc. for EPGE.

4.3.2 Sedawgyi Hydropower Plant

(1) General condition

The same items and specifications are applied to the rehabilitation for the existing two units.

To examine the rehabilitation design, the basic specification of the existing units is applied basically for the units rehabilitated.

Table 4.3-2 Turbine Basic Specification (Existing Unit)

	unit	Maximum	Normal	Minimum
Net Head	m	34.56	28.23	15.75
	ft	113.38	92.63	51.68
Output	kW	14,174	13,055	3,900
Discharge	m^3/s	45.1	51.7	29.7
	cfs	1592.5	1825.5	1048.7
Speed	min^{-1}	250		

To improve the turbine efficiency and runner cavitation characteristics, the profiles of runner blades/runner hub and guide vanes are to be designed newly. Additionally, the water passage profile of the inner head cover are to be re-designed corresponding to the new profile/dimensions of runner hub.

Among the corresponding parts/items for the rehabilitation, the details are described in the following clauses, consumable parts inevitably replaced during the overhaul work and replacement parts/components newly manufactured in this project are included. The new replacement parts/components will have the consistency on the dimensions, etc. with the existing components to be used successively.

The components/parts of the turbine main structure to be rehabilitated are shown in the "Sectional Assembly of Vertical Kaplan Turbine" in the Drawing No. SDW_001 by coloring.

(2) Turbine model test

(a) The CFD (Computational Fluid Dynamics) is to be used for the development of the new runner having improved efficiency and cavitation characteristics and for the new guide vanes.

(b) To study/verify the performance and characteristics of the new runner and new guide vanes in detail, the homologous model turbine is to be manufactured and tested in a model test facility. The standard of JIS B8103 "Methods for model tests of hydraulic turbine and reversible pump-turbine" will be applied for the test.

(c) The turbine model test will be witnessed by the client (EPGE) and the consultant

(3) Turbine runner

1) Runner basic specification

(a) The existing runner including runner vanes, a hub and its mechanism is to be replaced with new one. (for two units)

(b) The number of vanes are to be six (6), the same number as the existing one.

(c) The outside diameter of the new runner is to be same as the existing one. The material is to be equivalent to the existing one.

(d) The new runner should have enough mechanical strength for the maximum speed-no-load condition.

(e) The new runner hub should be coupled to the existing turbine shaft.

2) Runner vane

(a) The profile of the new runner vanes should be designed to improve turbine efficiency and cavitation characteristics in harmony with the profile and dimensions of the new runner hub.

(b) The position, profile and dimensions of fins on the suction surface of vanes at the runner periphery should be examined. And, the cavitation characteristics around the fin should be studied during the turbine model test.

3) Runner hub

(a) The profile of outer surface of the new runner hub should be optimum for the turbine performance in harmony with the profile of the newly developed runner vanes.

(b) The oil-less technology is to be applied for the mechanical structure in the new hub.

(c) The self-lubricated bearings are to be applied to bearing portions of the vane operating mechanism in the hub.

(4) Guide vane & operating mechanism

1) Guide vane (for two units)

(a) All existing guide vanes are to be replaced with new ones. Additional two (2) pieces of guide vanes in total for two (2) units are to be supplied as one item of spare parts.

(b) The profile of the new guide vane is to be newly developed to improve turbine efficiency.

(c) The stem dimensions of the new guide vane should be same as the existing ones.

2) Guide Vane Stem Bush (for two units)

(a) All existing guide vane bearings and stem bushes are to be replaced with new ones.

(b) The design dimensions should be same as the existing ones. And the materials should be equivalent to the existing ones.

3) Shear pins and its breakage detectors (for two units)

(a) All existing shear pins, breakage detectors, and related parts should be replaced to new ones.

(b) The lead wires having required length from each breakage detector to the adjacent terminal box should be supplied.

4) Guide vane operating mechanism (for two units)

(a) As for the guide vane operating mechanism, the consumable parts such as bearing bushes, etc. and parts needed for assembly work are to be supplied. The other existing components should be used successively, if the conditions of those components are satisfactory.

5) Guide vane servomotor (for two units)

(a) The major components are to be used successively.

(b) The piston rings and consumable parts are to be replaced with new ones.

(5) Head cover, bottom ring

1) Inner head cover (for two units)

(a) The existing inner head cover is to be replaced with newly designed one.

(b) The outer profile of inner head cover should be designed to improve the turbine efficiency in harmony with the new runner profile.

(c) The mechanical structure should be designed optimally in consideration of the structure of turbine guide bearing and turbine shaft seal device which are to be newly designed.

(d) The vacuum breaker valves are to be replaced with new ones. The important portions should be re-designed to improve its performance and durability, if necessary.

2) Outer head cover (for two units)

(a) The existing one is to be used successively.

(b) The guide vane stem bushes are to be replaced with new ones.

(c) If the facing plates were attached, the plates are to be replaced with new ones.

3) Bottom ring (for two units)

(a) The existing one is to be used successively.

(b) The guide vane stem bushes are to be replaced with new ones.

(c) If the facing plates were attached, the plates are to be replaced with new ones.

(6) Turbine guide bearing

(a) The existing one is to be replaced with new one. (for two units)

(b) The segment type bearing should be applied to the new one.

(c) The structure of the new one should be designed to minimize the oil leakage from the oil tank.

(d) The structure should be designed aiming for easy inspection and maintenance.

(e) The bearing pads of the number for one (1) unit are to be supplied as one of spare parts.

(7) Turbine shaft seal device

(a) The existing one is to be replaced with new one. (for two units)

(b) The device should be designed using the latest technology in consideration of sealing performance, durability and maintenance.

(c) The existing shaft sleeve is to be replaced with new on. The material is equivalent to the existing one. The design should be conducted in harmony with the new shaft sealing components.

(8) Runner blade operating mechanism

1) Runner blade return mechanism

(a) The mechanism is to be replaced with new one. (for two units)

(b) The new design of the components should be conducted in harmony with the replacement of the generator exciter with brush-less one and the replacement of the turbine governor with digitalized one.

2) Runner blade servomotor mechanism (for two units)

(a) The oil-head is to be replaced with newly designed one, if necessary to consider the structure of the newly designed generator exciter.

(b) The new design of the components should be conducted in harmony with the replacement of the generator exciter with brush-less one and the replacement of the turbine governor with digitalized one.

(c) The oil supply pipes needed for the rehabilitation out of all oil supply pipes in turbine shaft are to be replaced with newly designed ones, and the other pipes are to be used successively.

(d) The piston rings and consumable parts in the runner blade servomotor are to be replaced with new ones.

(e) According to the dimensional change by the rehabilitation of the generator exciter, the external pressure oil pipes, etc. connected to the oil head should be newly designed after examining the portion of the pipe replacement.

(9) Cooling water system equipment

The components noted below used for the cooling water supply system (for turbine and generator) are to be replaced with new ones. (for one set)

As for those components, drawings, etc. of the existing system, including below drawing, should be used for the design.

"Schematic diagram of water piping", (P-00 021 116)

(a) Electrical equipment

1. Water feed pump sets (2 sets)
2. Motor-driven valves (2 sets)
3. Local control panel (an integrated panel for 1. and 2.)

(b) Main water strainer

- The existing two (2) hand-operated main strainers are to be replaced with new two (2) automatic motor-driven strainers

- The mesh of filters are to be equivalent to the existing ones.
- The local control panel for the motor-driven strainers is to be supplied.

(c) Piping

The small diameter pipes using SGP (Steel Gas Pipe), noted below, are to be replaced with new SUS (Steel Use Stainless) pipes.

- Pipe No. 11-01; (25A); Guide bearing cooling water supply pipe
- Pipe No. 11-03; (25A); Shaft sealing box water supply pipe
- Pipe No. 12-06; (50A); Head cover drain pipe
- Pipe No. 12-09; (25A); Discharge pipe for guide bearing cooling water

Necessary quantity, having the surplus of 20% or more, of the pipe materials needed for the replacement of above pipes, piping components such as elbows and such components as flanges, etc. needed for the connection to the existing pipes are to be supplied

The existing valves for the piping are to be used successively.

The replacement work at site is to be conducted by EPGE. The all welding workers, some workers can conduct stainless steel welding, are to be dispatched by EPGE, and they will work under the instruction by the supervisors of the contractor.

(10) Drainage system equipment

The components noted below used for the water drainage system are to be replaced with new ones. (for one set)

As for those components, drawings, etc. of the existing system, including below drawing, should be used for the design.

"Schematic Diagram for Water Piping" in the Drawing No. SDW_002.

(a) Electrical equipment

1. Head cover drainage pumps
2. Station drainage pumps
3. Draft tube dewatering pumps
4. Local control panels for each pump set (for 1, 2, 3)

(b) Water level detector

- Water level detectors for station drainage pit
- Water level detectors for draft tube dewatering pit
- The lead wires having required length from each component to the adjacent terminal boxes.

(11) Oil system equipment

The components noted below used for the pressure oil supply system are to be replaced with new ones. (for one set)

As for those components, drawings, etc. of the existing system, including below drawing, should be used for the design.

"Schematic Diagram for Oil and Air Piping" in the Drawing No. SDW_003.

(a) Oil sump tank set including all related accessories
(b) Air compressor sets including all related accessories
(c) Oil-pump and motor set for leakage oil system
(d) Local control panels for above equipment ((a), (b), (c))

(12) Electrical/mechanical small equipment (for turbine and generator)

As for the equipment in this item, the existing drawings, (attached drawings, etc.), on the turbine and generator system are to be used for the rehabilitation design. The small electrical/ mechanical equipment except for the main equipment described previously is specified as follows. (for one set)

The monitoring and measuring components, noted below by an example, are to be replaced with new ones.

(a) Water piping system

- Pressure gauges
- Pressure gauges with electric contact
- Pressure switches
- Flow relays
- Flow indicators
  (However, the flow indicators, one for each unit and two in total, for measuring water supply quantity to each heat exchanger for cooling the oil for generator bearings should have the specification of displaying the water quantity measured on the panel in the control room.)
- Water strainers for shaft sealing box
- Others
- The lead wires having required length from each electrical component to the adjacent terminal boxes.

(b) Oil and air piping system (High pressure and lubrication system)

- Safety valves
- Pressure gauges
- Pressure switches
- Pressure reducing valve (for air tank system)
- Oil filters (for leakage oil system)
- Limit switches
- Solenoid valves
- Oil level switches
- Oil level gauges
- Oil level sight glasses
- Thermometers
- Thermal relays
- Others
- The lead wires having required length from each electrical component to the adjacent terminal boxes.

(13) Wearing/consumable parts for overhaul (for turbine and generator)

Required quantities of the wearing/ consumable parts noted below for turbine and generator components, which are inevitably replaced with new ones for the overhaul work, are to be supplied for the rehabilitation. (for one set)

- O-rings
- Gasket
- Packings
- Others

(14) Special tools (for turbine and generator)

(a) Among the special tools for existing turbine and generator supplied originally at the completion, the missing tools at present are to be supplied. (for one set)

(b) New special tools required for newly designed components for the rehabilitation are to be supplied.

(c) On the other hand, the missing special tools unnecessary for the new design are not included in the tools to be supplied. (for one set)

(15) Spare parts (for turbine and generator)

(a) The quantities of each spare part, except for the spare parts designated separately in the other clause, are to be same as ones in the spare parts list of the existing turbine/generator. (for one set)

(16) Turbine governor

(a) This item is to be specified in Chapter 6

(17) Turbine flow meter (piezometer type)

(a) This item is to be specified Chapter 6.

(18) Nondestructive test (NDT)

NDT is to be conducted by EPGE. EPGE will prepare the materials and equipment needed for the NDT. The test results are to be reviewed by a supervisor dispatched by the contractor during the rehabilitation work.

(19) Embedded pipes & exposed pipes

The inside of the existing embedded pipes and exposed pipes is to be cleaned by EPGE.

(20) Station overhead crane

In the process of discussions with EPGE, the rehabilitation of the crane was to be conducted completely by EPGE. But, finally the rehabilitation concept was finalized as follows.

(a) A supervisor of the crane manufacture is to inspect and identify the components to be replaced and/or repaired, in the early stage after the contract.

(b) The crane manufacturer is to procure the necessary components for the rehabilitation immediately after the inspection.

(c) The crane rehabilitation work is to be carried out by EPGE workers, in time for the main rehabilitation work of the power plant, under the supervision of the crane supervisor.

(d) The crane supervisor is to check and confirm the final conditions of the crane after the rehabilitation.

(21) Paintings for rehabilitation work

Repair painting for the rehabilitation work, for inside/exposed surface of the casing, draft tube, etc., is to be conducted by EPGE. And, the paints and solvents, etc. will be prepared by EPGE. The contractor should provide the paint specifications, quantities, painting procedures, etc. for EPGE.

CHAPTER 5

REHABILITATION OF GENERATOR AND AUXILIARY EQUIPMENT

Chapter 5 Rehabilitation of Generator and Auxiliary Equipment

5.1 Method, Results of Site Inspection and Issues

5.1.1 Baluchaung No.1 Hydropower Plant

(1) Generator (Unit 1 and Unit 2)

There are no abnormal apparent symptoms except dust-coats at the surface of stator and rotor coils. However, the decrease of insulation function is assumed due to the aging deterioration (Photo 5.1-1).

Stator and Rotor Coil (Upper)

Stator and Rotor Coil (Lower)

Stator and Rotor Coil (Upper)

Photo 5.1-1 Stator and Rotor Coil

There is oil leakage at the surface of upper bracket from the upper bearing oil tank. There is also oil leakage from the tank due to the crack at welding points of upper bracket of No. 1 unit (Photo 5.1-2).

Oil Leakage on Upper Bracket

Oil Leakage from Welding Line

Photo 5.1-2 Upper Bracket

There have been frequent troubles of the leakage at air coolers. Total twelve spare parts of the air cooler had been installed at first but currently only six parts are stored (Photo 5.1-3).

Air Cooler (Installed)

Spares (6 unit)

Photo 5.1-3 Air Cooler

Brake ring is damaged by the slide scaring. Decrease of the reliability due to the deterioration of braking control equipment may cause the burning accident of bearing in the shutdown procedures of turbine and generators (Photo 5.1-4).

Sliding Scarring of Brake Ring

Brake

Photo 5.1-4 Brake System

Photo 5.1-5 Oil Lifter

There is slight roughness at the surface of slip rings. Inside of the collector ring cover is coated by carbon powder of brush. In addition, oil from the upper bearing oil tank is splattered around collector rings (Photo 5.1-6).

Roughness at Surface of Slip Ring and Carbon Brush Powder

Inside of the Collector Ring Cover

Photo 5.1-6 Collector

Regarding electric relays (cooling water discharge, oil level and bearing temperature), scale of lower bearing oil level meter cannot be read. It may be the decrease of reliability due to the deterioration of each relay and cause some serious accidents of turbine and generators (Photo 5.1-7).


Oil Gauge at Lower Bearing


Dial Thermometer for each Bearing

Oil Gauge at Upper Bearing

Discharge Meter of Cooling Water

Photo 5.1-7 Electric Relays

CO_2 firefighting system for the generators have never been maintained. The system have not been maintained. The system is not functional (Photo 5.1-8).

Photo 5.1-8 CO_2 Fire Fighting System

(2) Exciters

Damaged FCB

FCB (installed)

Photo 5.1-9 FCB (Field Circuit Breakers)

There have been many troubles in FCB. Spare parts of them have been already finished up as of now. If serious troubles occur in them in the future, turbine and generators cannot operate (Photo 5.1-9).

Coating at the lead of exciters is partially come off due to the aged deterioration. There are damages including main conductors.

Polluted Lead

Photo 5.1-10 Excitation Transformer

5.1.2 Sedawgyi Hydropower Plant

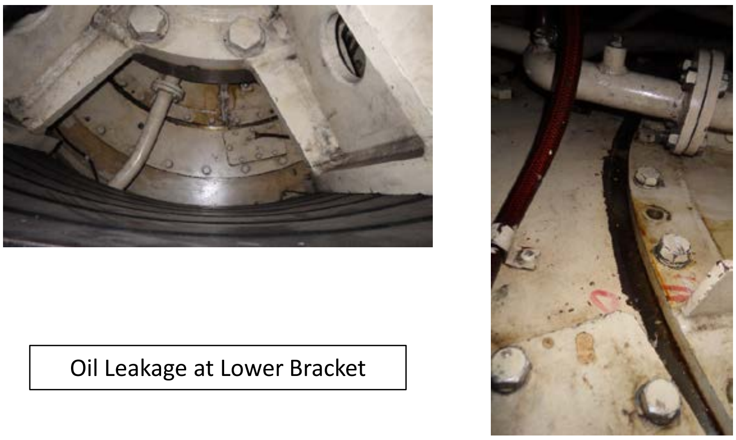
(1) Generator (Unit 1 and Unit 2)

Defective appearances are not observed by the visual inspection except the dust coating on the surface of stator and rotor coils (Photo 5.1-11).

Photo 5.1-11 Stator and Rotor Coil

There is oil leakage at the upper bracket from oil tank of the upper bearing and at the lower bracket from oil tank of the lower bearing (Photo 5.1-12).

Oil Leakage at Upper Bracket



Oil Leakage at Lower Bracket

Photo 5.1-12 Upper and Lower Bracket

Hotspots by the unbalance of the brake are observed. Splash protection materials of brake powder at Unit-2 are partially disappeared. Splash protection materials of brake powder at Unit-1 are partially in touch with the brake ring. Reliability is supposed to decrease due to the deterioration of brake control equipment. It may cause the burning accident of bearing in the shutdown process of turbine and generator (Photo 5.1-13).

Unit-1
Splash protection materials of brake powder are partially in touch with the brake ring

Unit-2
Hotspot and Disappearance of Splash Protection Materials

Photo 5.1-13 Brake System

Carbone brush powder is splashed around the slip ring. There are no spare parts for Carbone brush produced by original manufacturers and brush made by Indian manufacture is currently used. Oil from the oil tank of the upper bearing is splashed around the collector ring. Surface of the lower slip ring of Unit-2 is slightly rough (Photo 5.1-14).

Pulse pickup sensors for the velocity detector are in troubles (4 of 6 parts in Unit 1 and 3 of 6 for Unit-2). In addition, mechanical speed switch and earthing brush are also in troubles in both Units. If troubles of the sensor happen, it is assumed that the turbine and generator can't operate (Photo 5.1-15).

Carbone Brush Powder
Slight Roughness at Lower Slip Ring
Oil Leakage from Upper Bearing

Photo 5.1-14 Collector

Sensor of Unit-1 (Two in Troubles)

Sensor of Unit-1 (Three in Troubles)

Mechanical Speed Switch

Earthing Brush

Photo 5.1-15 Speed Signal Generator

Inside of the cooling water piping for air cooling system is slightly coated with the rust and mud (Photo 5.1-16).

Photo 5.1-16 Cooling Water Piping for Air Cooler

In past, the oil lifter was clogged. Reliability is supposed to decrease due to the deterioration of the main body of equipment and control equipment. It may cause the burning accident of thrust bearing in the starting and stopping process of turbine and generator (Photo 5.1-17).

Photo 5.1-17 Oil Lifter

Vibration of electronic pump occurs in the lubricating oil cooling unit (1 of 2 system in both Unit). There is much oil leakage from the pump. Regarding the Unit-1, the pump pressure meter is lost. Reliability is supposed to decrease due to the deterioration of the electric pump and control equipment. It may cause burning accidents of turbine and generator due to the temperature rising of all bearings (Photo 5.1-18).

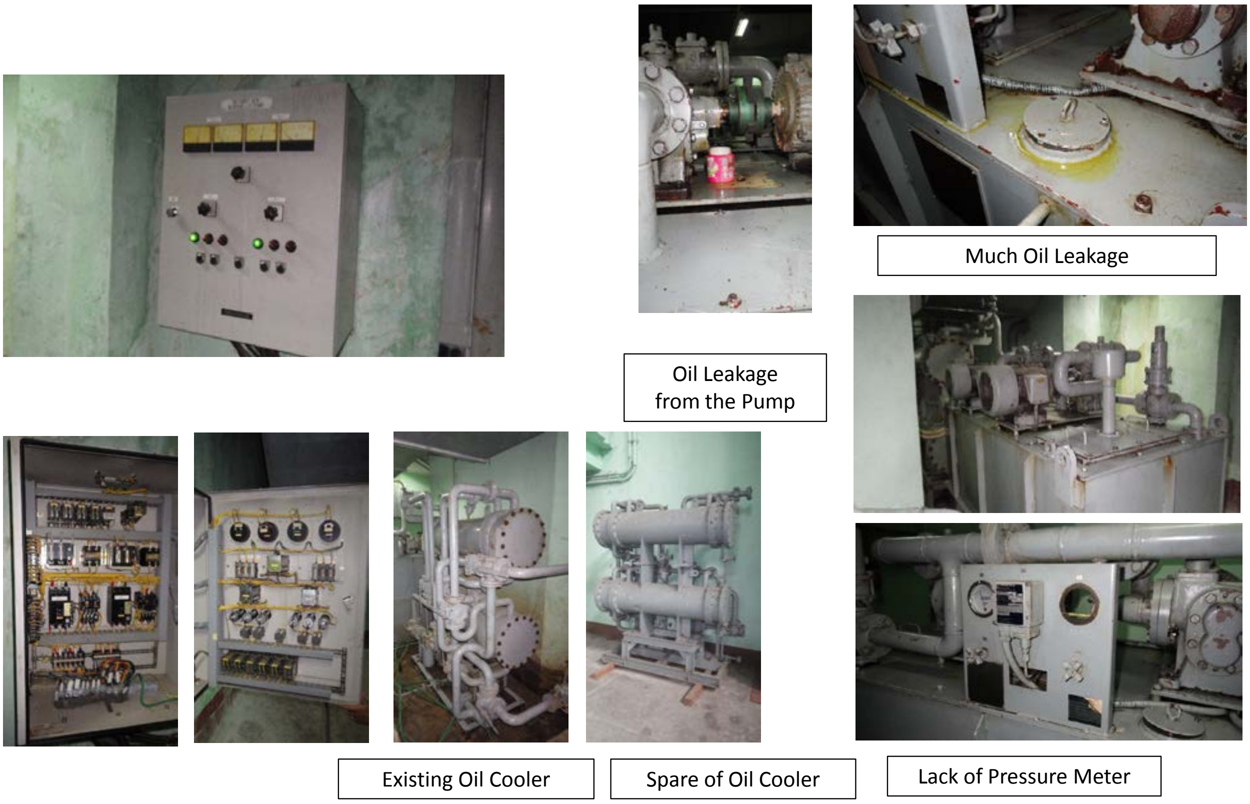


Photo 5.1-18 Lubricating Oil Cooling Unit

Reliability is supposed to decrease due to the deterioration of the control system for generator heater (Photo 5.1-19).

Photo 5.1-19 Generator Heater

Regarding relays (Discharge, Oil and Temperature), the dial temperature gauge installed at the generator gauge panel has the trouble. Most of flow meters (Oil and Water) are not functioned. It is also difficult to judge whether the equipment is in proper operation or not. Oil gauge for the bearing can’t be read. Reliability is supposed to decrease due to the deterioration of relays. It may cause serious accidents of turbine and generator (Photo 5.1-20).

Trouble of Indicator of Dial Temperature Gauge

Flow Meter of Cooling Water (Electric Wire is unconnected)

Flow Meter of Oil and Water (Value is Unread)

Oil Gauge of the Lower and Upper Thrust

Photo 5.1-20 Relays

CO_2 firefighting system is for the generators have never been maintained. The system have not been maintained. The system is not functional (Photo 5.1-21).

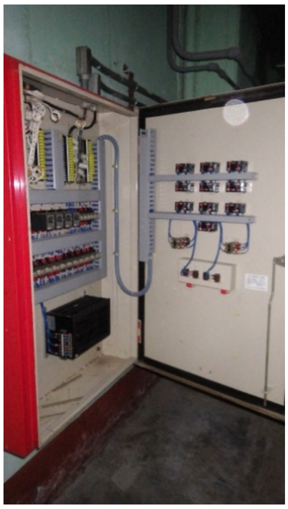


Photo 5.1-21 CO_2 Fire Fighting System

(2) Exciters

There are no spare parts for FCB. In the case of troubles, turbine and generator can't operate. Although excitation transformers don't have troubles, but reliability is supposed to decrease due to the deterioration (Photo 5.1-22).

Excitation Transformer

Control Panel of Exciter

FCB (no Spare Parts)

Photo 5.1-22 Exciters

(3) LTC (Line Terminal Cubicles)

Insulating repair works of LTC-3 11kV power cable in Unit-1 (A phase to main transformer and C phase to 11kV switchgear) had been implemented due to the accident (Photo 5.1-23).

Photo 5.1-23 Repair of 11kV Power Cable

(4) Neutral Grounding Device

The neutral grounding transformer is dry type. The reliability is supposed to decrease due to the deterioration (Photo 5.1-24).

Photo 5.1-24

5.2 Identification of Rehabilitation Items and Spare Parts

5.2.1 Baluchaung No.1 Hydropower Plant

(1) Screening of existing facilities/equipment for the rehabilitation

There are several damages due to age deterioration because overhaul works have not been carried out since the commencement of commercial operation. Therefore overhaul work should be carried out as soon as possible. It is recommended that the following rehabilitation items should be planned with the overhaul work.

Table 5.2-1 Screening of Existing Facilities/Equipment for the Rehabilitation Project (Baluchaung No.1 HPP - Generator)

Hydropower Plant **Baluchaung No.1**
Facilities/Equipment **Generator**

*1 Check items
✓ :Problem
NA :Not available
blank: No problem

*2 Screening for the Rehabilitation Project
A :Required
B :Recommended
C :Not Required

*3 Measures
R :Replacement
P :Repair
A :Addition
I :Inspection

Components	Application	Check item*1				Screening*2	Measures*3	Remarks
		aged deterioration	apparent inspection	trouble record	availability of spare parts			
Non Destructive Test	✓	✓	✓	✓	✓	A	I	crack at welding of bracket. Shaft, bracket, stator frame, rotor spoke and etc.
Stator Coil	✓	✓	NA		✓	A	R	Replacement work depends on the evaluated the remaining life year.
Rotor Coil	✓	✓	NA		✓	A	R	insulation renewal
Generator Guide Bearing	✓	✓	NA			A	R	upper and lower bearings
Generator Thrust Bearing	✓	✓	NA			A	R	Plastic bearing will be considered for the improvement of reliability.
Oil Lifter	✓	✓	✓		✓	A	R	
Oil Cooler	✓	✓	NA	✓	✓	A	R	frequent water leakage
Air Cooler	✓	✓	✓	✓	✓	A	R	decrease of spare parts (original; 12 present; 6)
Break System		✓	✓	✓	✓	A	R	break ring, break and Jack
CO_2 Fire Fighting System		✓	✓	✓	✓	B	R	Countermeasure such as portable fire extinguisher is possible.
Excitation System		✓	✓	✓	✓	A	R	Brushless exciter will be considered.
Overhaul Parts (Electric Relay)	✓	✓	✓	✓	✓	A	R	dial thermometer, oil level gauge and flow meter

HPP : Hydropower Plant

(2) Detail rehabilitation items

1) Overhaul (including non-destructive test)

Generator shall be disassembled, and wear parts and consumable parts shall be replaced. In addition, non-destructive tests shall be conducted for the generator shaft, brackets, stator frame, rotor spoke and so on at site.

2) Stator winding and rotor winding

It is supposed that reliability of the stator winding and rotor winding are decreased due to the aging deterioration. Remaining life year of the stator winding will be evaluated by using the operating hours and start/stop times. The replacement shall be considered on a basis of the evaluated remaining life year.

3) Bearing

It is supposed that the existing bearings have damages such as peeling and the reliability are decreased. The bearings shall be replaced. The thrust bearing will be changed from the Babbitt pad to Plastic pad. In the case, abbreviation of the oil lifter system shall be considered.

4) Oil lifter

Oil lifter including the control system shall be replaced. In the case that the thrust bearing will be changed to plastic pad, abbreviation of the oil lifter shall be considered.

5) Oil cooler

There were frequent water leakage on the oil cooler. The oil cooler shall be replaced, and appropriate numerical spare parts shall be provided.

6) Air cooler

The air coolers shall be replaced, and appropriate numerical spare parts shall be provided.

7) Brake system

Brake jack and brake ring system shall be replaced.

8) CO_2 firefighting system

Firefighting system is necessary for the generators. It is recommended that portable fire extinguishers should be considered as countermeasure of the existing CO_2 firefighting system.

9) Excitation system

The excitation system shall be replaced from existing static system to brushless system for reliable operation and minimum maintenance. And AVR (Automatic Voltage Regulator), including the excitation transformer, shall be also replaced to new digital type.

10) Electric relays

The relays (cooling water discharge, oil level and bearing temperature) shall be replaced as consumable parts of overhaul work.

5.2.2 Sedawgyi Hydropower Plant

(1) Screening of existing facilities/equipment for the rehabilitation

There are several damages due to age deterioration because overhaul works have not been carried out since the commencement of commercial operation. Therefore overhaul work should be carried out as soon as possible. It is recommended that the following rehabilitation items should be planned with the overhaul work.

Table 5.2-2 Screening of Existing Facilities/Equipment for the Rehabilitation Project (Sedawgyi HPP - Generator)

Hydropower Plant **Sedawgyi**
Facilities/Equipment **Generator**

*1 Check items
✓ :Problem
NA :Not available
blank: No problem

*2 Screening for the Rehabilitation Project
A :Required
B :Recommended
C :Not Required

*3 Measures
R :Replacement
P :Repair
A :Addition
I :Inspection

Components	Application	Check item*1				Screening*2	Measures*3	Remarks
		aged deterioration	apparent inspection	trouble record	availability of spare parts			
Non Destructive Test	✓	✓	✓	✓	✓	A	I	shaft, bracket, stator frame, rotor spoke and etc.
Stator Coil	✓	✓	NA		✓	A	R	Replacement work depends on the evaluated the remaining life year.
Rotor Coil	✓	✓			✓	A	R	insulation renewal
Generator Guide Bearing	✓	✓				A	R	upper and lower bearings
Generator Thrust Bearing	✓	✓			✓	A	R	Plastic bearing will be considered for the improvement of reliability
Oil Lifter	✓	✓	✓		✓	A	R	
Speed Relay	✓	✓	✓	✓	✓	A	R	Digital type will be considered.
Air Cooler	✓	✓	✓		✓	A	R	
Excitation System	✓	✓	✓	✓	✓	A	R	Brushless exciter will be considered.
Lubricating Oil Cooling Unit		✓	✓	✓	✓	A	R	
Break System		✓	✓		✓	A	R	break ring, break and Jack
Generator Heater		✓	✓		✓	B	R	If any trouble occurs in it, it is not necessary to stop generator.
Neutral Grounding Device		✓	✓		✓	A	R	Replacement of the neutral transformer shall be considered.
Cooling Water Piping (for air cooler)			✓			B	P	cleaning works of the inside
CO_2 Fire Fighting System		✓	✓	✓	✓	B	R	Countermeasure such as portable fire extinguisher is possible.
Overhaul Parts (Electric Relay)	✓	✓	✓	✓	✓	A	R	dial thermometer, oil level gauge and flow meter

(2) Detail rehabilitation items

1) Overhaul (including non-destructive test)

Generator shall be disassembled, and wear parts and consumable parts shall be replaced. In addition, non-destructive tests shall be conducted for the generator shaft, brackets, stator frame, rotor spoke and so on at site.

2) Stator winding and rotor winding

It is supposed that reliability of the stator winding and rotor winding are decreased due to the aging deterioration. Remaining life year of the stator winding will be evaluated by using the operating hours and start/stop times. The replacement shall be considered on a basis of the evaluated remaining life year.

3) Bearing

It is supposed that the existing bearings have damages such as peeling and the reliability are decreased. The bearings shall be replaced. The thrust bearing will be changed from the Babbitt pad to Plastic pad. In the case, abbreviation of the oil lifter system shall be considered.

4) Oil lifter

Oil lifter including the control system shall be replaced. In the case that the thrust bearing will be changed to plastic pad, abbreviation of the oil lifter shall be considered.

5) Speed Relay (Speed monitoring device)

The existing speed signal generator and mechanical speed switch shall be replaced to new digital type on the top part of generator.

6) Air cooler

The air coolers shall be replaced, and appropriate numerical spare parts shall be provided.

7) Excitation system

The excitation system shall be replaced from existing static system to brushless system for reliable operation and minimum maintenance. And AVR, including the excitation transformer, shall be also replaced to new digital type.

8) Lubricating oil cooling unit

The heat exchanger, oil tank, motor, pump and control system shall be completely replaced. The appropriate numerical spare parts of heat exchanger shall be provided.

9) Brake system

Brake jack and brake ring system shall be replaced.

10) Generator heater

It is recommended that the control system should be replaced. The new system will be installed in the central control center to be replaced.

11) Neutral grounding device

The neutral transformer shall be replaced to mold type.

12) Cooling water piping

It is recommended that the inside should be cleaned up during overhaul.

13) CO_2 firefighting system

Firefighting system is necessary for the generators. It is recommended that portable fire extinguishers should be considered as countermeasure of the existing CO_2 firefighting system.

14) Electric relays

The relays (cooling water discharge, oil level and bearing temperature) shall be replaced as consumable parts of overhaul work.

5.3 Basic Design on Rehabilitation of Generator and Auxiliary Equipment

5.3.1 Baluchaung No.1 Hydropower Plant

(1) General Condition

Existing two (2) units are rehabilitated with same specification.

The following specification is one of existing generators. Specification for rehabilitation is basically the same.

- Vertical shaft, three (3) phase, synchronous generator
- Rated capacity: 15,500 kVA
- Rated voltage: 11 kV
- Rated power factor: 90%
- Rated rotating speed: 375 min-1
- Runaway speed: 800 min-1

All of design conditions are not changed. Short-circuit ratio, generator features and guaranteed temperatures are not changed.

Rehabilitated facilities/equipment and the contents, which are mentioned in detail below, includes the consumable and exchanged parts to be exchanged necessarily at rehabilitation works. Fig. 5.3-1 shows the comparison between before and after the rehabilitation works.

(2) Stator winding

Stator coils shall be replaced for recovery of the dielectric strength. All of temperature detectors shall be replaced. Insulation class shall be B. The generator features shall not be changed.

(3) Rotor winding

Rotor coils shall be replaced for recovery of the dielectric strength. The coil brace shall be replaced. The generator features shall not be changed.

(4) Guide bearing (upper and lower)

The upper and lower guide bearing shall be replaced. The type shall be segment. The material shall be white metal (WJ2). All of temperature detectors, dial type temperatures, temperature relays, oil level switches and water contamination detectors shall be replaced. The upper and/or lower brackets shall be modified for the replacement, if necessary.

(5) Thrust bearing

The bearings shall be replaced. The material shall be changed to plastic type. All of temperature detectors, dial type temperatures and temperature relays shall be replaced. The upper bracket shall be modified for the replacement, if necessary.

(6) Oil cooler

Oil coolers for upper bearing and lower bearing shall be replaced. The water flow meters shall be replaced.

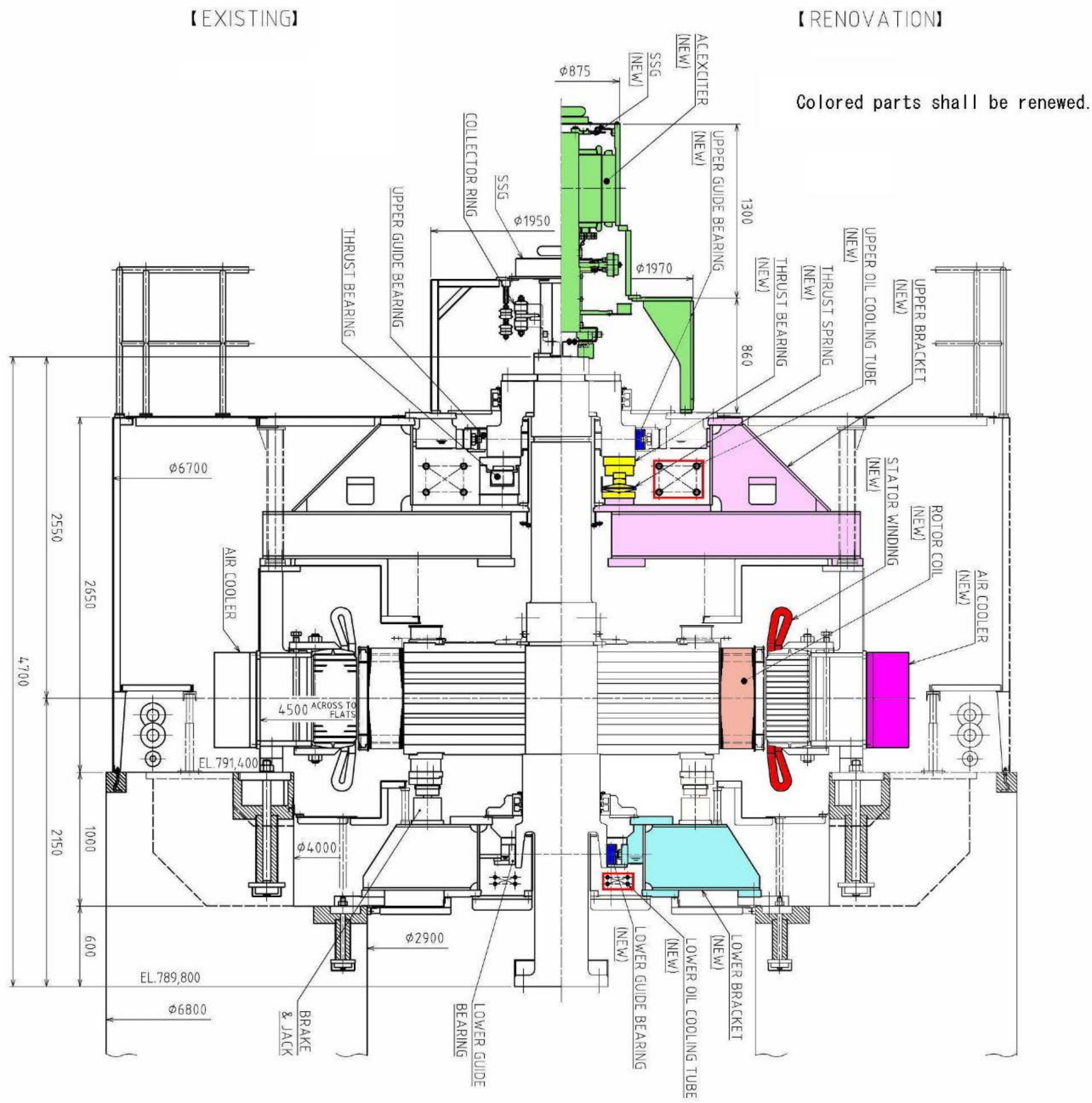


Fig. 5.3-1 Comparison between Before and After the Rehabilitation Works (Generator, Baluchaung No.1 HPP)

(7) Air cooler

Air coolers shall be replaced. The temperature rise of generator windings and thrust/upper/ lower bearings shall not be changed. All of temperature detectors, dial type temperatures and temperature relays shall be replaced.

(8) Brake system

It was recommended that the brake jack and brake ring system shall be replaced. However, it was finally decided that the replacement was excluded from a scope of this project because the work was possible by EPGE.

(9) Excitation system

Excitation system including AVR and excitation transformer shall be replaced. The type shall be changed to AC (brushless) exciter. The excitation transformer cubicle and all equipment in it shall be replaced. The excitation transformer shall be mold type. The speed relay shall be replaced to digital type. The generator features shall not be changed. The new excitation system shall be designed in consideration of replacement of stator and rotor windings.

(10) Spare parts

Six (6) coils shall be provided.
Two (2) oil coolers for upper bearing and two (2) oil coolers for lower bearing shall be provided.

5.3.2 Sedawgyi Hydropower Plant

(1) General Condition

Existing two (2) units are rehabilitated with same specification. The following specification is one of existing generators. Specification for rehabilitation is basically the same.

- Vertical shaft, three (3) phase, synchronous generator
- Rated capacity: 13,888 kVA
- Rated voltage: 11 kV
- Rated power factor: 90%
- Rated rotating speed: 250 min-1
- Runaway speed: 687 min-1

All of design conditions are not changed. Short-circuit ratio, generator features and guaranteed temperatures are not changed.

Rehabilitated facilities/equipment and the contents, which are mentioned in detail below, includes the consumable and exchanged parts to be exchanged necessarily at rehabilitation works. Fig. 5.3-2 shows the components/parts shall be replaced for rehabilitation.

(2) Stator winding

Stator coils shall be replaced for recovery of the dielectric strength. All of temperature detectors shall be replaced. Insulation class shall be F. The generator features shall not be changed.

(3) Rotor winding

Rotor coils shall be replaced for recovery of the dielectric strength. The generator features shall not be changed.

(4) Guide bearing (upper and lower)

The upper and lower guide bearing shall be replaced. The type shall be segment. The material shall be white metal (WJ2). All of temperature detectors, dial type temperatures, temperature relays and oil level switches shall be replaced.

(5) Thrust bearing

The bearings shall be replaced. The material shall be changed to plastic type. All of temperature detectors, dial type temperatures and temperature relays shall be replaced.

(6) Air cooler

Air coolers shall be replaced. The temperature rise of generator windings and thrust/upper/ lower bearings shall not be changed. All of temperature detectors, dial type temperatures and temperature relays shall be replaced. .

(7) Brake system

Brake ring, brake and jack shall be replaced. The limit switches shall be replaced. The air/oil pressure for them shall be not changed.

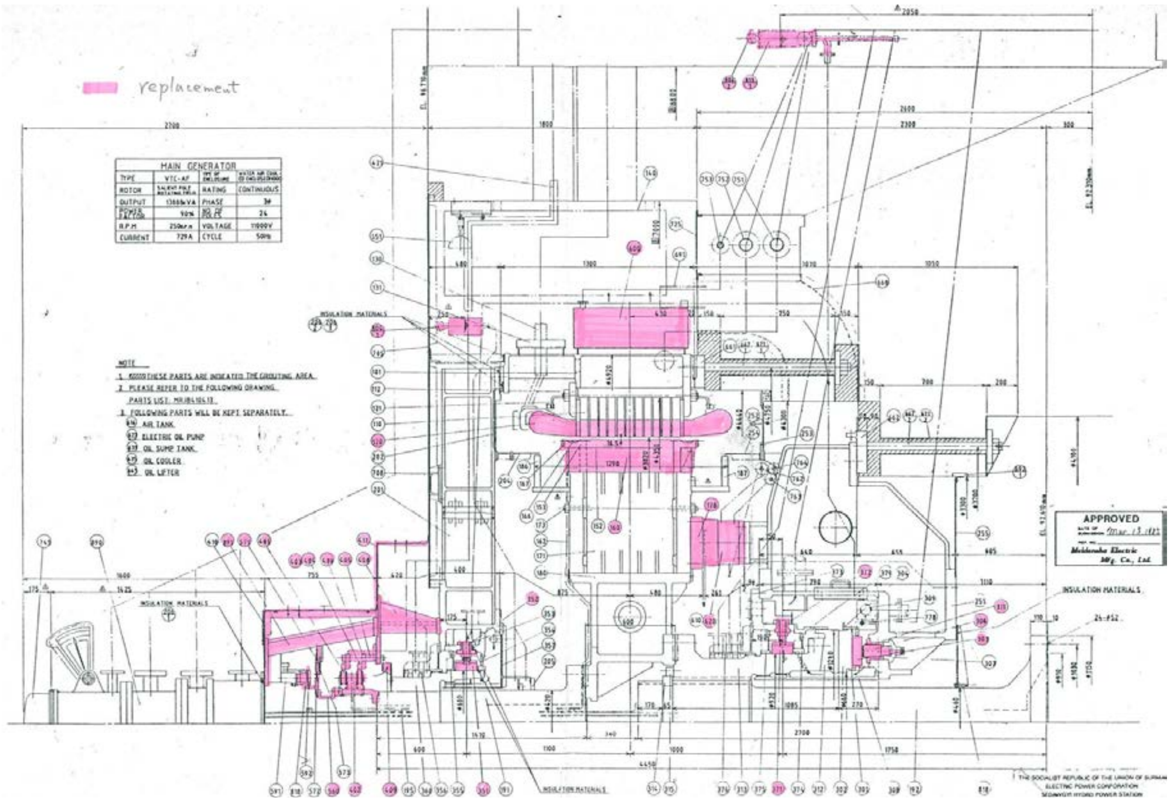


Fig. 5.3-2 Components/Parts shall be Replaced for Rehabilitation (Generator, Sedawgyi No.1 HPP)

(8) Lubrication oil cooling system

All system including the local control panel on wall shall be replaced.

(9) Excitation system

Excitation system including AVR and excitation transformer shall be replaced. The type shall be changed to AC (brushless) exciter. The excitation transformer shall be mold type. The speed relay shall be replaced to digital type. The generator features shall not be changed. The new excitation system shall be designed in consideration of replacement of stator and rotor windings. The generator top cover shall be modified by rehabilitation of turbine oil head.

(10) Generator heater

It was recommended that the heater including the local control panel on wall shall be replaced. However, it was finally decided, in the fifth mission, that the replacement of generator heater was excluded from a scope of this project because the work was possible by EPGE.

(11) Neutral grounding device

The neutral grounding transformer shall be replaced to mold type. The specification shall not be changed.

(12) Generation meter for each generator

Generation meter for each generator shall be newly installed. The meters shall be on a control panel in the control room.

(13) Spare parts

Six (6) coils shall be provided.

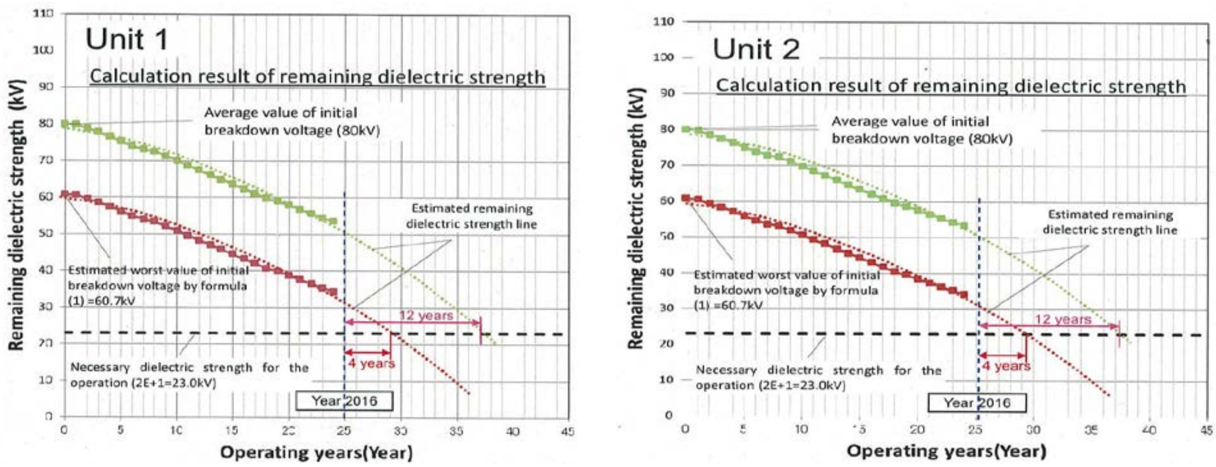
Two (2) air coolers for each generator, which is totally four (4) air coolers for the power plant, shall be provided.

One (1) lubrication oil cooler shall be provided.

Lifetime Evaluation of Stator Winding Insulation

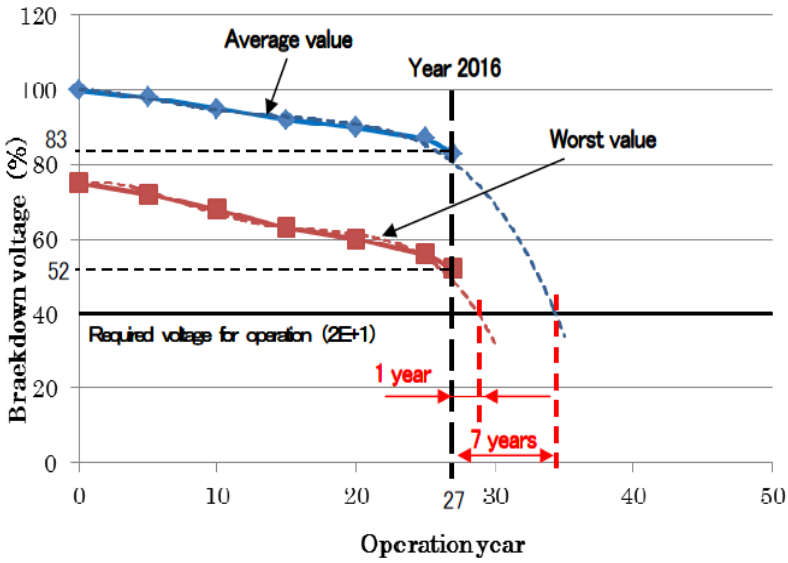
1. Necessary Dielectric Strength : 2E + 1 (=23.0kV)
2. Evaluation Method : The remaining dielectric strength is estimated by using the operating history (operating frequency and total operating hours)

Baluchaung No1.



The remaining lifetime of Unit 1 and Unit 2 are estimated to be approximately four (4) years in worst case. The Consultant strongly recommend rewinding stator coil of both units in the earliest opportunity.

Sedawgyi : Unit 1 and Unit 2 are almost same points.



The remaining lifetime of Unit 1 and Unit 2 are estimated to be approximately one (1) year in worst case. The Consultant strongly recommend rewinding stator coil of both units in the earliest opportunity.

Baluchaung No.1 (as of Dec. 2015)

Unit 1
Operating frequency (Number of start and stop) : 323
Operating hours : 178,590

Unit 2
Operating frequency (Start and stop) : 338
Operating hours : 180,027

Sedawgyi (as of Dec. 2015)

Unit 1
Operating frequency (Start and stop) : 242
Operating hours :213,117

Unit 2
Operating frequency (Start and stop) : 193
Operating hours : 223,882

(*) The operating hours and the number of start & stop in some years are not obtained. The Consultant estimated the data from the obtained years' data.

CHAPTER 6

REHABILITATION OF CONTROL AND PROTECTION SYSTEM

Chapter 6 Rehabilitation of Control and Protection System

6.1 Method, Results of Site Inspection and Issues

6.1.1 Baluchaung No.1 Hydropower Plant

Site inspection results of control and protection equipment at Baluchaung No.1 HPP (Hydropower Plant) are summarized as shown below table.

Table 6.1-1 Summary of Inspection Results of Control and Protection Equipment at Baluchaung No.1 HPP

Equipment		Condition
Control and protection Panel	➢ Control Panel Room ➢ DC Control Panel ➢ Control Panel of Auxiliary Equipment	Reliability of the control and protection panel is remarkably decreased due to the deterioration of following items; - Protection panel, - Automatic control panel for power generation, - Control buttons, - Timer, - Relays - Auxiliary relays - Record system
Control Cable	➢ Overall Control Cable	Reliability of the control cables is remarkably decreased due to the deterioration of outer coating and deformation and rust development of the cable terminal.
Fire Alarm System	➢ Overall Building	Fire alarm system such as the central control panel, respective alarm panels, fire detectors and fire extinguishers have been never maintained since the commissioning. Aging deterioration is remarkably developed and it is not functional.
Communication System	➢ Control Equipment of Power Generation ➢ Communication Equipment	Communication equipment for power generation control and communication is seriously deteriorated and is not functioned.
Governor Control Equipment	➢ Regulator Panel ➢ Actuator Panel ➢ Control Panel of Turbine Automatic Operation ➢ Return Mechanism	Reliability of all control panels is decreased due to the aging deterioration of electrical components of power sources, control buttons and relays. Reliability of mechanical equipment is also decreased due to the pollution of turbine oil and coating of grease.
Exciter Control Equipment	➢ AVR (Automatic Voltage Regulator)	Reliability of all control panels is decreased due to the aging deterioration of electrical components of power sources, control buttons and relays.
Water Level Gauge	➢ Gauge for the Dam Operation ➢ Gauge for the Power Generation	Gauges for power generation control and river operation are seriously deteriorated and are not functioned.

6.1.2 Sedawgyi Hydropower Plant

Site inspection results of control and protection equipment at Sedawgyi HPP are summarized as shown below table.

Table 6.1-2 Summary of Inspection Results of Control and Protection Equipment at Sedawgyi HPP

Equipment		Condition
Control and protection Panel	➢ Control Panel Room ➢ DC and AC Control Panel ➢ Turbine and Generator Panel ➢ Control Panel of Auxiliary Equipment	Reliability of the control and protection panel is remarkably decreased due to the deterioration of following items; - Protection panel, - Automatic control panel for power generation, - Control buttons, - Timers, - Relays - Auxiliary relays - Record system
Control Cable	➢ Overall Control Cable	Reliability of the control cables is remarkably decreased due to the deterioration of outer coating and deformation and rust of the cable terminal.
Governor Control Equipment	➢ Regulator Panel ➢ Actuator Panel ➢ Control Panel of Turbine Automatic Operation ➢ Return Mechanism	Reliability of all control panels is decreased due to the aging deterioration of electrical components of power sources, control buttons and relays. Reliability of mechanical equipment is also decreased due to the pollution of turbine oil and coating of grease.
Exciter Control Equipment	➢ AVR	Reliability of all control panels is decreased due to the aging deterioration of electrical components of power sources, control buttons and relays.
Water Level Gauge	➢ Gauge for the Dam ➢ Gauge for the Power Generation	Water level gauges at the reservoir and tailrace had been broken and not functioned long time ago..
Communication System	➢ Control Equipment of Gate Operation ➢ Communication Equipment	Communication equipment for gate control and communication is seriously deteriorated and is not functioned.
Fire Extinguishers	➢ Overall Building	Although contents of fire extinguishers have been refilled, hoses and nozzles are seemed to be damaged by the aging deterioration.
Ventilation System	➢ Exhaust Equipment ➢ Air Supply Equipment	Reliability of the ventilation system is remarkably decreased due to the deterioration of following items; - Exhaust equipment - Air supply equipment (2 of 3 are broken), - Fan motors, - Control buttons, - Timers, - Relays
Air conditioning System	➢ Control Panel Room ➢ Rectifier Room	Air conditioning system at the control panel room had been broken and air conditioners of panel types are installed. An air conditioner at rectifier room is remarkably deteriorated. Reliability of the air conditioning system is decreased.

6.2 Identification of Rehabilitation Items and Spare Parts

6.2.1 Baluchaung No.1 Hydropower Plant

(1) Screening of existing facilities/equipment for the rehabilitation

Replacement of control and protection system is essential to contribute a stable and reliable electric power supply because it has already passed almost 28 years since COD and they have many mechanical and electrical failures.

The rehabilitation plan of control and protection system is recommended as follows.

Table 6.2-1 Screening of Existing Facilities/Equipment for the Rehabilitation Project (Baluchaung No.1 HPP - Control and Protection System)

Hydropower Plant	**Baluchaung No.1**
Facilities/Equipment	**Control and Protection System**

*1 Check items
✓ :Problem
NA :Not available
blank: No problem

*2 Screening for the Rehabilitation Project
A :Required
B :Recommended
C :Not Required

*3 Measures
R :Replacement
P :Repair
A :Addition
I :Inspection

Components		Application	Check item*1: aged deterioration	apparent inspection	trouble record	availability of spare parts	Screening*2	Measures*3	Remarks
1. Operation Board		✓	✓	✓	✓	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
2. Speed Governor System		✓	✓	✓	✓	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
3. Automatic Voltage Regulator		✓	✓	✓	✓	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
4. Protection Relay (Analog Type)		✓	✓	✓	NA	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
5. SSG Speed Monitor		✓	✓	✓	NA	NA	A	R	SSG speed monitor will be replaced because brushless exciter is adopted.
6. Sequencer for Water Level Control		✓	✓	✓	NA	NA	A	R	Total digital system shall be adopted including water level meter for pondage and data transmission equipment.
7. Control Cable			✓	✓	NA	NA	A	R	Total digital system shall be adopted including water level meter for pondage and data transmission equipment.
8. Fire Alarm System			✓	✓	NA	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
9. Communication System	pondage water level gauge		✓	✓	NA	NA	A	R	On the power generation operation, the Communication System including the level gauge needs to be updated because of the water level information necessary.
	Tailrace water level gauge		✓	✓	NA	NA	A	R	
	Other water level gauge		✓	✓	NA	NA	B	R	Communication system is broken, however, the generator operation is performed by using mobile radio.
10. Air Conditioning System			✓	✓	NA	✓	A	R	Air conditioning system shall be replaced for cooling electronic components, because digital boards will be considered.

(2) Detail rehabilitation items

1) Operation Board

Replacement of Generator Panel, Automatic Control Panel and Recorder Panel is essential because the reliability as a control panel is declined due to the aging degradation and failures of timers, auxiliary relays, recorders, meters and others. Total digital system should be adopted as a new operation board.

2) Speed Governor System

Replacement of Speed Governor System such as GOV-Reg/Act Panel, Turbine Control Cubicle and Return unit is essential because the reliability is declined by failures of electrical components, grease adhering, degraded operation oil and aging degradation of operation switches, meters and relay units.

3) Automatic Voltage Regulator (AVR)

The reliability of AVR is declined by the failures of electrical components and the aging degradation of operating switches, meters and relay units. Moreover, aging degradation of and oil leakage from field circuit breaker cause the reliability decline. Therefore, replacement of AVR is essential.
In this rehabilitation, one digital control device including both GOV (Governor) and AVR is adopted.

4) Protection Relay (Analog Type)

Replacement of protection relay is essential because the reliability of it is declined by the failures and aging degradation of electrolyte capacitors, timers, auxiliary relay units and others.
In this rehabilitation, digital maintenance-free protection relay with self-test function is adopted.

5) SSG (Speed Signal Generator) Speed Monitor

Replacement of speed monitor and relays for adapting brushless exciter system is necessary. In this rehabilitation, new digital speed monitor is installed on AVR panel and digital speed relays are installed on protection relay panel in the control room.

6) Sequencer for Water Level Control

Since water level control panel does not work now due to the failures of water level gauge and communication system, replacement of all equipment, including two (2) water level gauges at Pondage intake gate and water level data transceiver, is essential for the total digital system configuration.

7) Control Cable

The reliability of control cable for protection, control and auxiliary equipment is declined by the aging degradation of cable armor, deformation of terminal and rust. Therefore, replacement of control cable is essential in this rehabilitation.

8) Fire Alarm System

Fire alarm control panel, smoke detectors and fire extinguishers have never been maintained since COD (Commercial Operation Date). Replacement of all equipment is essential due to the aging degradation.

9) Communication System

- Pondage water level gauge
  Since water level gauge and data transceiver is broken, replacement of communication and

water level gauge is essential for acquiring the water level information contributing to the stable and reliable operation.

- Tail Race Water Level gauge
  Since water level gauge and data transceiver is broken, replacement of communication and water level gauge is essential for acquiring the water level information contributing to the stable and reliable operation.

- Other water level gauge
  Although the communication system is broken, operation is performed without hindrance by the mobile radio communication. Since water level information is important for stable and reliable operation, replacement of communication system is recommended.

10) Air-conditioning System

Replacement of air-conditioning system is essential for cooling electrical components which is installed in digital control and protection devices.

6.2.2 Sedawgyi Hydropower Plant

(1) Screening of existing facilities/equipment for the rehabilitation

Replacement of control and protection system is essential to contribute a stable and reliable electric power supply because it has already passed almost 30 years since COD and they have many mechanical and electrical failures.

The rehabilitation plan of control and protection system is recommended as follows.

Table 6.2-2 Screening of Existing Facilities/Equipment for the Rehabilitation Project (Sedawgyi HPP - Control and Protection System)

Hydropower Plant **Sedawgyi**
Facilities/Equipment **Control and Protection System**

*1 Check items
✓ :Problem
NA :Not available
blank: No problem

*2 Screening for the Rehabilitation Project
A :Required
B :Recommended
C :Not Required

*3 Measures
R :Replacement
P :Repair
A :Addition
I :Inspection

Components	Application	Check item*1				Screening*2	Measures*3	Remarks
		aged deterioration	apparent inspection	trouble record	availability of spare parts			
1. Operation Board	✓	✓	✓	✓	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible.
2. Automatic Voltage Regulator	✓	✓	✓	✓	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
3. Vibration Monitor	✓	✓	✓	NA	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
4. Generator Gauge Board (G22)	✓	✓	✓	NA	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
5. Indication Lamp	✓	✓	✓	NA	NA	A	R	All indication Lamps shall be LED type.
6. Control Cable	✓	✓	✓	NA	NA	A	R	Total digital Control cables shall be replaced for new installation of control and protective device system shall be adopted including water level meter for pondage and data transmission equipment.
7. Ventilation	✓	✓	✓	NA	NA	A	R	(Exhaust Equipment and Air Supply Equipment)
8. Electro-Mechanical and Static Relay	✓	✓	✓	NA	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
9. 400V House Service Equipment	✓	✓	✓	NA	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
10. Governor Control Equipment		✓	✓	NA	✓	A	R	Since spare parts were discontinued, the procurement of them are impossible
11. Fire Extinguishers		✓	✓	NA	NA	B	R	Though fire extinguishing compositions were replaced 3 years ago, JICA Survey Team recommend the replacement of the fire extinguishers because the bottles and rubber horses were made more than 30 years ago.
12. Communication System		✓	✓	NA	✓	B	R	Communication System is broke, however, the generator operation is performed by using mobile radio.
13. Air Conditioning System		✓	✓	NA	✓	A	R	Air conditioning system shall be replaced for cooling electronic components, because digital boards will be considered.

(2) Detail rehabilitation items

1) Operation Board

Replacement of Generator Panel, Automatic Control Panel and Recorder Panel is essential because the reliability as a control panel is declined due to the aging degradation and failures of timers, auxiliary relays, recorders, meters and others. Total digital system should be adopted as a new operation board.

2) Automatic Voltage Regulator

The reliability of AVR is declined by the failures of electrical components and the aging degradation of operating switches, meters and relay units. Moreover, aging degradation of and oil leakage from field circuit breaker cause the reliability decline. Therefore, replacement of AVR is essential.
In this rehabilitation, one digital control device including both GOV and AVR is adopted.

3) Vibration Monitor

Since vibration monitor is broken, replacement of vibration monitor and meter is essential.

4) Generator Gauge Board

The reliability of generator gauge board is declined by the aging degradation and especially no maintenance record of analog type temperature relay after COD. Since temperature recorder is also broken, replacement of generator gauge board is essential in this rehabilitation.

5) Indication Lamp

Since the type of indication lamp is light bulb, LED (Light Emitting Diode) type is adopted on the replaced machines and panels.

6) Control Cable

The reliability of control cable for protection, control and auxiliary equipment is declined by the aging degradation of cable armor, deformation of terminal and rust. Therefore, replacement of control cable is essential in this rehabilitation.

7) Ventilation

Since automatic-control ventilation system does not work properly because of the failures and aging degradation, system replacement is essential.

8) Electro-Mechanical and Static Relay

In this rehabilitation, digital static relay is adopted for all relays due to its high reliability.

9) 400V House Service Equipment

The reliability of low voltage equipment is declined by the failure and aging degradation. Since low voltage equipment is important to supply power for auxiliary equipment which is necessary for the generator operation, replacement of low voltage equipment is essential.

10) Governor Control Equipment

The reliability of generator control equipment is declined by the failures of electrical components and the aging degradation of operating switches, meters and relay units. Moreover, grease adhering and degraded operation oil causes the reliability decline. Therefore, replacement of generator control equipment is essential. In this rehabilitation, one digital control device including both GOV and AVR is adopted.

11) Fire Extinguishers

Although fire extinguishing compositions were replaced 3 years ago, early replacement of fire extinguishers with new one is recommended. It has been 30 years since cylinder and hose were manufactured.

12) Communication System

Although the communication system is broken, operation is performed without hindrance by the mobile radio communication. Since water level information is important for stable and reliable operation, replacement of communication system is recommended.

13) Air Conditioning System

Since the air-conditioning system is broken, replacement of air-conditioning system is essential for cooling electrical components which is installed in digital control and protection devices.

6.3 Basic Design on Rehabilitation of Control and Protection System

6.3.1 Baluchaung No.1 Hydropower Plant

(1) General

Modification or improvement of the two installed hydraulic turbine generators and switching equipment as well as the station service facilities based on below specifications are proposed.

a. Duplication of power sources (DC: Direct Current and AC: Alternating Current) of all control and protection facilities
b. LEDs are used as indicator on all control and protection facilities.
c. All control and protection facilities are designed as self-standing panel based on the earthquake-resistant specifications.

(2) Main control board and automatic control unit

Display and control of all facilities such as power-generating facilities (hydraulic turbine generator, station service circuits, and auxiliary equipment) and transforming facilities (switching devices) shall be operated and monitored on the main control board and sequencer board, in an integrated manner from the control room.

SCADA (Supervisory Control And Data Acquisition) system shall be omitted from the scope of the Project according to the discussion with EPGE (Electric Power Generation Enterprise).

(3) Automatic recording system

All information and data necessary to operate and monitor the power plant shall be automatically recorded and stored by the automatic recording system and shall be easily read out as necessary. The automatic recording system shall be a paperless design and installed at the control room.

(4) Protection relay system

All transmission protection systems (for high-voltage system), plant protection systems (for hydraulic turbine generator and transformer) and station service protection systems (for station service facilities) shall be designed to apply digital protection relays.

(5) Excitation system (AVR)

For the adaption of brushless exciter, the functions of excitation system shall be protected and controlled by the integrated GOV/AVR protection controller.

(6) Governor

Control system (regulator panel) of the governor shall meet the “Digital PID-GOV” specifications.

Operating mechanism (actuator panel) of governor and turbine control cubicle shall be upgraded.

(7) Auxiliary equipment control center panel

No. 1 and No. 2 turbine generators and plant common auxiliary equipment shall be protected and controlled from the auxiliary equipment control center. These control parameters shall include “Automatic/Manual” and “Run/Stop”.

(8) Spare parts and accessories

The number of spare parts and accessories for the control and protection devices shall be prepared in order to maintain operation and monitor of the plant.

(9) Communication System

① Detail information of rehabilitation plan for Civil equipment is described in Chapter 9.
② Detail information of rehabilitation plan for Communication System equipment is described in Chapter 10.

(10) Plant Accessory Equipment

1) Fire Alarm System

The central control panel, respective alarm panels and fire detectors shall be replaced. The portable fire extinguisher shall not be replaced by the discussion with EPGE.

2) Air-conditioning system

Air-conditioning system in the control room shall not be replaced by the discussion with EPGE.

6.3.2 Sedawgyi Hydropower Plant

(1) General

Modification or improvement of the two installed hydraulic turbine generators and switching equipment as well as the station service facilities based on below specifications are proposed.

a. All control and protection facilities are basically designed as digital type.
b. Duplication of power sources (DC and AC) of all control and protection facilities
c. All control and protection facilities are designed to have automatic-inspection functions.
d. All control and protection facilities are designed as self-standing panel based on the earthquake-resistant specifications.

(2) SCADA system

Power generating facilities (hydraulic turbine generator and station service circuit), transforming facilities (switching facilities) and dam facilities (dam water level data and checking gate operation) and auxiliary equipment (display of flow indicator) shall be integrated to SCADA system to establish the monitoring and controlling system. The facilities shall be installed at the control room.

In Myanmar, SCADA system for load dispatching information is under construction. Therefore, the specifications of SCADA system of this HPP shall ne in accordance with this system.

(3) Main control board and automatic control unit

The power generating facilities (hydraulic turbine generator and station service circuit), transforming facilities (system switching facilities) and dam facilities (dam water level data and checking gate operation) and auxiliary equipment (display of flow indicator) shall be integrated in an all-in-one protective control unit and shall be monitored and controlled from the main control room of the HPP.

(4) Automatic recording system

All information and data for operation and monitoring of the HPP shall be automatically recorded and stored by the automatic recording system. It shall be easily read out as necessary. The automatic recording system shall be a paperless design and installed at the control room.

(5) Protection relay system

T/L (Transmission Line) protection (for high-voltage system), plant protection (for hydraulic turbine generator and transformer) and station service protection (station service facilities) shall be integrated in an all-in-one protective control system.

(6) Excitation system (AVR)

For the adaption of brushless exciter, functions of excitation system shall be protected and controlled by the integrated all-in-one protective control unit and exciter control panel (local panel).

(7) Governor

Control method of the governor (regulator panel) shall be “Digital PID-GOV” which detects dam water level and tailrace water level to enable the optimal and high-efficient runner vane control. The governor operation mechanism (actuator panel) and turbine control cubicle shall be updated to meet the specifications described above.

(8) Power generator vibration measuring unit

The vibration sensor at the lower bracket and vibration measuring unit shall be updated as a set. The vibration measuring unit shall be incorporated into the integrated control and protection unit located at the control room.

(9) AC and DC control power panel

The AC and DC control power panel shall be updated because of duplication of control power sources for control and protection devices, resulting in increased NFB for the supply sources.

(10) Water level gauge (dam and tailrace)

Update the dam water level gauge and tailrace water level gauge for the runner vane control, the water discharge measurement and the water level measurement/indication. (The detail information is described in Section 9.3.2 Basic Design on Rehabilitation of Civil Facilities.)

(11) Spare parts and accessories

The number of spare parts and accessories for control and protection devices shall be prepared to maintain operation and monitor of the power plant.

(12) 400V House Service Equipment

Detail information of rehabilitation plan for station service equipment is described in Chapter 7.

(13) Internal Communication System

Communication equipment between HPP and dam shall not be replaced based on the discussion with EPGE.

(14) Plant Accessory Equipment

1) Ventilating devices

As for ventilating devices, 3 air-intake units, 3 air-exhaust units (roof-mounted), and intake/exhaust control panels are proposed to be updated. Specifications of intake and exhaust units shall be the same as existing devices, but the control panel shall be lightning protection design.

Flow regulating valve of the ventilation duct shall be repaired. Filter with a new one shall be replaced.

2) Air-conditioning system

Digitalization of control and protection systems requires modification of air-conditioning in the control room to prevent temperature rising.

3) Portable fire extinguisher

The portable fire extinguishers shall not be replaced based on the discussion with EPGE.

CHAPTER 7

REHABILITATION OF RELEVANT SUBSTATION AND TRANSMISSION LINE FACILITIES INSIDE POWER PLANTS

Chapter 7 Rehabilitation of Relevant Substation and Transmission Line Facilities inside Power Plants

7.1 Method, Results of Site Inspection and Issues

Visual inspection was adopted and carried out by JICA (Japan International Cooperation Agency) Study Team for the inspection of relevant substation and transmission line facilities for both Baluchaung No.1 HPP (Hydropower Plant) and Sedawgyi HPP.

7.1.1 Baluchaung No.1 Hydropower Plant

(1) 132/11 kV Main Transformers (Generator Transformer)

The current conditions of main transformer are relatively good even though some rust developments were found on 11 kV bushing, because there is no oil leakage, deterioration and peeling at the tank, gasket and radiators of main transformers. Additionally, there is no vibrations and abnormal noise in main transformers under the normal operation.

Regarding the spare unit of main transformer, although there is one spare transformer in switchyard, its conditions are also good due to no using until now.

Furthermore, as the result of checking the ordinary maintenance records, the trip of the main transformers circuit by high oil temperature has not been confirmed

Source: Prepared by JICA Survey Team

Photo 7.1-1 Main Transformers

(2) 132 kV Switchgear in Switchyard

1) 132kV Gas Circuit Breakers

The 132 kV gas circuit breakers are usually tripped on three phases by operation of switch in phase A, however, the circuit breaker cannot be operated normally, because the connection failure between mechanical and electrical device of phase A circuit breaker has been occurred. Furthermore, gas pressure level of phase C are relatively low compared with other phases.

2) Disconnectors

Operating conditions of disconnectors are good even under the on-load disconnection. And also, there is no deterioration in insulators, blade and contact parts. On the other hand, there are some rust developments in supporting structures. It may incur the collapse of disconnectors.

3) Current Transformers

There is no outstanding problem in current transformers and the line current is measured correctly.

4) Capacitor Voltage Transformers

There is no outstanding problem in capacitor voltage transformers and the line voltage is measured correctly.

5) Lighting Arrestors

The foundations of surge arrestor in phase B has been settled down to the ground. Even though temporary treatment for the base plate of supporting structures has been conducted, it may incur the collapse of surge arresters.


Source: Prepared by JICA Survey Team

Photo 7.1-2 132 kV Switchgear

(3) 11 kV Busbar

HDCC (hard-drawn copper conductor) 1000 mm^2 has been installed in 11 kV busbar, however, the maximum current capacity is not enough. Additionally, since the damages by overheat on the cable clamps in order to connect 11 kV busbar and main transformer are appeared due to the loose connection. Temporary treatment by bypass conductor has been conducted.


Source: Prepared by JICA Survey Team

Photo 7.1-3 11 kV Busbar and Cable Clamp

(4) 132 kV Busbar

Although there is no outstanding deterioration in 132 kV busbar which is consisted of HDCC 250 mm^2 and accessories such as cable clamps and insulator strings, it is desirable to replace to new one considering lack of spare parts and further aged deterioration.

(5) 11 kV Power Cables

The aged deterioration including insufficient insulation has been appeared in 11 kV power cables between powerhouse and switchyard. Additionally, spare parts for 11 kV power cables are insufficient.

(6) 11 kV Main and Local Cubicle

Although LOCCB (low oil content circuit breakers) have been applied in 11 kV main and local cubicles, there is some oil leakage from LOCCB. Some troubles such as flash over in LOCCB has been reported for five times at Unit 1 circuit. Additionally, the size of the cubicle for 11 kV is quite large compared with the current standard design.

Source: Prepared by JICA Survey Team

Photo 7.1-4 11 kV Switchgear (LOCCB)

(7) 11/11 kV Tie Transformers

One unit of 11/11 kV transformer is under repair works due to the accident of flash over at the 11 kV bushing, and the roof of transformer has been gauche.

There is no meter for oil temperature in order to check the insulation failure of oil.
There is no changeover method between two transformers automatically, because station staff has changed the connection of 11 kV cables currently.

(8) Low Voltage Switchgear

Although there is no outstanding deterioration in low voltage switchgear, some front panel is not able to open and close. Additionally, the size of each ACBs and MCCB (molded case circuit breaker) is large compared with the current standard design. Additionally, the spare parts for circuit breakers are not available.

(9) Station Service Transformers

The conditions of station service transformers are relatively good.
The trip by overload or temperature rise has not been recorded until now.

(10) AC Panels

As well as low voltage switchgear, there is no outstanding deterioration in AC (Alternating Current) panels but the size of each circuit breakers are large compared with the current design. Additionally, the spare parts for circuit breakers are not available.

(11) DC Panels

As well as low voltage switchgear, there is no outstanding deterioration in DC (Direct Current) panels but the size of each circuit breakers are large compared with the current design. Additionally, the spare parts for circuit breakers are not available.

(12) DC Battery Charger

Although there is no outstanding deterioration in DC chargers, it is desirable to replace to new one corresponding to replacement of DC batteries as described below.

(13) DC Batteries

DC batteries have never been replaced after operation of power station. Therefore the level of electrolytic solution in DC batteries is quite low because the leakage of it has been occurred. Additionally, the green rust development is founded on the termination of each batteries due to the no cover.

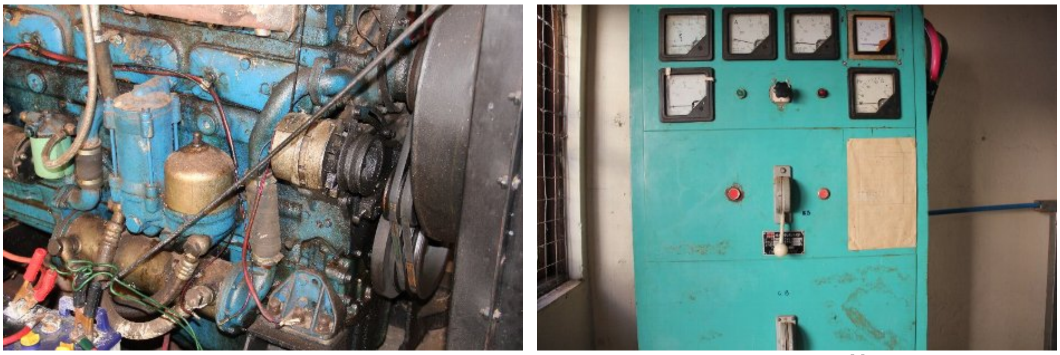
Source: Prepared by JICA Survey Team

Photo 7.1-5 DC Batteries

(14) Emergency Diesel Generator (EDG)

The operating conditions of EDG are quite bad due to the aging, the oil leakage and low quality. Additionally, EDG is not fixed to the foundation due to no anchor bolts though there is hole for anchor bolts at base plate.

In addition to the above, there is no meter for checking the power factor and watthour, etc. in the control panel.



Source: Prepared by JICA Survey Team

Photo 7.1-6 EDG

(15) Transmission Line Control Panels

In current design for line protection panel in Myanmar, distance relay as main protection and over current and grounding fault relay as back-up protection is applying. However, line protection panels for transmission line between Baluchaung No.1 and Baluchaung No.2 HPPs have only distance relay.

Source: Prepared by JICA Survey Team

Photo 7.1-7 Transmission Line Protection Panel

7.1.2 Sedawdyi Hydropower Plant

(1) 132/11 kV Main Transformers (Generator Transformer)

There is remarkable oil leakage at the tank, gasket and radiator, etc. in all units. And, there is some rust development in local control panels.

There is no vibrations and abnormal noise in main transformers under the normal operation.

As the result of checking the ordinary maintenance records, the trip of the main transformers circuit by high oil temperature has not been confirmed.


Source: Prepared by JICA Survey Team

Photo 7.1-8 Main Transformers

(2) 132 kV Switchgear in Switchyard

1) 132 kV Gas Circuit Breakers

Spring charge mechanism for the 132 kV gas circuit breakers is not operating by remote control. Thus, station staff has to operate manually. Especially, regarding the 132 kV gas circuit breakers in transmission line bay to Kyaukpahtoe, although auto switching operation in case of earth fault in transmission line is possible, other switching operation shall be done manually.

2) Disconnectors

Operating conditions of disconnectors are good even under the on-load disconnection. And also, there is no deterioration in insulators, blade and contact parts.

3) Current Transformers

The current transformers in Sedawgyi substation have not been replaced until now. 132 kV red phase current transformer of the Kyaukpahtoe S/S circuit was burnt in 2007 and was replaced.

4) Capacitor Voltage Transformers

The voltage for both transmission lines is not able to be measured due to the failure of secondary windings in capacitor voltage transformers.

5) Lightning Arrestors

The counter value of surge arresters on the main transformer side is differed vastly with respect to each phase. Thus, it is considerable the counter is not operating correctly.

Source: Prepared by JICA Survey Team

Photo 7.1-9 132 kV Switchgear

(3) 11 kV Busbar and Cables

Insulator which supports the terminal between 11 kV busbar and 11 kV cable for one phase was modified because it had insulation failure.

There is insulation deterioration of 11 kV cables by aging.

(4) 11 kV Switchgear

Although OCB (Oil Circuit Breakers) have been applied in 11 kV switchgear, there is only one OCB for two station service circuits. Additionally, there is also one OCB for two generator circuits. Therefore, changeover of circuit shall be done by man-powered interchanging of OCB.

11 kV switchgear panel for irrigation feeder have been replaced to new one because flash over had happened on OCB.

There is no method for receiving the power from 132 kV system.

Source: Prepared by JICA Survey Team

Photo 7.1-10 11 kV Switchgear

(5) 11/11 kV Tie Transformers

There is remarkable oil leakage at the tank, gasket and radiator, etc. 11 kV bushing has been reinforced due to the flashover.

Source: Prepared by JICA Survey Team

Photo 7.1-11 11/11 kV Tie Transformer

(6) Low Voltage Switchgear

Although there is no outstanding deterioration in low voltage switchgear, the size of each ACBs and MCCB is large compared with the current standard design.

(7) Station Service Transformers

There is remarkable oil leakage at the tank, gasket, conservator and radiator, etc. in all units. Low voltage bushing has been reinforced due to insulation failure by the flashover.

Source: Prepared by JICA Survey Team

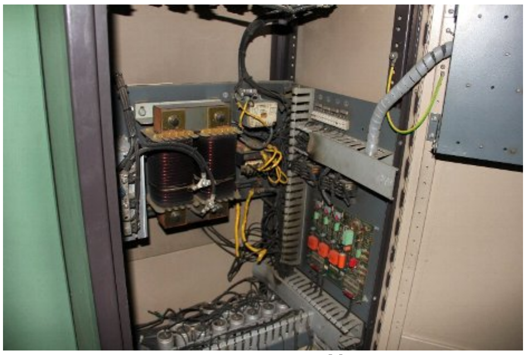
Photo 7.1-12 Station Service Transformers

(8) DC Panels

As well as low voltage switchgear, there is no outstanding deterioration in DC panels but the size of each circuit breakers is large compared with the current design.

(9) DC Charger

There is noise in both panels and the temperature of the panels is rising without opening the front door.



Source: Prepared by JICA Survey Team

Photo 7.1-13 DC Battery Charger

(10) DC Batteries

Each DC batter banks were replaced to new one on 2009 and 2012. The leakage and low level in electrolytic solution in DC batteries have not been founded after replacement.

(11) EDG

The operating conditions of EDG are relatively good compared with its age. However, auto changeover equipment is not mounted on the EDG in case of black out in the power station.

7.2 Identification of Rehabilitation Items and Spare Parts

7.2.1 Baluchaung No.1 Hydropower Plant

(1) Screening of existing facilities/equipment for the rehabilitation

As described in Section 7.1.1, the aged deterioration of facilities except for 132/11 kV main transformer and some 132 kV switchgear equipment such as capacitor voltage transformer was found by site inspection. Additionally, there are no spare parts for replacement of facilities such as 132 kV circuit breakers and 11 kV circuit breakers.

Therefore, it is required to replace or repair the following items. Meanwhile, some facilities are not necessary to replace or repair though rehabilitation works were required in application.

Table 7.2-1 Screening of Existing Facilities/Equipment for the Rehabilitation Project (Baluchaung No.1 HPP - Substation Equipment)

Hydropower Plant **Baluchaung No.1**
Facilities/Equipment **Substation Equipment**

*1 Check items
✓ :Problem
NA :Not available
blank: No problem

*2 Screening for the Rehabilitation Project
A :Required
B :Recommended
C :Not Required

*3 Measures
R :Replacement
P :Repair
A :Addition
I :Inspection

Components	Application	Check item*1 aged deterioration	apparent inspection	trouble record	availability of spare parts	Screening*2	Measures*3	Remarks
Generator Transformer	✓					C		Spare transformer has not been used.
132 kV Circuit Breaker	✓	✓	✓	✓	✓	A	R	Auxiliary relay in Phase A has recorded false operation.
Lighting Arrester	✓	✓	✓		✓	A	R	Foundation in Phase B has been settled down to the ground.
132 kV Disconnectors			✓		✓	B	P	Only repairing steel structure
11 kV Busbar		✓	✓	✓	✓	A	R	Current capacity of 11 kV busbar is not enough under normal operation.
132 kV Busbar					✓	A	R	Spare parts are not available
11 kV Power Cables		✓			✓	A	R	Aged deterioration and insufficient isolation are found. Spare parts are not available
11/11 kV Tie Transformer		✓	✓	✓	✓	A	R	automatic changing function shall be equipped
11 kV Main and Local Cubicle		✓		✓	✓	A	R	LOCB shall be replaced to VCB
LV Switchgear		✓			✓	A	R	Spare parts are not available and ACB and MCCB shall be replaced to current design
AC Panels		✓			✓	A	R	Spare parts are not available and MCCB shall be replaced to current design
DC Panels		✓			✓	A	R	Spare parts are not available and MCCB shall be replaced to current design
DC Battery Charger		✓			✓	A	R	Spare parts are not available and panels and rectifier shall be replaced to current design
DC Batteries		✓	✓	✓	✓	A	R	batteries have not been replaced since commencement of operation.
Emergency Diesel Generator Set		✓		✓	✓	A	R	Automatic operating function shall be equipped
Transmission Line Protection Panel		✓	✓		✓	A	R	Overcurrent and ground fault relay shall be equipped as back-up protection.

Source: Prepared by JICA Survey Team

(2) Detail rehabilitation items

1) Generator transformer

As reported in Section 7.1.1, the operating condition and results of visual inspection for generator transformer were good and serious aged deterioration was not found. Furthermore, in case some trouble is happened on one unit of transformer, spare transformer will be available to replace to existing one.
Therefore it is recommended NOT to replace generator transformer.

2) 132 kV Circuit breakers

Some operating troubles have been reported on 132 kV circuit breakers due to the false operation of auxiliary relay. Therefore it need to be required to replace new one including supporting structure.
Additionally, when replacement is conducted, all circuit breaker from phase A to phase C shall be replaced, because existing circuit breakers is operating for tripping on three phase.

3) Lighting arrester

As described in Section 7.1.1, the foundation of lightning arrester in Phase B has been settled down to the ground. Additionally, there is a discrepancy of measured numbers in the lightning counter.
Therefore, the lighting counter shall be replaced new one including its foundations.

4) 132 kV disconnector

The operation condition of 132 kV disconnectors are relatively fine ever the case of opening under the on-load disconnection. However, rusted supporting structure will cause the collapse of whole disconnectors. Therefore it is recommended to repair its structure to galvanized steel.

5) 11 kV Busbar

The maximum current capacity of existing 11 kV busbar conductors, HDCC 1000 mm^2, is about 1,730 A under 90 °C condition. On the other hand, the rated current of 11 kV circuit under normal operation will be 1,627 A. It means surplus for exceeded generation operation has not been secured.
Therefore, it is required to replace new conductors which have more capacity such as ASCR (Aluminum Conductor Steel Reinforced) 1,520mm^2, etc. Furthermore, corresponding to replacement the 11 kV busbar conductor, cable head and cable clamp shall also be replaced.

6) 132 kV Busbar

Replacement of 132 kV busbar is necessary due to lack of spare parts. Additionally, further aged deterioration in future will be concerned.

7) 11 kV Power Cables

11 kV power cables have not been replaced since powerhouse start operation. In this result, insufficient isolation is appeared in each cables. Therefore, 11 kV power cables are recommended to be replaced.

8) 11/11 kV Tie Transformers

11/11 kV tie transformers shall be replaced in accordance with site inspection as described in Section 7.1.1. When these transformers are replaced, automatic function of operation changing shall be equipped in order to change the operation in case one transformer has some problems.
Therefore, it is required to add one 11 kV switchgear board for 11/11 kV tie transformer with interlock switch for changing-over in new 11 kV cubicle as described in the following.

9) 11 kV Main and local cubicle

Existing 11 kV circuit breakers installed in main and local cubicle are required to be replaced VCB (vacuum circuit breaker) in order to avoid the trouble and failure by oil leakage. Corresponding the replacement of 11 kV circuit breakers, 11 kV cubicle including CT, VT and surge absorber shall also be replace new one with the current standard design concept.

10) LV switchgear

Type and size of existing LV circuit breakers such as ACB (air circuit breaker) and MCCB are quite old because these circuit breakers were manufactured over 25 years before.
As well as 11 kV main and local cubicle, LV switchgear including circuit breaker, VT and CT shall also be replaced new one with the current standard design concept.

11) AC panels

Type and size of existing MCCB are quite old because these circuit breakers were manufactured over 25 years before.
As well as the above, AC panels including circuit breaker, VT and CT shall also be replaced new one with the current standard design concept.

12) DC panels

Type and size of existing MCCB and MCB (miniature circuit breakers) are quite old because these circuit breakers were manufactured over 25 years before.
As well as the above, DC panels including circuit breaker shall also be replaced new one with the current standard design concept.

13) DC battery charger

Type and size of existing battery charger panel and rectifiers are quite old because these facilities were manufactured over 25 years before.
Corresponding to the replacement of DC batteries as mentioned below, DC battery charger including panel and rectifier shall also be replaced new one with the current standard design concept.

14) DC Batteries

DC batteries for station service load supply shall be replaced, because batteries have not been replaced since power station started operation. It is required that long lifetime batteries are adopted in order to secure the time until next replacement. It is also required that type of new batteries is valve-regulated lead-acid battery.

15) EDG set

EDG set shall be replaced to new one, because the aged deterioration and oil leakage have been found at motor, generator and oil tank. Additionally, function of automatic starting operation shall be equipped in new EDG set.
Not only voltage and ampere meter but also other necessary meter such as power factor meter shall be installed in local control panel for EDG set.

16) Transmission line protection panel

In order to match the standard concept for transmission line protection, existing transmission line panel shall be replaced with distance relay as main protection and overcurrent and ground fault relay as back-up protection.
Furthermore, transmission line panel for Baluchaung No.1 HPP in Baluchaung No.2 HPP shall also be replaced in order to decrease the discrepancy of reliability between both power stations, because its protection panel have not been replaced as well as Baluchaung No.1 HPP.

7.2.2 Sedawgyi Hydropower Station

(1) Screening of existing facilities/equipment for the rehabilitation

As described in Section 7.1.2, the aged deterioration of almost facilities was found by site inspection. Additionally, there are no spare parts for replacement of facilities such as 132 kV circuit breakers and 11 kV circuit breakers.

Therefore, it is required to replace the following items:

Table 7.2-2 Screening of Existing Facilities/Equipment for the Rehabilitation Project (Sedawgyi HPP - Substation Equipment)

Hydropower Plant **Sedawgyi**
Facilities/Equipment **Substation Equipment**

*1 Check items
✓ :Problem
NA :Not available
blank: No problem

*2 Screening for the Rehabilitation Project
A :Required
B :Recommended
C :Not Required

*3 Measures
R :Replacement
P :Repair
A :Addition
I :Inspection

Components	Application	Check item*1 aged deterioration	apparent inspection	trouble record	availability of spare parts	Screening*2	Measures*3	Remarks
Generator Transformer	✓	✓	✓	✓		A	R	Oil leak at main tank, gasket and radiator is remarkable. All transformers shall be replaced.
Switchyard Equipment (All)	✓	✓	✓	✓	✓	A	R	Switchgear equipment such as CB and CVT is not operating normally.
132/11 kV Powerhouse Service Transformer	✓					A	A	Foundation in Phase B has been settled down to the ground.
Shunt Reactor	✓					B	-	Depending on the result of system analysis under the off-peak load
11 kV Vacuum Circuit Breaker	✓	✓	✓	✓	✓	A	R	Quantity of CB is not enough for system operation.
Power Cable	✓	✓	✓	✓	✓	A	R	Insulation level have been decreased.
11 kV Phase Shift Transformer	✓	✓	✓	✓	✓	A	R	Oil leak at main tank, gasket and radiator is remarkable. Flash over at 11kV insulator had been recorded.
Powerhouse Service Transformer	✓	✓	✓	✓	✓	A	R	Oil leak at main tank, gasket and radiator is remarkable. Flash over at LV insulator had been recorded.
Emergency Diesel Generator Set	✓	✓			✓	A	R	Automatic operating function shall be equipped.
Plant DC Battery Bank	✓				✓	B	R	Batteries have been replaced on 2009 and 2012.
DC Battery Charger		✓	✓		✓	A	R	Abnormal noise is detected at rectifier.
Transmission Line Protection Panel		✓	✓		✓	A	R	Analog relay shall be replaced to digital one in order to secure the reliability.

Source: Prepared by JICA Survey Team

(2) Detail rehabilitation items

1) Generator transformer

As reported in Section 7.1.2, oil leakage at main tank, gasket and radiator, etc. in all units of main transformers was found, outstandingly. It has possibility that the oil leak cause serious fault of main transformer in near future.
So, it is required to replace all units of main transformer as soon as possible.

2) Switchyard Equipment (All)

As mentioned below, all 132 kV switchyard equipment shall be replaced to new one.

a) 132 kV Circuit breakers

Automatic spring charge function of all 132 kV circuit breakers has been broken as reported in site inspection. Therefore operating staff in power station should charge the spring motor coil manually. This inconvenient operation will cause the lagging of switching operation and affect operation of the relevant substations.
In order to secure the reliability of system grid, all 132 kV circuit breakers shall be replaced.

b) Current transformers

Actually, 132 kV red phase current transformer of the Kyaukpahtoe circuit was burnt in 2007 and it was replaced. It is considerable that its "burnt" accident was depending on the aged deterioration caused by the moisture in the equipment. Same situation shall be considered in other current transformers.
Therefore, current transformers shall be replaced.

c) Capacitor voltage transformers

Capacitor voltage transformers in transmission line circuit have not been operated since the secondary circuit has broken and line voltage is not measured. In order to secure the reliability of transmission line circuit, these capacitor voltage transformers shall be replaced.

3) 132/11 kV station service transformer

Sedawgyi HPP supplies the generating power not only to 132 kV system grid but also to 11 kV distribution circuits to irrigation and residential area. Previously, 132/33 kV transformer had been installed in switchyard and supply the power through 33 kV line. However, its transformer has been removed and there is no method for supplying the electricity power to local area from 132 kV grid. Therefore alternative power supply method to local area shall be considered even if power plant stops it's generating.

Although it is one of the best alternative to install 132/11 kV transformer in switchyard, to supply the electricity from 11 kV circuit is considered because the space of switchyard is limited.

4) Shunt reactor

Usually, shunt reactor is not installed in the switchyard of hydropower station, because the generating reactive power is able to be controlled by APFR or AQR according to demand of reactive power in the grid. On the other hand, in case hydropower station stops its generating operation, the busbar voltage of 132 kV switchyard will be raised at the off-peak load case by the Ferranti effect. Hence, it is considerable to install the shunt reactor in 132 kV switchyard.

However, necessity of installation shunt reactor shall be based on the result of system analysis. Additionally, in case of Sedawgyi HPP, two transmission lines, incoming to Aupinglae S/S (Substation) and outgoing to Kyaukpahtoe S/S, are connected to substation. Therefore it is more effective to install the shunt reactor at Kyaupahtoe S/S.

5) 11 kV VCB

As reported in Section 7.1.2, OCB has been applied to 11 kV switchgear except for irrigation feeder. However, the numbers of circuit breaker are not enough against the numbers of pane, because some OCB had troubles such as flash over and there was no spare circuit breaker.

In order to keep the reliable operation, circuit breaker shall be installed in each panel (feeder). Therefore these 11 kV panels shall be replaced with VCB so as to avoid the trouble and failure by oil leakage.

6) Power cable

Power cables not only 11 kV circuit but also low voltage circuit have not been replaced since the commencement of power station. Therefore it is not suspected the aged deterioration like decrease of insulation level has been occurred. Therefore all power cables shall be replaced to the new one.

7) 11 kV phase shift transformer

As well as 132/11 kV main transformers, oil leaks at tank, gasket and radiator were remarkable. It has possibility that the oil leak cause serious fault of main transformer in near future. In order to secure the reliability for supplying 11 kV circuit, this 11 kV tie transformer shall be replaced new one.

8) Station service transformer

Although there are two station service transformers for normal and stand-by. However, same as other transformers which are installed in outside of the power plant, oil leakage at tank, gasket and radiator is also remarkable.

It required replacing station service transformer to dry type transformer and to be installed in 11 kV switchgear cubicle for easy maintenance and avoiding the aged deterioration by oil leakage.

9) EDG set

EDG set shall be replaced to new one because of its aged deterioration. Additionally, function of automatic starting operation shall be equipped in new EDG set.

10) Plant DC battery bank

As reported in Section 7.1.2, DC batteries, 2 sets of 300 AH batteries, were replaced in 2009 and 2012. Therefore the conditions of existing batteries are relatively good.

However, the rehabilitation work by the Project will be done in around 2019. It means existing DC batteries will be aged about 10 years after its installation. Therefore, it is desirable to replace new batteries in the Project.

11) DC battery charger

Type and size of existing battery charger panel and rectifiers are quite old because these facilities were manufactured over 25 years before. Additionally, abnormal noise in DC battery charger was detected during the site inspection.

Therefore, DC battery charger including panel and rectifier shall be replaced to the new one with the current standard design concept.

12) Transmission line protection panel

Protection scheme of existing transmission line protection panels is matched to the standard concept in Myanmar. However, its protection relay is mechanical type and found the aged deterioration because these protection panels have not been replaced until now.

Meanwhile, the transmission line protection panel to Sedawgyi HPP in Aupinglae S/S was replaced in 2010 and the digital relays have been equipped in the panel. Therefore, in order to ensure consistency of the reliability, it is required to replace new protection panel.

7.3 Basic Design on Rehabilitation of relevant Substation and Transmission Line Facilities inside Power Plants

Basic design of substation and transmission line facilities for both power plants is carried out based on the result of the screening sheet including EPGE's (Electric Power Generation Enterprise) comment.

7.3.1 Baluchaung No.1 HPP

(1) 132 kV Circuit Breaker

132 kV circuit breaker after rehabilitation will be SF6 gas type, with three-pole collective arrangement and for outdoor use. The circuit breaker shall be suitable for single-pole tripping and rapid auto-reclosing, provided with a motor-operated spring mechanism, and shall comply with the related IEC standards/recommendations.

The ratings of 132 kV circuit breaker is recommended as follows:

Rated voltage		145 kV
Rated normal current		800 A
Rated frequency		50 Hz
Rated short-circuit breaking current		20 kA, 1sec
Rated interrupting time		less than or equal to 3 cycle
Rated operating sequence		O - 0.3 sec. - CO - 1 min. - CO
Rated closing operation voltage		230 V DC
Rated control voltage		230 V DC
Rated insulation level		
(a)	Rated short-duration power-frequency withstand voltage (r.m.s. values)	275 kV
(b)	Rated lightning impulse withstand voltage (peak value)	650 kV

The circuit breaker shall be equipped with motor-charged spring operated mechanism for 230V DC and the mechanism shall ensure uniform and positive closing and opening.

Rehabilitation quantity: 1 set (3 phase)

(2) Lightning arrester

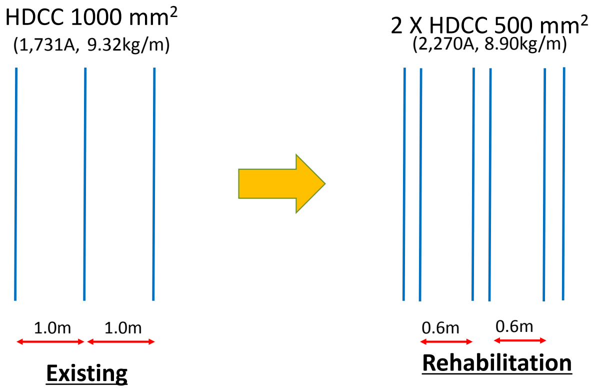
As the result of discussion with EPGE, lightning arrester is not including to the scope of rehabilitation in this Project because foundation of lighting arrester will be repaired by EPGE.

(3) 132 kV disconnector

As the result of discussion with EPGE, 132 kV disconnector is not including to the scope of rehabilitation in this Project because steel structure of 132 kV disconnector will be repaired by EPGE.

(4) 11 kV Busbar

The existing conductor for 11 kV busbar is a HDCC 1,000 mm² and its continuous current carrying capacity is 1,731 A at its permissible operating temperature of 90°C against rated current capacity of 1,627 A under normal generating operation. It is recommended to replace conductor to 2 × HDCC 500mm² which has 2,270 A under 90°C condition, in order to secure the surplus current for abnormal operation. In addition, gantry structure for 11 kV busbar is not necessary to replace because weight of 2 × HDCC 500 mm² is lighter than HDCC 1,000 mm². Furthermore, after replacement to 2 × HDCC 500 mm², the insulation clearance of 11 kV busbar will be secured as shown in the following figure:



Source: Prepared by JICA Survey Team

Fig. 7.3-1 Comparison of Conductor for 11 kV Busbar in Baluchaung No.1 HPP

Table 7.3-1 Composition of 11 kV Busbar in Baluchaung No.1 HPP

No.	Item	Qty.
1	HDCC 500mm²	86 m
2	Cable clamp (T-clamp)	6 pcs
3	Insulator string	4 sets

Source: Prepared by JICA Survey Team

(5) 132 kV Busbar

132 kV busbar conductor, related insulator strings and accessories such as cable clamps and connection wire, etc. shall be replaced to new one due to the aged deterioration. The conductor size of 132 kV busbar will be replaced to HDCC 250 mm² same as the existing one.
Replacement area for 132 kV busbar is shown as follows:

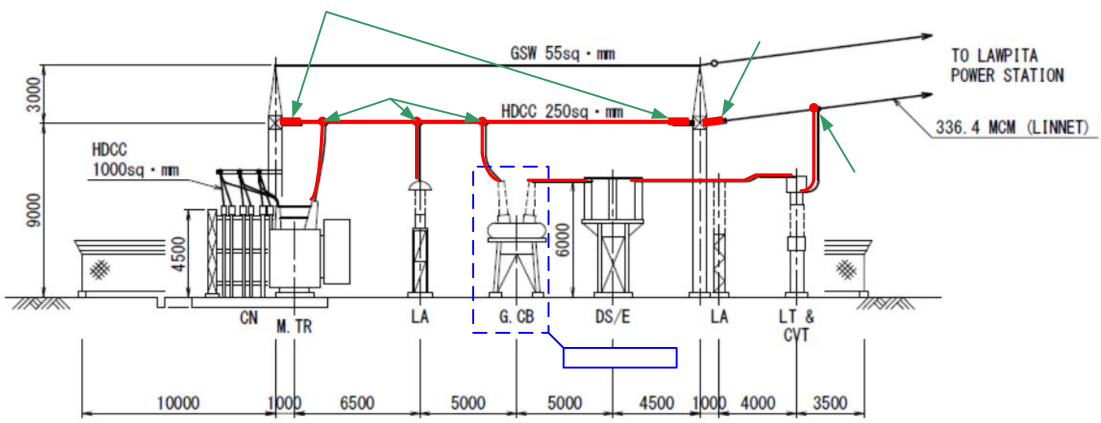


Fig. 7.3-2 Replacement Area for 132 kV Busbar in Baluchaung No.1 HPP

Source: EPGE

Table 7.3-2 Composition of 132 kV Busbar in Baluchaung No.1 HPP

No.	Item	Qty.
1	HDCC 250mm^2	228 m
2	Cable clamp (T-clamp)	9 pcs
3	Insulator string with arching horn	3 sets
4	Insulator string without arching horn	6 sets

Source: Prepared by JICA Survey Team

(6) 11 kV Cable

11 kV cables for each section as mentioned in the following shall be replaced. It is recommended to apply cross-linked polyethylene cable.

Table 7.3-3 Section Table for 11 kV Cables in Baluchaung No.1 HPP

No.	From	To	Length	Size
1	11 kV Main Cubicle	132/11kV Main Transformers	135 m	600 mm^2
2	11 kV Main Cubicle	11/11 kV Tie Transformer 1	73 m	250 mm^2
3	11 kV Main Cubicle	11/11 kV Tie Transformer 2	73 m	250 mm^2
4	11/11 kV Tie Transformer 1	11 kV Local Cubicle	58 m	60 mm^2
5	11/11 kV Tie Transformer 2	11 kV Local Cubicle	58 m	60 mm^2
6	11 kV Local Cubicle	11/0.4 kV Station Service Tr.1	15 m	60 mm^2
7	11 kV Local Cubicle	11/0.4 kV Station Service Tr.2	15 m	60 mm^2
8	11 kV Local Cubicle	11 kV Dawtacha Intake Feeder	82 m	60 mm^2
9	11 kV Local Cubicle	11 kV Loikaw Feeder	92 m	60 mm^2
10	11 kV Local Cubicle	11 kV Baluchaung No.2 Feeder	102 m	60 mm^2

Source: Prepared by JICA Survey Team

(7) 11/11 kV Tie transformer

As the result of discussion with EPGE, 11/11 kV tie transformers are not including to the scope of rehabilitation in this Project because serious problems have not found during site inspection.

(8) 11 kV Main and Local Cubicles

11 kV main and local cubicles shall be replaced due to the aged deterioration and lack of spare parts. Additionally, one feeder cubicle for spare of 11/11 kV tie transformer shall be added in order to save labor for changing the connection when some troubles occur in one unit of 11/11kV tie transformer, because, currently, 11 kV cable is connected to only one unit 11/11 kV tie transformer as mentioned in Section 7.1.1.(7).

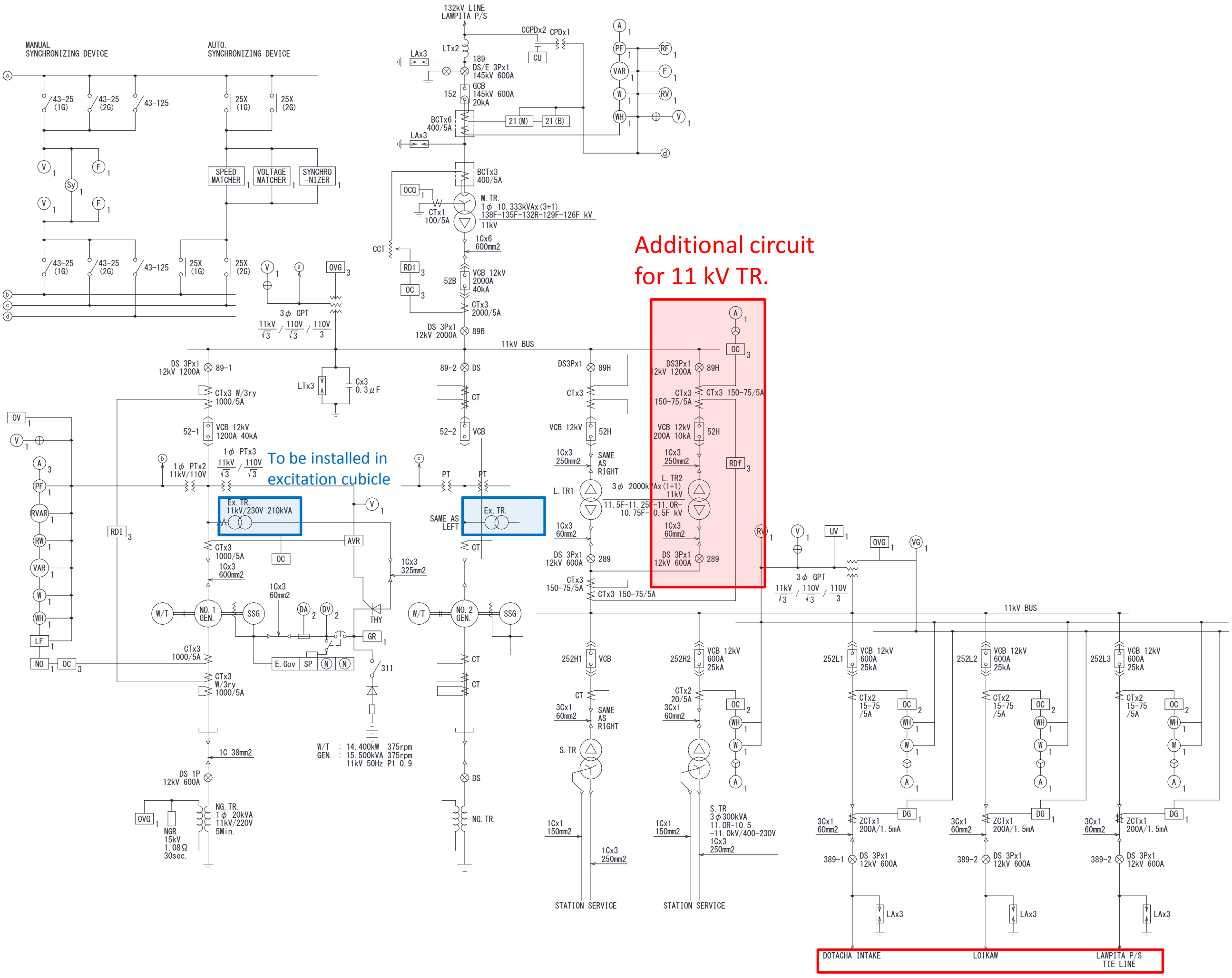
11 kV main and local cubicles are of circuit breakers, disconnectors, current transformers, voltage transformers and surge absorbers, etc. in indoor type and self-supporting metal-enclosed panel.

Furthermore, circuit breaker of vacuum type shall be applied to new 11 kV cubicle so as to reduce the space and secure the reliability.

The rated current of each circuit breaker is recommended as follows:

✧	Generator feeder:	1,200 A
✧	Main transformer feeder	2,000 A
✧	11/11kV transformer feeder	1,200 A (11 kV main cubicle)
✧	11/11kV transformer feeder	600 A (11 kV local cubicle)
✧	11/0.4 kV station service transformer feeder	600 A
✧	11 kV distribution line feeder	600 A

<u>Rehabilitation quantity: 12 panels</u>



Source : Prepared by JICA Survey Team

Fig. 7.3-3 Single Line Diagram of 11 kV circuit after Rehabilitation Work in Baluchaung No.1 HPP

(9) LV Switchgear

LV switchgear after rehabilitation will be of indoor type and self-supporting metal-enclosed panel.

The following switchgear and equipment will be mounted in the LV switchgear cubicle:

1) 11/0.4 kV station-service transformer circuit 1
- (a) One (1) ACB (630 A)
- (b) Three (3) measuring current transformers
- (c) One (1) set of power cable terminals for 400 V power cable connection to the station-service transformer

2) 11/0.4 kV station-service transformer circuit 2
- (a) One (1) ACB (630 A)
- (b) Three (3) measuring current transformers
- (c) One (1) set of power cable terminals for 400 V power cable connection to the station-service transformer

3) 300 kVA EDG circuit
- (a) One (1) ACB
- (b) Three (3) measuring current transformers
- (c) One (1) set of power cable terminals for 400 V power cable connection to the EDG

4) Common motor control center circuit
- (a) One (1) ACB (630 A)

5) Unit No.1 motor control center circuit
- (a) One (1) ACB (630 A)

6) Unit No.2 motor control center circuit
- (a) One (1) ACB (630 A)

7) AC panel 2 circuit
- (a) One (1) ACB (630 A)

8) AC panel 1 circuit
- (a) One (1) MCCB (225 AF)

9) DC battery charger circuit 1
- (a) One (1) MCCB (225 AF)

10) DC battery charger circuit 2
- (a) One (1) MCCB (225 AF)

11) Overhead traveling crane circuit
- (a) One (1) MCCB (225 AF)

12) Spare circuit
- (a) One (1) ACB (630 A)
- (b) One (1) MCCB (225 AF)

13) 400 V common bus
- (a) Three (3) measuring voltage transformers

(10) AC Panel

The AC panels shall be of floor-standing, metal-enclosure type distribution panels and shall be installed in the low tension cubicle room.

The AC panels consist of the following equipment.

1) AC panel 1

- ✧ One (1) set of 400/230 V three-phase four-wire buses
- ✧ One (1) power transformer having suitable rating for AC control source supply
- ✧ Thirteen (13) pieces of MCCB or MCBs

2) AC panel 2

- ✧ One (1) set of 400/230 V three-phase four-wire buses
- ✧ One (1) voltage transformer with suitable output for measuring
- ✧ Ten (10) pieces of MCCB or MCBs

(11) DC Panel

The DC panels shall be of floor-standing, metal-enclosure type distribution panels and shall be installed in the low tension cubicle room.

The DC panels consist of the following equipment.

1) DC panel 1

- ✧ One (1) set of 230 V DC buses
- ✧ Twelve (12) pieces of MCCB or MCBs

2) DC panel 2

- ✧ One (1) set of 230 V DC buses
- ✧ Eleven (11) pieces of MCCB or MCBs

(12) DC Battery Charger

Two sets of DC battery charger shall be replaced. The DC battery chargers are of rectifier, floor standing, metal-enclosure type and shall be installed in the low tension cubicle room.

The rating of rectifier is mentioned as below:

- ✧ Rated output voltage 230 V
- ✧ Rated output current 100 A
- ✧ Rated input voltage 400 V
- ✧ Charging mode Floating/Equalizing

(13) DC Battery Bank

Two (2) sets of the existing storage batteries shall be replaced. The new batteries shall be located at the same places as the existing ones.

Lead acid, valve-regulated type is recommended as the new storage batteries. Each battery set shall have a capacity of 300 ampere-hour at 10-hour discharge rate.

The new storage batteries shall be provided with steel or wooden racks of acid proof type.

(14) EDG

The existing EDG shall be replaced due to the aged deterioration. As new diesel generator set, one (1) 300 kVA emergency diesel engine generator set complete with the necessary switchgear and accessories shall be installed to supply emergency electric power for operation of auxiliary equipment for black-starting the main generator unit. The diesel engine generator set shall be installed in the diesel generator house located near the power plant.

Desirable specification of new generator is mentioned as below:

- ✧ Duty type — Continuous running duty
- ✧ Rated output — 300 kVA
- ✧ Rated voltage — 400/230 V of three-phase four-wire system
- ✧ Rated frequency — 50 Hz
- ✧ Rated power factor — 0.8 lagging

(15) Transmission Line Protection Panel

The transmission line panels in both Baluchaung No.1 HPP and Baluchaung No.2 HPP shall be replaced due to the reason as mentioned in Section 7.2.1 (2) 14). The new transmission line panels shall be of floor-standing, metal enclosure type. And also, the following protection replays shall be equipped at the transmission line protection panel in order to match the standard concept for T/L protection in Myanmar.

- ✧ Distance Relay (21) — Main Protection
- ✧ Over current/ground fault relay(50/51N) — Back-up protection

7.3.2 Sedawgyi Hydropower Plant

(1) Generator Transformer

The generator transformers in Sedawgyi HPP shall be replaced due to serious oil leakage and the aged deteriorations as mentioned in Section 7.1.2 (1).

<u>Rehabilitation quantity: 7 banks (2units of 3 phase plus one spare bank)</u>

1) General

Two (2) sets of the generator transformers shall be a three-phase bank of three (3) single-phase transformers, which are intended to be connected to 11 kV switchgear through 11 kV cables and 11kV busbar. Additionally, the three (3) single-phase transformers shall be arranged for star-delta connection to form a three-phase bank.

2) Type and cooling method

a) Type of generator transformer

Each phase of the generator transformer shall be of single-phase, oil-immersed, two-windings, outdoor type power transformer intended to be connected to the generator via 11 kV switchgear.

b) Cooling method

The cooling method of each-phase transformer shall be the self-cooled type (ONAN).

3) Rating

The rating of the generator transformer after rehabilitation is recommended as below:

<table>
<tr><td colspan="2">Rated power</td><td colspan="2">5.1 MVA for each phase</td></tr>
<tr><td colspan="2">Rated frequency</td><td colspan="2">50 Hz</td></tr>
<tr><td colspan="2">Rated voltage ratio</td><td colspan="2">132/11 kV</td></tr>
<tr><td colspan="2">Shor circuit impedance</td><td colspan="2">10.0 %</td></tr>
<tr><td colspan="2">Rated insulation level</td><td>HV</td><td>LV</td></tr>
<tr><td>(a)</td><td>Rated short-duration power-frequency withstand voltage (r.m.s. values)</td><td>275 kV</td><td>28 kV</td></tr>
<tr><td>(b)</td><td>Rated lightning impulse withstand voltage (peak value)</td><td>650 kV</td><td>75 kV</td></tr>
</table>

(2) 132 kV Switchgear

The 132 kV switchgear in Sedawgyi HPP shall be replaced due to the aged deterioration and inoperative of circuit breaker.

There are two options for rehabilitation of the 132 kV switchgear in Sedawgyi HPP in case of both AIS (Air Insulated Switchgear) same as the existing one and GIS (Gas Insulated Switchgear).

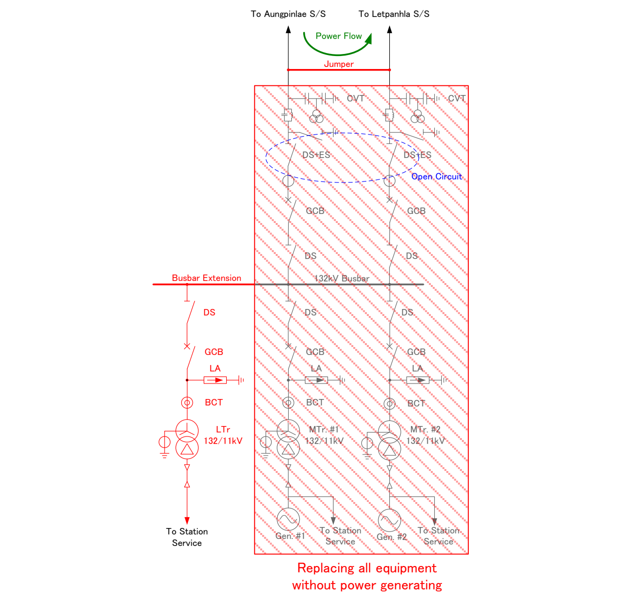
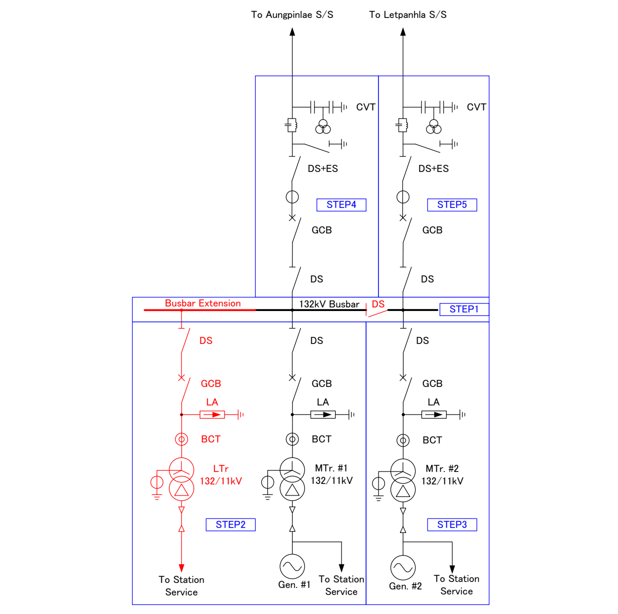
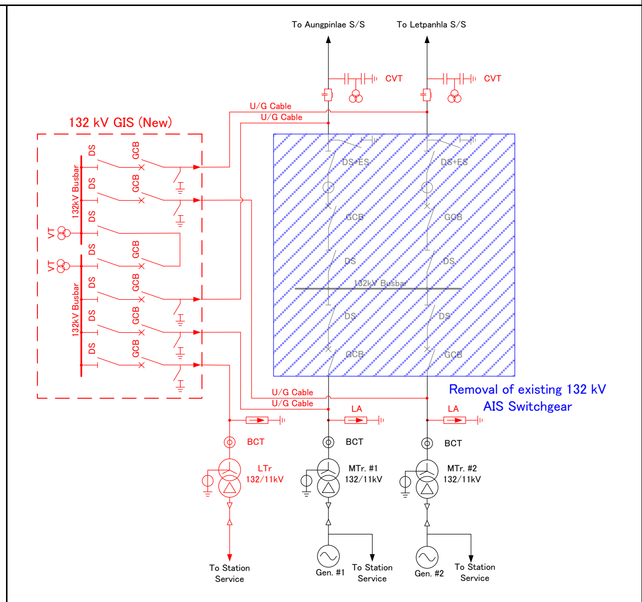
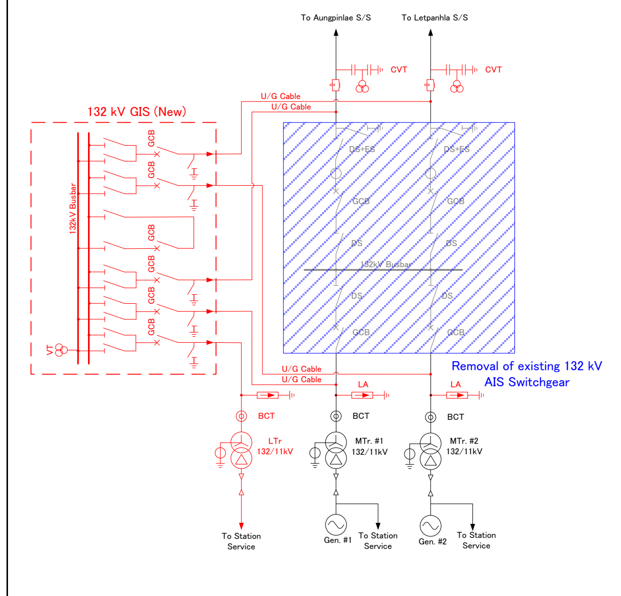
GIS has the benefit for reducing installation space and the time of power outage for 132 kV system compared with AIS. On the other hand, the staff of the power plant have had a knowledge of operation and maintenance for AIS.

The benefit and issues for each switchgear are able to be compared as the following table:

Based on the discussion with EPGE, the JICA Survey Team agreed to apply the AIS for 132 kV switchgear as the rehabilitation equipment, because of low cost and easy transferring of operation and maintenance knowledge.

Detailed method during rehabilitation work is mentioned in Chapter 12.

Table 7.3-4 Comparison of Replacement for 132kV Switchyard in Sedawgyi HPP

Alternatives	Plan A Continuous operation of transmission line		Plan B One-by-one replacement to New AIS		Plan C Replacement to New GIS (1)		Plan D (Reference) Replacement to New GIS (2)	
Switchgear	Air Insulated Switchgear (AIS)				Gas Insulated Switchgear (GIS)			
Busbar Arrangement	Single Busbar Arrangement						Double Busbar Arrangement	
System Configuration								
Methodology for replacement	STEP 1 : Installation of Jumper between T/L to Aunglinlae S/S and Letpanhla S/S STEP 2 : Removal of existing switchgear STEP 3 : Installation of new switchgear STEP 4 : Removal of Jumper		STEP 1 : Replacement of existing busbar STEP 2 : Replacement of switchgear (TR#1) and installation of local transformer and its switchgear STEP 3 : Replacement of switchgear (TR#1) STEP 4 : Replacement of switchgear (T/L1) STEP 5 : Replacement of switchgear (T/L2)		STEP 1 : Installation of 132 kV GIS STEP 2 : Installation of local transformer STEP 3 : Installation 132 kV Underground cables between GIS and gantry structures STEP 4 : Changing connection to GIS STEP 5 : Replacement of existing switchgear		STEP 1 : Installation of 132 kV GIS STEP 2 : Installation of local transformer STEP 3 : Installation 132 kV Underground cables between GIS and gantry structures STEP 4 : Changing connection to GIS STEP 5 : Replacement of existing switchgear	
System Reliability	Same as existing system	B	Same as existing system	B	Higher than AIS	A	High reliability	AA
O & M	Same as existing equipment	B	Same as existing equipment	B	Easy maintenance	A	Easy Maintenance	A
Safety for Construction	Replacement work will be done without live-wire operations	A	Safety clearance of 3.6m from live part required by Japanese government is hard to keep (*Note)	D	GIS will be installed at empty space in switchyard.	B	GIS will be installed at empty space in switchyard	B
Power Outage	Jumper shall be installed under no-voltage operation of transmission line.	D	132 kV switchgear is replaced according to the order of replacement of turbine-generator unit	B	Power outage is required during construction of cable terminal head for underground cables.	A	Power outage is required during construction of cable terminal head for underground cables.	A
Economic Efficiency	4.1 mil. USD (Incl. equipment, off shore materials, spare parts, offshore special tools and Technical Advisory service)	A	4.1 mil. USD (Incl. equipment, off shore materials, spare parts, offshore special tools and Technical Advisory service)	A	7.8 mil. USD (Incl. equipment, off shore materials, spare parts, offshore special tools and Technical Advisory service)	C	7.9 mil. USD (Incl. equipment, off shore materials, spare parts, offshore special tools and Technical Advisory service)	D
Remarks (Pending issues)	- Setting value of distance relay in transmission line protection panel installed in Aungpunlae S/S and Letpanhla S/S shall be changed. - Although the location for installation of jumper is assumed on the way between terminal and second tower from Sedawgyi HPP, construction method shall be confirmed. - Operation of transmission line is continuous, while power supply from Sedawgyi HPP is impossible.		- When 132 kV busbar is replaced, operation of all equipment such as transmission line and turbine-generator shall be stopped. - Two or three hours for connection time to busbar is estimated - Required clearance for field work from live parts is to be reviewed in consideration with Japanese regulation. - New gantry structure shall be installed at rock field. - There is no space for installation of bus section DS		- Only changing-over time to circuit will be power outage time by precedent installation of GIS in empty space. - Outdoor type GIS is recommended in order to make good use of available space in switchyard. - Power outage will be required during construction of cable head to underground cable at gantry structure for transmission line and main transformers.		- There is not enough space for installation of double busbar schemed GIS in switchyard. - System reliability by adoption of double busbar will be increased, because 132 kV switchyard in Sedawgyi HPP has been operating as switching station for transmission line to Aungpinlae S/S and LEtpanhla S/S - For reference, there is also no space for installation of double busbar scheme AIS in current switchyard.	
Reference Drawing	Layout Plan A&B (AIS)				Layout Plan C (GIS)		N/A	

*(*Note) Refer to Director-General Notification 759th Japanese Labor Standards Bureau on December 17, 1975*
Reference AA: Perfect A: Excellent, B : Good, C : Bad, D:Poor

Source: Prepared by JICA Survey Team

1) Circuit breaker

The 132 kV circuit breakers shall be SF6 gas type, with three-pole collective arrangement and for outdoor use. The circuit breakers shall be suitable for single-pole tripping and rapid auto-reclosing, provided with a motor-operated spring mechanism, and shall comply with the related IEC standards/recommendations.

Rehabilitation quantity: 5 sets (3 phase)

The rating of the 132 kV circuit breakers after rehabilitation is recommended as below:

Rated voltage		145 kV
Rated normal current		2,500 A
Rated frequency		50 Hz
Rated short-circuit breaking current		40 kA, 1sec
Rated interrupting time		less than or equal to 3 cycle
Rated operating sequence		O - 0.3 sec. - CO - 1 min. - CO
Rated closing operation voltage		230 V DC
Rated control voltage		230 V DC
Rated insulation level		
(a)	Rated short-duration power-frequency withstand voltage (r.m.s. values)	275 kV
(b)	Rated lightning impulse withstand voltage (peak value)	650 kV

2) Disconnectors with earthing switches

The 132 kV disconnectors shall be three-phase and air break type with horizontal operation. Earthing switches shall be triple-pole, single-throw, vertical single break and manual three-phase group operation type. The disconnectors and earthing switches shall be suitable for outdoor use. The earthing switches shall be mounted on the disconnectors if possible.

Rehabilitation quantity: 7 sets (3 phase)

The rating of the 132 kV disconnecters and earthing switches after rehabilitation is recommended as below:

Rated voltage		145 kV
Rated normal current		2500 A
Rated frequency		50 Hz
Rated short-circuit breaking current		40 kA, 1sec
Rated control voltage		230 V DC
Rated insulation level		
(a)	Rated short-duration power-frequency withstand voltage (r.m.s. values)	275 kV
(b)	Rated lightning impulse withstand voltage (peak value)	650 kV

3) Current transformer

The 132 kV current transformer shall be single-phase, porcelain-insulated, oil-immersed and air-tight sealed post insulator type, for outdoor use and shall be designed in accordance with IEC 60044-1.

Rehabilitation quantity: 12 pcs

The rating of 132 kV current transformer after rehabilitation is recommended as below:

Rated voltage		145 kV
Rated frequency		50 Hz
Rated insulation level		
(a)	Rated short-duration power-frequency withstand voltage (r.m.s. values)	275 kV
(b)	Rated lightning impulse withstand voltage (peak value)	650 kV
Rated current ratio		As specified in single line diagram of Sedawgyi HPP
Accuracy classes		5P20 for protection class 0.5 for metering

4) Capacitor voltage transformers

The 132 kV voltage transformers shall be single-phase, capacitor type san shall be designed in accordance with IEC 60044-5.

Rehabilitation quantity: 9 pcs

The rating of the 132 kV capacitor voltage transformer after rehabilitation is recommended as below:

Rated voltage		145 kV
Rated frequency		50 Hz
Voltage ratio		$\frac{132\text{ kV}}{\sqrt{3}} : \frac{110\text{ V}}{\sqrt{3}} : \frac{110\text{ V}}{3}$
Accuracy classes		0.5
Rated insulation level		
(a)	Rated short-duration power-frequency withstand voltage (r.m.s. values)	275 kV
(b)	Rated lightning impulse withstand voltage (peak value)	650 kV

5) Surge arresters

The 120 kV surge arresters shall be gapless, metal-oxide, outdoor use and heavy duty type. The arresters shall be designed in accordance with IEC 60099-4.

Rehabilitation quantity: 12 pcs

The rating of the 120 kV arresters after rehabilitation is recommended as below:

Rated voltage		120 kV
Rated frequency		50 Hz
Nominal discharge current		10 kA
Long-duration discharge class		Class 3 (IEC 60099-4)
Pressure-relief current		40 kA
Rated insulation level		
(a)	Rated short-duration power-frequency withstand voltage (r.m.s. values)	275 kV
(b)	Rated lightning impulse withstand voltage (peak value)	650 kV

(3) 132/11 kV Power Service Transformer

In order to supply the power to station service load and 11 kV distribution line to local area and irrigation gate under the situation in case the generator stop its operation, the method shall be considered in a system after rehabilitation.

So as to satisfy the above condition, the method either to install additional 132/11 kV transformer in switchyard or to change the synchronizing system to 11 kV are considered.

As compared in the following table, to install the additional 132/11 kV transformer has the benefit for the condition of power outage in the power station.

1) General

One (1) set of the additional 132/11 kV transformer shall be a three-phased, which are intended to be connected to the generators through 11 kV cable and 11 kV busbar.

2) Type and cooling method

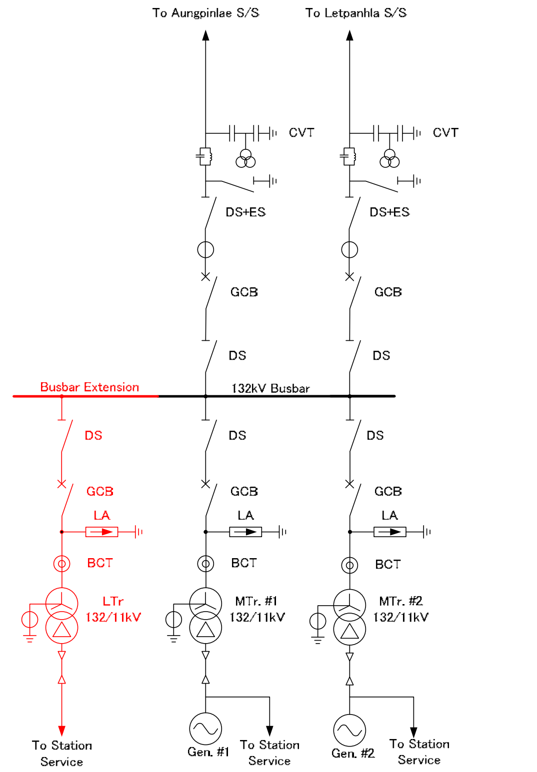
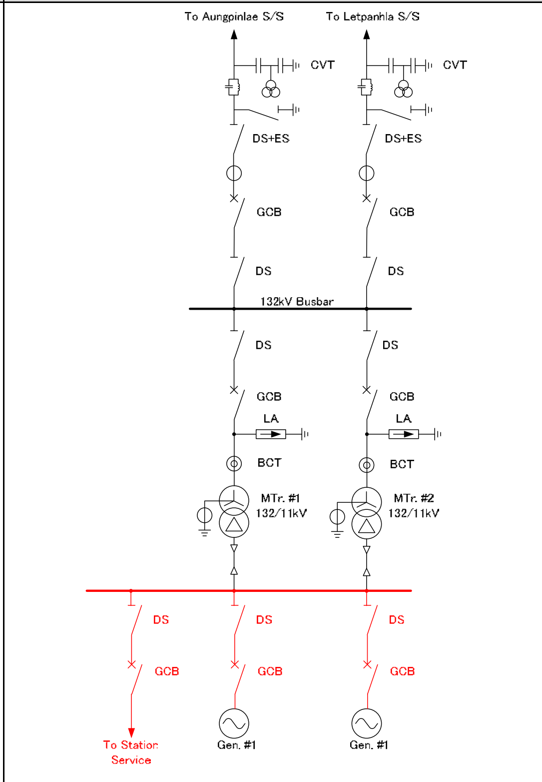
a) Type of generator transformer

The additional 132/11 kV transformer shall be of three-phased, oil-immersed, two-windings, outdoor type power transformer intended to be connected to 11 kV switchgear in power plant.

b) Cooling method

The cooling method of the additional 132/11 kV transformer shall be the self-cooled type (ONAN).

Table 7.3-5 Comparison for Supplying the Power under the Situation of Stopping Generators

<table>
<tr><th rowspan="2">Plan</th><th>Alternative-1</th><th>Alternative-2</th></tr>
<tr><th>Additional 132/11kV Transformer</th><th>11kV Synchronizing System</th></tr>
<tr><td>System Configuration</td><td>
</td><td>
</td></tr>
<tr><td>System Reliability</td><td>This alternative plan has a reliability, because power supply is able to be continued if both generators stop its operation</td><td>In case some troubles are happened on both main transformers, it is impossible to supply to the station services.</td></tr>
<tr><td>Operating</td><td>Operating mechanism will be same as the existing system.</td><td>Operating mechanism will be changed from the existing one drastically.</td></tr>
<tr><td>Evaluation</td><td>Recommend</td><td>Not Recommend</td></tr>
</table>

Source: Prepared by JICA Survey Team

3) Rating

The rating of the additional 132/11 kV transformer after rehabilitation is recommended as below:

Rated power		5 MVA	
Rated frequency		50 Hz	
Rated voltage ratio		132/11 kV	
Shor circuit impedance		10.0 %	
Rated insulation level		HV	LV
(a)	Rated short-duration power-frequency withstand voltage (r.m.s. values)	275 kV	28 kV
(b)	Rated lightning impulse withstand voltage (peak value)	650 kV	75 kV

(4) 11 kV Switchgear

11 kV switchgear shall be replaced due to the aged deterioration and lack of spare parts.

11 kV switchgear is of circuit breakers, disconnectors, current transformers, voltage transformers and surge absorbers, etc. in indoor type and self-supporting metal-enclosed panel.

Furthermore, circuit breaker of vacuum type shall be applied to new 11 kV cubicle so as to reduce the space and secure the reliability.

The rated current of each circuit breaker is recommended as below:

- ✧ Generator feeder: 2,000 A
- ✧ 11/11kV transformer feeder 1,250 A
- ✧ 11/11kV transformer feeder 1,250 A
- ✧ 11/0/4 kV station service transformer feeder 600 A
- ✧ 11 kV distribution line feeder 600 A

Rehabilitation quantity: 10 panels

(5) Power Cables

11 kV cables for each section as mentioned in the following shall be replaced. It is recommended to apply cross-linked polyethylene cable.

Table 7.3-6 Section Table for 11 kV Cables in Sedawgyi HPP

No.	From	To	Length	Size
1	132/11 kV Main Tr. 1	Generator 1	200 m	600 mm^2
2	132/11 kV Main Tr. 2	Generator 2	200 m	600 mm^2
3	132/11 kV Additional Tr.	11 kV Switchgear	200 m	250 mm^2
4	Generator 1	11 kV Switchgear	50 m	600 mm^2
5	Generator 2	11 kV Switchgear	50 m	600 mm^2
6	11/0.4 kV Station Service Tr.1	LV Switchgear	30 m	250 mm^2
7	11/0.4 kV Station Service Tr.2	LV Switchgear	30 m	250 mm^2
8	11 kV Switchgear	11/11 kV Tie Transformer	80 m	250 mm^2
9	11 kV Tie Transformer	11 kV Switchgear	80 m	250 mm^2
10	11 kV Switchgear	Irrigation Feeder	300 m	60 mm^2
11	11 kV Switchgear	Local Power Supply	300 m	60 mm^2

Source: Prepared by JICA Survey Team

(6) 11 kV Phase Shift Transformer

One (1) set of 11/11 kV phase shift transformer to divide the section of 11 kV circuit installed in outdoor shall be replaced due to serious oil leakage and the aged deterioration.

1) General

The new 11/11 kV transformer shall be a three-phased, which are intended to be connected to both the 11 kV switchgear generators through 11 kV cable.

2) Type and cooling method

a) Type of generator transformer

The new 11/11 kV transformer shall be of three-phased, oil-immersed, two-windings, outdoor type power transformer intended to be connected to 11 kV switchgear in power plant.

b) Cooling method

The cooling method of the new 11/11 kV transformer shall be the self-cooled type (ONAN).

3) Rating

The rating of the new 11/11 kV transformer after rehabilitation is recommended as below:

<table>
<tr><td colspan="2">Rated power</td><td colspan="2">5 MVA</td></tr>
<tr><td colspan="2">Rated frequency</td><td colspan="2">50 Hz</td></tr>
<tr><td colspan="2">Rated voltage ratio</td><td colspan="2">11/11+2 × 2.5 % kV</td></tr>
<tr><td colspan="2">Shor circuit impedance</td><td colspan="2">About 7.0 %</td></tr>
<tr><td colspan="2">Rated insulation level</td><td>Primary side</td><td>Secondary side</td></tr>
<tr><td>(a)</td><td>Rated short-duration power-frequency withstand voltage (r.m.s. values)</td><td>28 kV</td><td>28 kV</td></tr>
<tr><td>(b)</td><td>Rated lightning impulse withstand voltage (peak value)</td><td>75 kV</td><td>75 kV</td></tr>
</table>

(7) Station Service Transformer

Two (2) units of the station service transformer to supply the power to the station installed in outdoor shall be replaced due to serious oil leakage and the aged deterioration.

1) Type and cooling method

The new station service transformer shall be of three-phase, indoor-installation, encapsulated-winding, cast-resin mold, dry type power transformer to be housed in an 11 kV switchgear.

2) Rating

The rating of the new station service transformer kV transformer after rehabilitation is recommended as below:

Rated power	500 kVA
Rated frequency	50 Hz
Rated voltage ratio	11/400 kV
Shor circuit impedance	About 5.0 %

Rated insulation level		Primary side	Secondary side
(a)	Rated short-duration power-frequency withstand voltage (r.m.s. values)	28 kV	3.6 kV
(b)	Rated lightning impulse withstand voltage (peak value)	75 kV	8 kV

(8) EDG

The existing EDG shall be replaced due to the aged deterioration. As new diesel generator set, one (1) 300 kVA emergency diesel engine generator set complete with the necessary switchgear and accessories shall be installed to supply emergency electric power for operation of auxiliary equipment for black-starting the main generator unit. The diesel engine generator set shall be installed in the diesel generator house located near the power plant.

Desirable specification of new generator is mentioned as below:

- ✧ Duty type — Continuous running duty
- ✧ Rated output — 300 kVA
- ✧ Rated voltage — 400/230 V of three-phase four-wire system
- ✧ Rated frequency — 50 Hz
- ✧ Rated power factor — 0.8 lagging

(9) Plant DC Battery Bank

Two (2) sets of the existing storage batteries shall be replaced. The new batteries shall be located at the same places as the existing ones.

Lead acid, valve-regulated type is recommended as the new storage batteries. Each battery set shall have a capacity of 300 ampere-hour at 10-hour discharge rate.

The new storage batteries shall be provided with steel or wooden racks of acid proof type.

(10) DC Battery Chargers

Two (2) sets of DC battery charger shall be replaced. The DC battery chargers are of rectifier, floor standing, metal-enclosure type.

The rating of rectifier is mentioned as below:

- ✧ Rated output voltage — 230 V
- ✧ Rated output current — 100 A
- ✧ Rated input voltage — 400 V
- ✧ Charging mode — Floating/Equalizing

(11) 400V House Service Equipment

400V house service equipment after rehabilitation shall be of indoor type and self-supporting metal-enclosed panel.

The following switchgear and equipment will be mounted in the LV switchgear cubicle:

1) Station-service transformer circuit 1

(a) Twenty (20) pieces of MCCBs

2) Station-service transformer circuit 2

(a) Twenty (20) pieces of MCCBs

3) Diesel generator circuit

(a) One (1) ACB
(b) Three (3) measuring current transformers
(c) Three (3) measuring voltage transformers
(d) One (1) Watt-hour meter
(e) One (1) set of power cable terminals for 400 V power cable connection to the EDG

4) Station service transformer circuit 1

(a) One (1) ACB
(b) Three (3) measuring current transformers
(c) Three (3) measuring voltage transformers
(d) One (1) Watt-hour meter
(e) One (1) set of power cable terminals for 400 V power cable connection to the station service transformer No.1

5) Bus tie circuit

(a) One (1) ACB
(b) Six (6) measuring voltage transformers

6) Powerhouse service transformer circuit 2

(a) One (1) ACB
(b) Three (3) measuring current transformers
(c) Three (3) measuring voltage transformers
(d) One (1) Watt-hour meter
(e) One (1) set of power cable terminals for 400 V power cable connection to the station service transformer No.2

7) Station service transformer circuit 3

(b) Twenty (20) pieces of MCCBs

8) Station service transformer circuit 4

(a) Twenty (20) pieces of MCCBs

(12) Transmission Line Protection Panel

The transmission line panels in Sedawgyi HPP shall be replaced due to the reason as mentioned in Section 7.2.2 (13). The new transmission line panels shall be of floor-standing, metal-enclosure type. And also, the following protection replays shall be equipped at the transmission line protection panel in order to match the standard concept for T/L protection in Myanmar.

✧ Distance Relay (21) Main Protection
✧ Over current/ground fault relay(50/51N) Back-up protection