3. 現地セミナー資料

Data Collection Survey on Southern African Power Pool

Power Engineering Seminar

Japanese technologies for integrating African power systems

2016/10/6 @ Harare

10/10 @ Pretoria

Energy for a New Era

Motive of JICA Survey

In Southern Africa, the development potential of countries which have natural resources such as hydropower, natural gas, coal, etc., has not been sufficiently realized, and the region has problems that are yet to be resolved, such as planned power outages implemented even in the Republic of South Africa whose power demand accounts for the majority of total power demand in the region. Also, most of the countries in the region except the Republic of South Africa need to prepare a practical plan for the development of electric power resources to supply electric power to areas of their own country that have not yet been electrified.

To address these issues, organizations such as the Southern African Development Community (SADC), the Southern African Power Pool (SAPP), and its member countries have prepared an energy master plan, and many donors such as the World Bank (WB), the United States Agency for International Development (USAID), the African Development Bank (ADB), etc. have provided cooperation to promote the master plan. However, the project has been delayed due to several constraints, such as shortage of funds for respective power development projects. In order to improve this situation, utilization of funding and technology from Japan have been increasingly desired in the region.

Motive of JICA Survey – Contd.


S A P P
Southern African Power Pool
Energising the region for economic development
MONTHLY REPORT
June 2016
Issue No. R06-16

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Meetings, Workshops and Conferences

SADC Ministerial Workshop of Energy & Water Crisis

SADC Ministerial Workshop on Water and Energy was held on 20 June 2016 in Gaborone, Botswana. SADC Ministers responsible for water and energy agreed to forge closer regional collaboration in promoting water and energy security, rather than addressing solutions mainly at national level. They emphasized on the need for the region to accelerate the implementation of priority energy and water infrastructure projects in the SADC Regional Infrastructure Development Master Plan (RIDMP). The RIDMP Energy Sector Plan has identified 73 power projects that will increase generation capacity from the current 56,000 MW and ensure that the projected demand of 96,000MW is surpassed by 2027. The Water Sector Plan contains a total of 34 infrastructure projects aimed at improving access to water in the region. Ministers called on the SAPP to ensure that all countries are fully connected to the regional power grid so that countries can share surplus power across borders. Member States were encouraged to exploit renewable energy sources, which are abundant in the region. However, for this to happen, there is need for innovation in the mobilization of financial resources.

The Ministers responsible for Energy in Zimbabwe and Mozambique took the opportunity to sign the Inter-Governmental Memorandum of Understanding (IGMOU) for the Mozambique-Zimbabwe-South Africa (MOZISA) transmission Interconnection project.

Seated from left: Hon Ministers Responsible for Energy in Mozambique (Hon. Minister Pedro Conceição Couto) and Zimbabwe (Hon. Minister Samuel Undenge) signing the MOZISA IGMOU during the SADC Energy Ministers Meeting in Gaborone, Botswana.

Human Resources Working Group Meeting

The SAPP Human Resources Working Group (HRWG) met in Windhoek, Namibia from the 20th to the 21st of June 2016. The Working Group reviewed the Human Resources Policies of the Coordination Centre.

SADC Ministerial Workshop of Energy & Water Crisis

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TICAD – Tokyo International Conference on African Development
Sustainable cooperation to take standpoint of African.

http://www.mofa.go.jp/region/africa/ticad/index.html

Every meeting is led by Japan, and co-organised by the United Nations, United Nations Development Programme(UNDP), the World Bank and the African Union Commission (AUC). In principle, invitations to attend TICAD are extended to all African heads of state and government, as well as international organisations, donor countries, private companies and civil society organizations. Until TICAD V, the summit-level meetings were held every five years in Japan. From 2016 onwards, the TICAD will be held every three years, hosted alternately in Africa and Japan. In response to the request from the African side, we have decided to hold TICAD VI in Africa (Kenya) and in 27-28 Aug it was held.

http://www.mofa.go.jp/afr/af2/page3e_000453.html

TICAD VI Ministerial Meeting
(Photo: TICAD VI)
(Photo: Cabinet Public Relations Office)

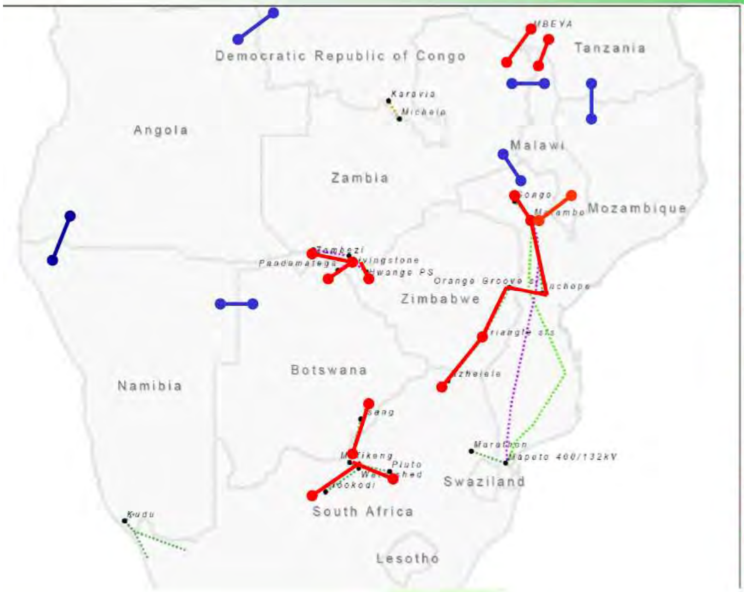
Summary of the Survey

Gathering the data for analyzing each plan

Country	Document	Remarks
Angola	Angola Energia 2025 - Ministterio da Energia e Aguas(2015)-MINEA	Policy
Botswana	Electricity Supply Industry in Botswana, Power Supply and Demand in Southern Africa(2013)-BPC	Hand out @ Conference
DR Congo	Nil	
Lesotho	Nil	
Malawi	Nil	
Mozambique	Master Plan Update Project, 2012-2027 Final Master Plan Update Report(2013)-EDM	
Namibia	National Integrated Resource Plan(2011)-ECB	
RSA	-Transmission Development Plan 2015-2026(2015)-Eskom -Integrated Resource Plan for Electricity 2010-2030 Update Report 2013(2013)-DoE	New IRP underway
Swaziland	Nil	
Tanzania	Power System Master Plan 2012 Update(2013)-MoEM	JICA Study underway
Zambia	JICA Study "Power system"	
Zimbabwe	System Development Plan(2015)-ZETDC	
SAPP	SAPP Pool Plan(2009)-SAPP	

Transmission Projects – to energize power trade

Planned Transmission Projects



Feasibility Stage / Project Preparation

1. ZTK
2. ZIZABONA
3. Moz-Malawi
4. MOZISA
5. BOSA
6. ANNA
7. Mal –Tanzania
8. STE

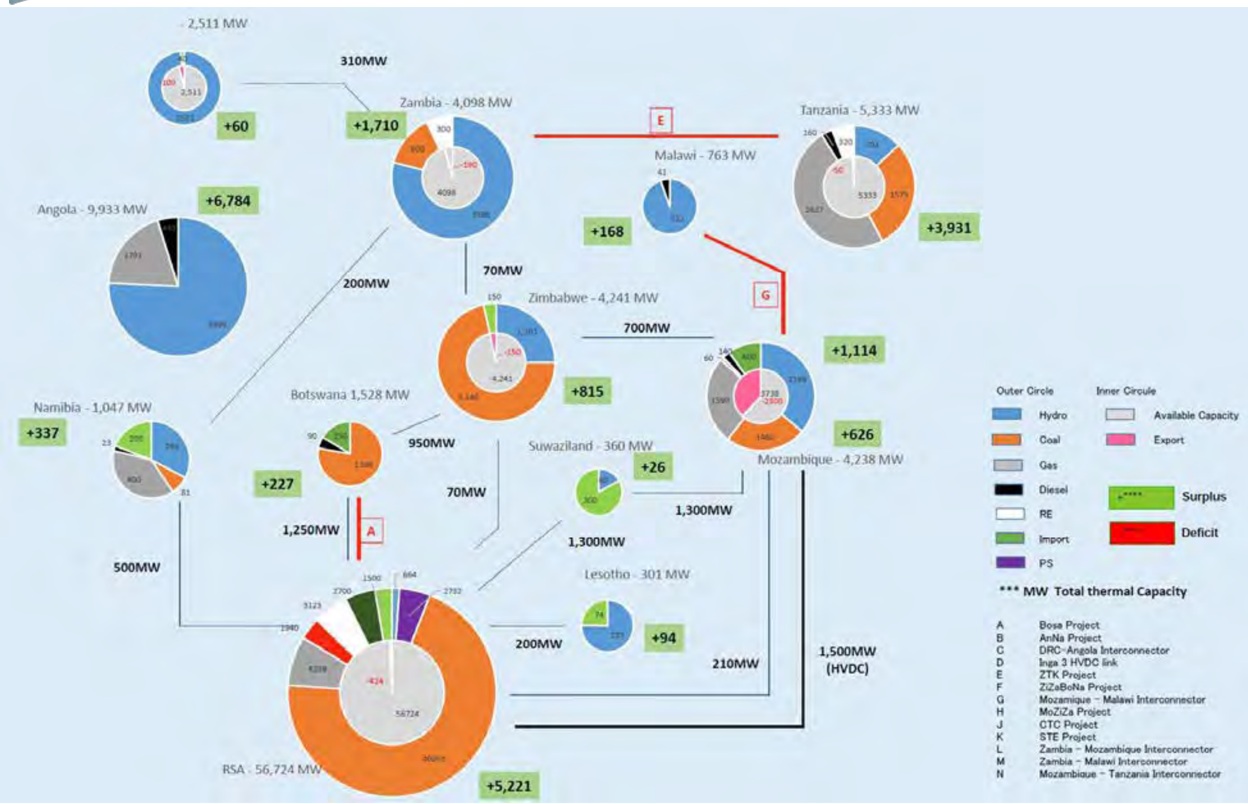
Pre-Feasibility Stage

1. Botsw - Nam
2. Zambia-Malawi
3. Zambia - Moz
4. Moz-Tanzania
5. DRC - Angola

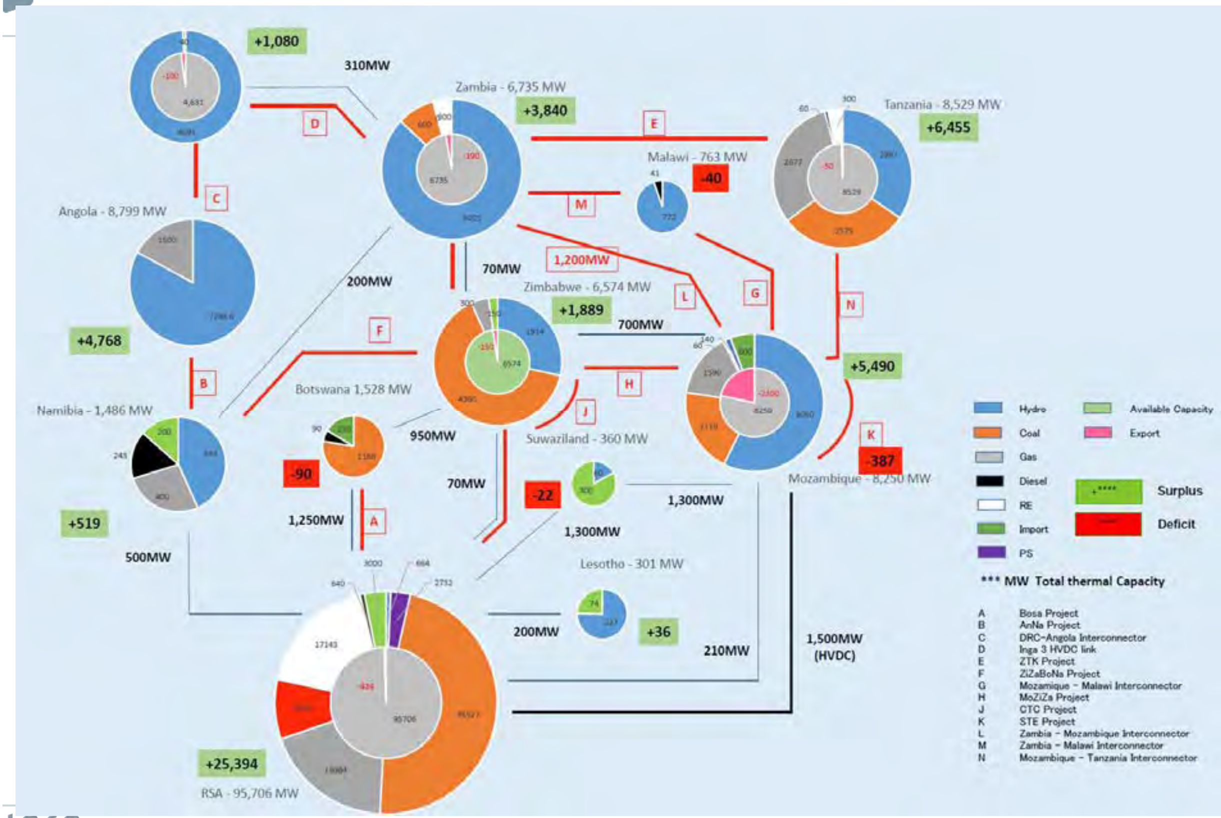
SOUTHERN AFRICAN POWER POOL

Source : SAPP C.C.

D-S Balance (Capacity base - 2020)



D-S Balance (Capacity base - 2030)



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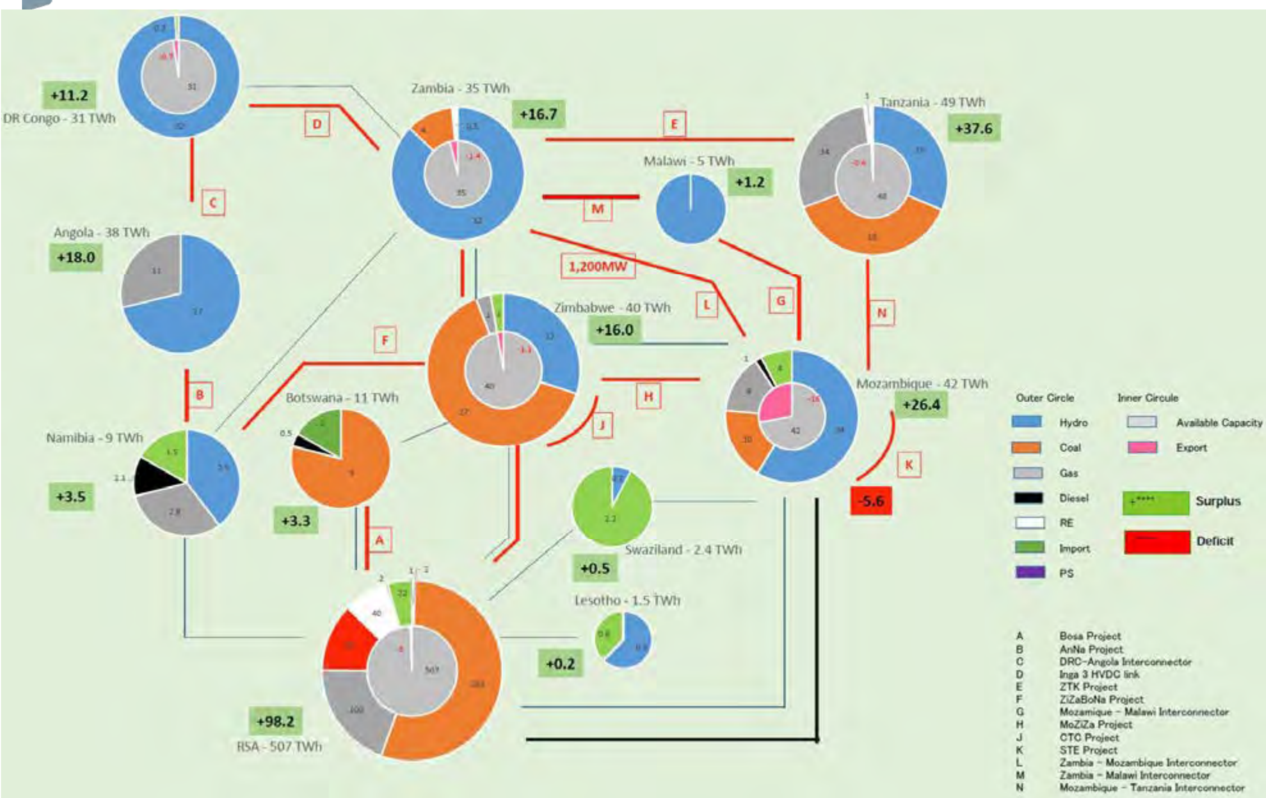
D-S Balance (Energy base - 2030)



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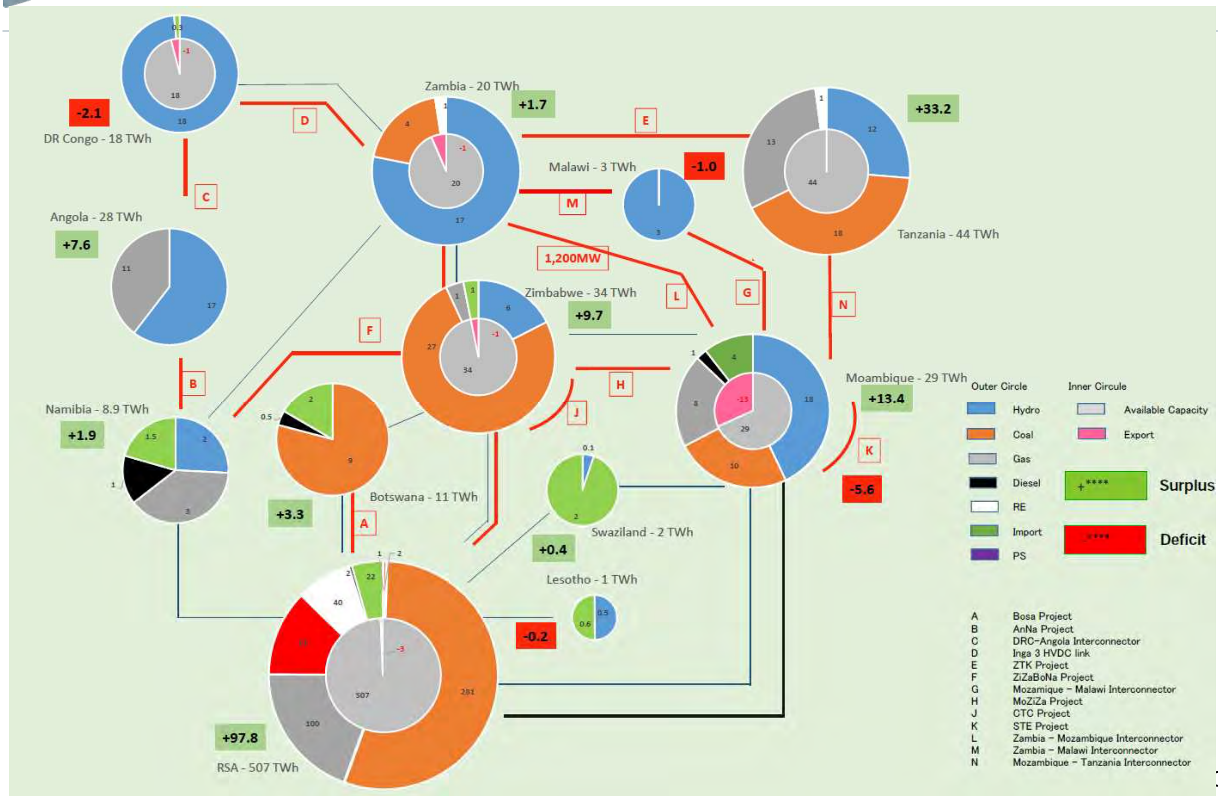
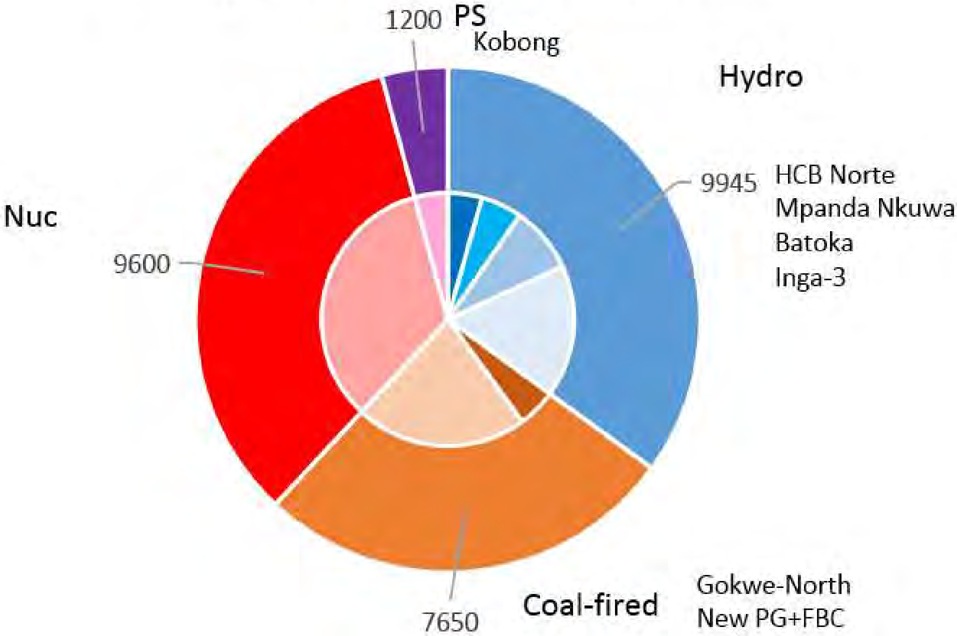
D-S Balance (cf. Energy base<drought> - 2030)



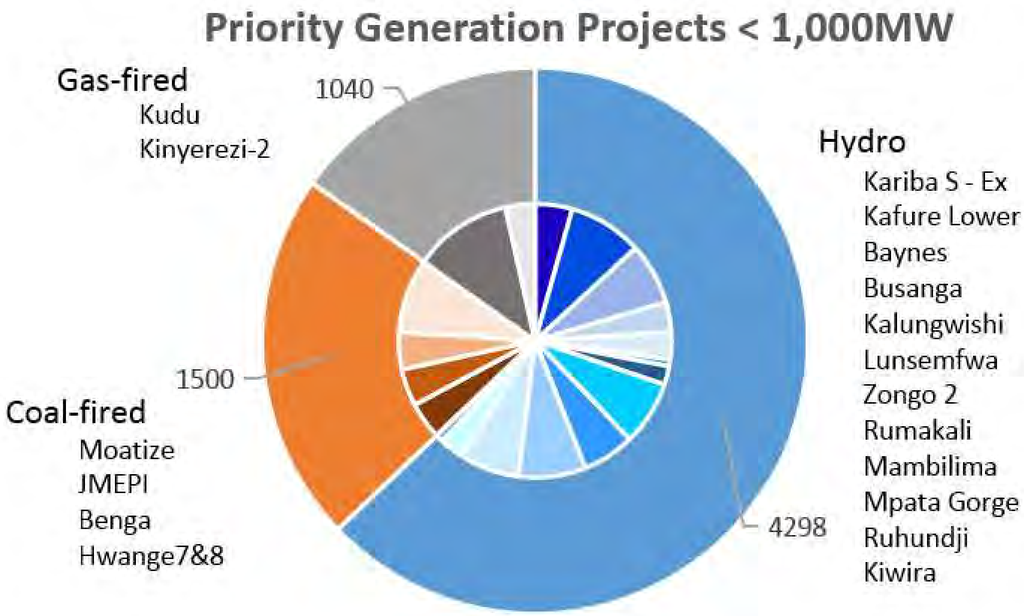
on

SAPP Priority Projects

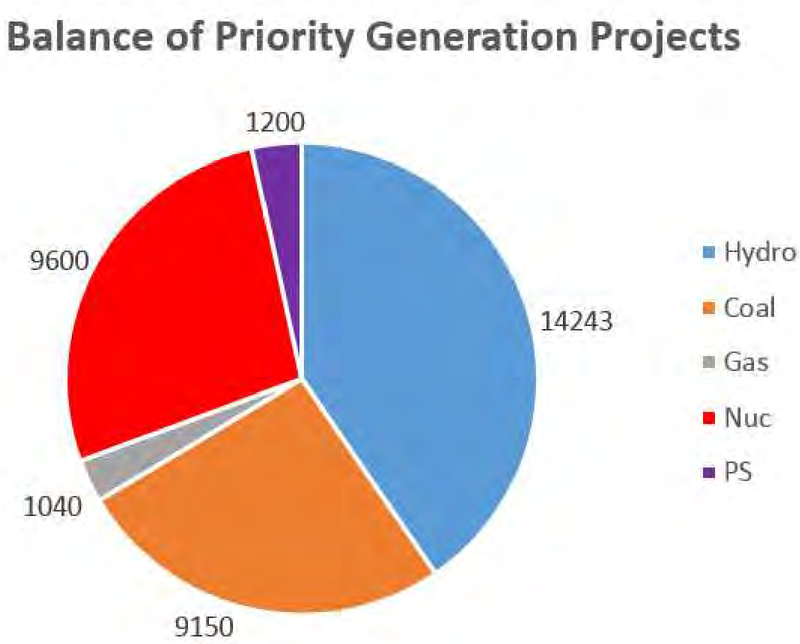
Priority Geeration Projects >1,000MW



SAPP Priority Projects



Priority to develop the power pool…



Issues to create the better power system

Keys.....

・High reliability in consideration with Total cost (CAPEX and OPEX)

・High efficiency generating the power including environmental constrains

・Easy to operate and assist operators with their knowledge

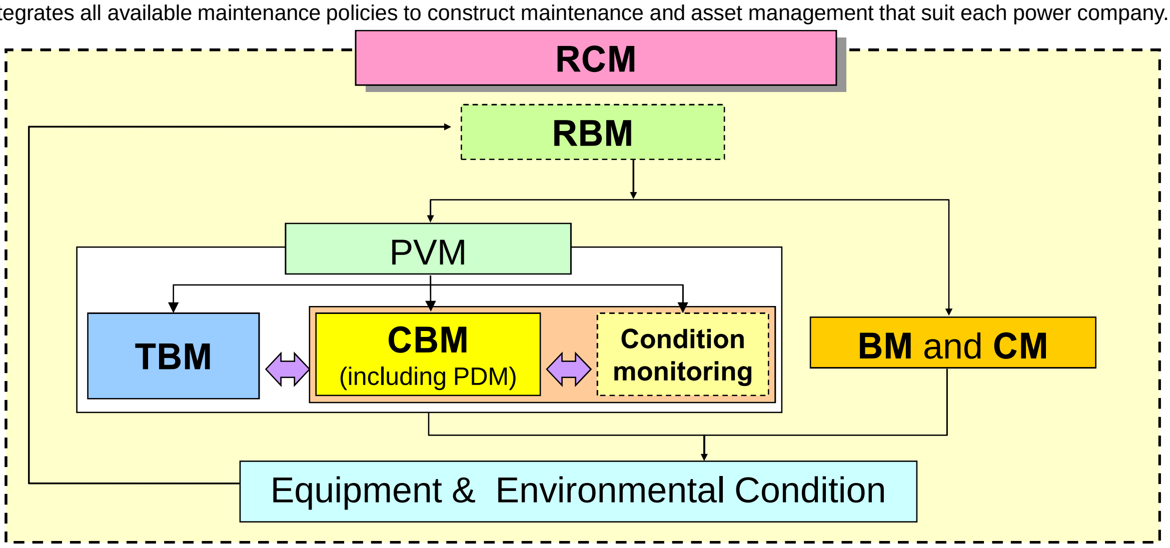
・Measures to prevent the occurrences of critical disturbances

Japanese Technologies collaborated with operations

Session 1: Operations and maintenance

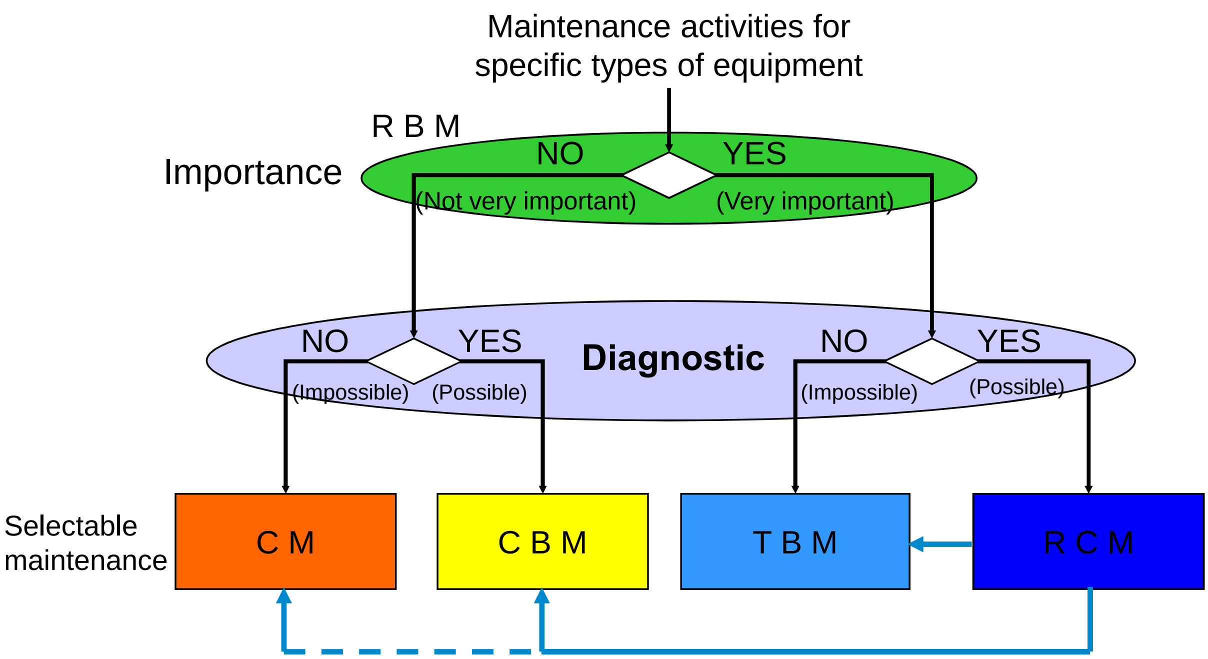
Reliability Centered Maintenance

RCM is a concept that
integrates all available maintenance policies to construct maintenance and asset management that suit each power company.



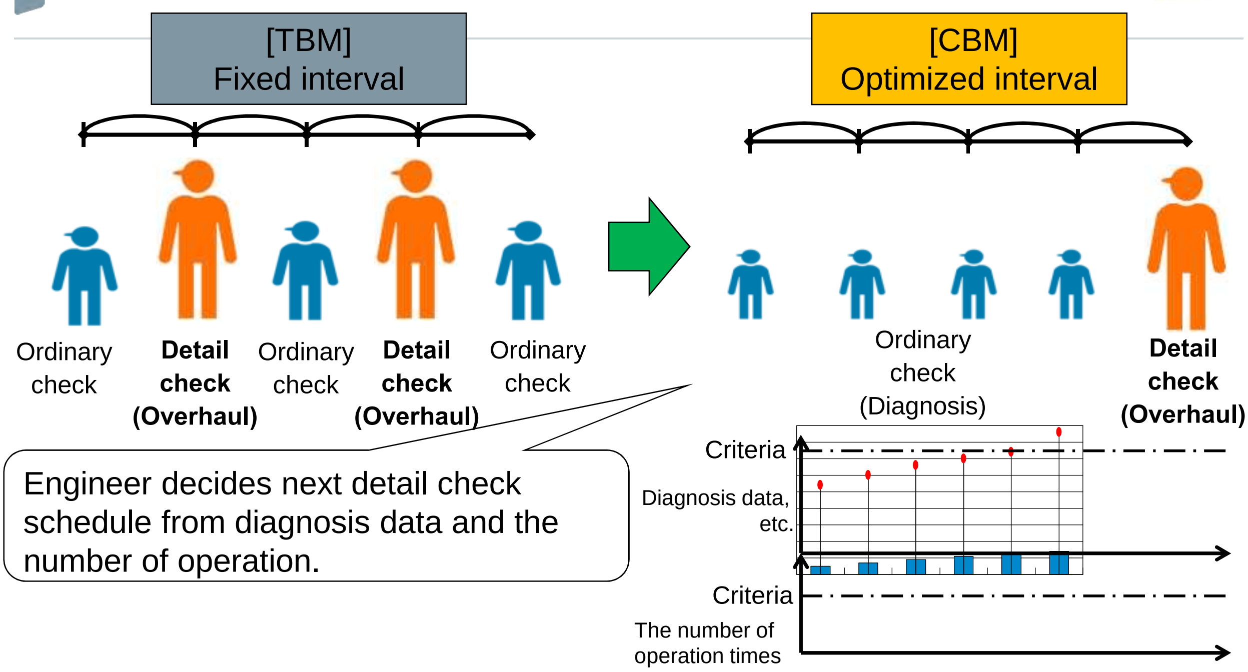
RCM: Reliability Centered Maintenance, RBM: Risk Based Management
PVM: Preventive Maintenance, CM : Corrective Maintenance
TBM: Time Based Maintenance, CBM: Condition Based Maintenance
PDM: Predictive Maintenance, BM : Breakdown Maintenance

Maintenance strategies



TBM to CBM

Change from TBM to CBM



/ Criteria and frequency are different on each equipment.
/ Criteria depends on various factors.
e.g. manufacturer manual, experience, research results

TBM to CBM

Condition Based Maintenance (CBM)

External Diagnosis

↓

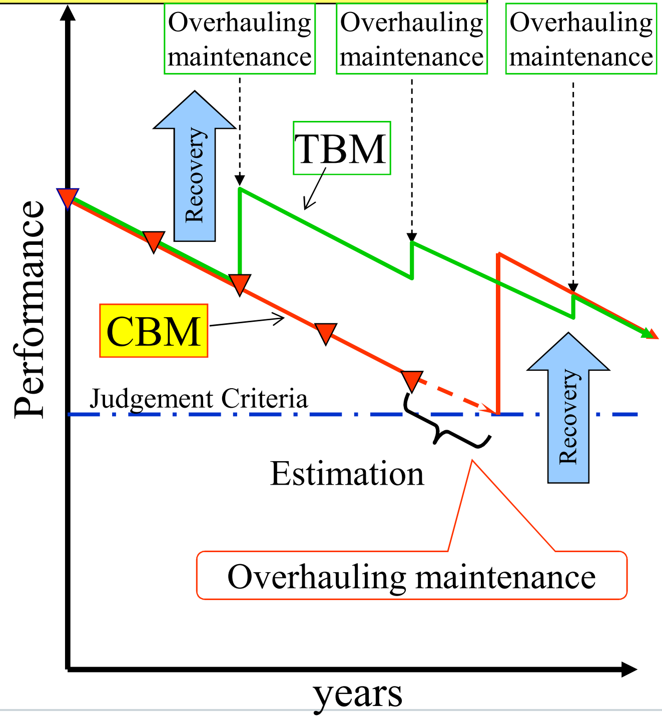
Diagnosis Data
Operation Data

↓

Trend of Condition

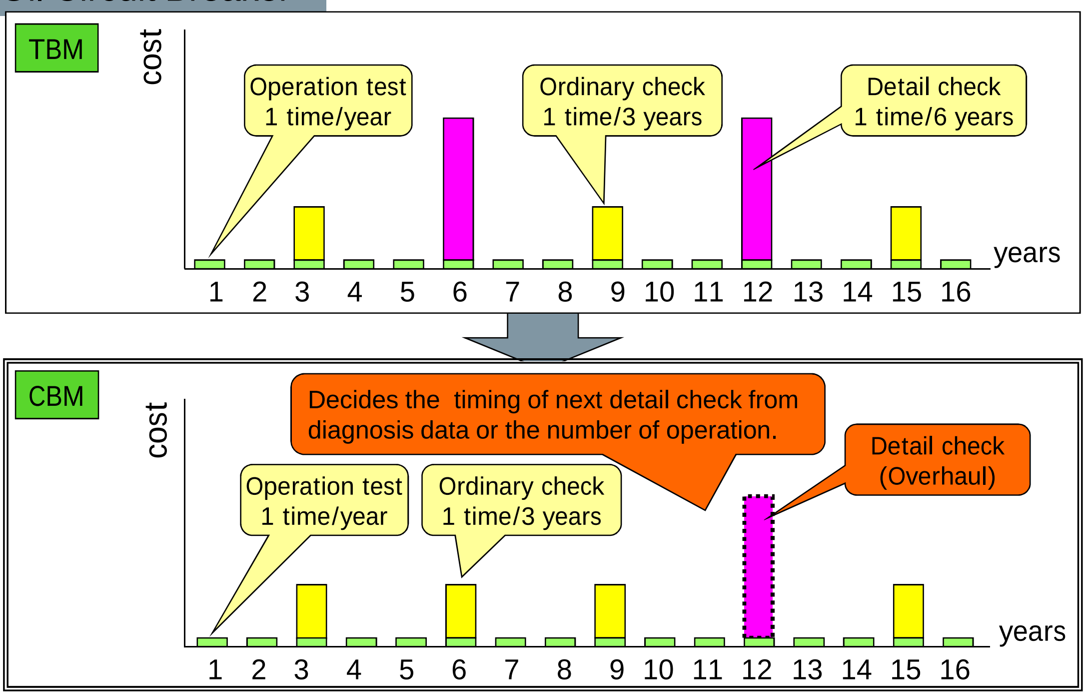
↓

Decision of Overhauling maintenance



Cultivation in thinking power, knowledge

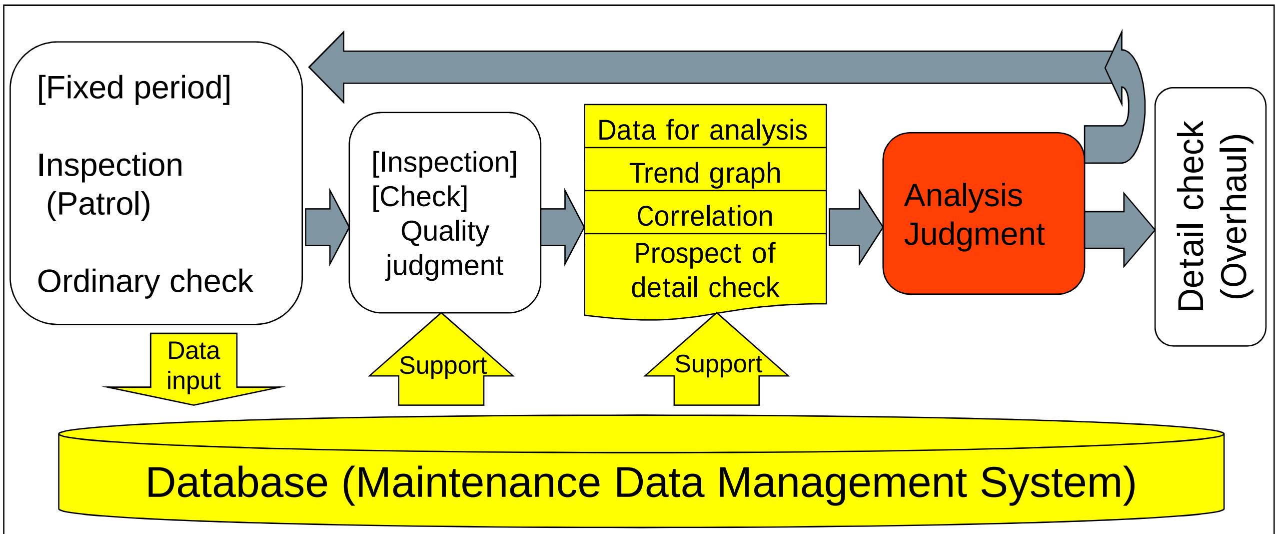
ex. Oil Circuit Breaker



CBM is able to reduce the maintenance cost.

Succession of knowledge for O & M

Maintenance Data Management



In order to realize CBM, we need to store the inspection and check data into database.
Therefore we established Maintenance Data Management System in 2001.

Example

Work item		Contents
Visual inspection on overall substation		Checking of terminal heating Checking of sound and smell Checking of fence breakage (for invader prevention) Checking of surroundings
Visual inspection specified to individual equipment	Transformer OCB	Checking of oil level Checking for oil leakage etc..
	GIS / GCB	Checking of open/close status Checking of gas pressure Checking of driving oil pressure and leakage etc...
	VCB (indoor)	Checking of open/close status Checking of sound at connection points, etc...

One of the important work contents is the checking of terminal heating.
For checking the terminal heating, “thermo-indication sticker” is useful.

Gathering information

Checking overhead line termination

Patrol of GIS

Recording temperature and humidity (Outside)

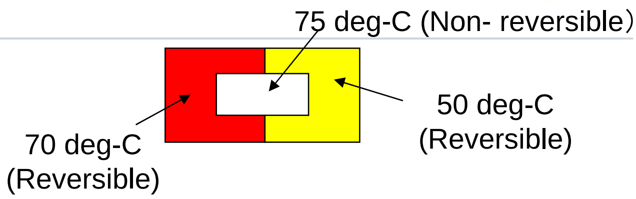
Checking inside box

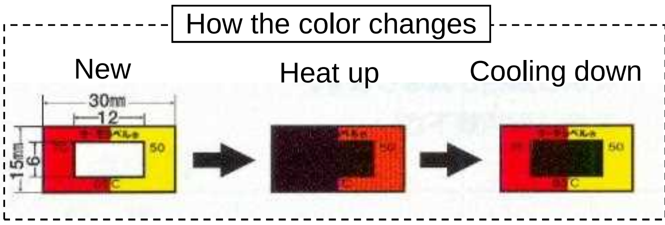
Checking and recording counter, pressure, etc.

Thermo-Indication Sticker

The thermo-indication sticker is a cost-effective method to roughly confirm the peak temperature and local heat history.

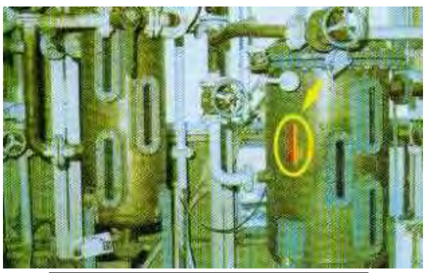
CHUBU widely applies this method to check the temperature condition during inspection.





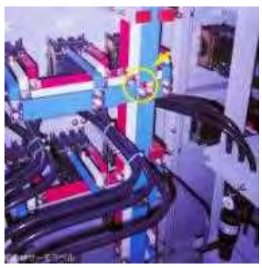
(Source: Website of NiGK Corporation)

Example



Oil Chamber

Overhead line termination



Control switching board

1. Transmission Facilities

GIS (Gas Insulated Switchgear)

Definition of "Reliability"

MaF (Major Failure) :
failure of switchgear and controlgear which causes the cessation of one or more of its fundamental functions. A major failure will result in an immediate change in the system operating conditions, for example, the backup protective equipment will be required to remove the fault or will result in mandatory removal from service within 30 min. for unscheduled maintenance.

MiF (Minor Failure) :
any failure of a constructional element or a subassembly which dose not cause a major failure of the switchgear and control gear.

- IEC 62271-1

GIS (Gas Insulated Switchgear)

Cigre Worldwide Survey All 29 Countries

Table 5-71: Distribution of major failure frequency in seven intervals of GIS manufacturing years - all data (absolute values within individual voltage classes)

MaF frequency [MaF/100 CB-bay-years] – all data		Voltage class [kV]						
		60≤U <100 kV	100≤U <200 kV	200≤U <300 kV	300≤U <500 kV	500≤U <700 kV	≥700 kV	Total
Period of manufacture	before 1979	0,51	1,98	0,14	4,05	0,00	0	0,89
	1979-1983	0,39	1,29	0,14	1,99	1,39	0	0,79
	1984-1988	0,50	0,64	0,13	1,36	0,00	2,08	0,57
	1989-1993	0,27	0,11	0,49	0,61	0,39	0	0,30
	1994-1998	0,20	0,13	0,46	0,34	0,58	0	0,23
	1999-2003	0,08	0,08	0,40	0,31	0,19	0,00	0,13
	2004-2007	0,40	0,33	0,22	0,58	0,00	0,00	0,36
	Total	0,31	0,24	0,33	0,88	0,50	1,18	0,37

MaF Frequency = **0.37 MaF / 100CB-bay-years**

Survey : 2008 - 2014

MaF frequency [MaF/100 CB-bay-years]		Voltage class [kV]			
		60≤U <200 kV	200≤U <500 kV	≥500 kV	Total
Period of manufacture	Before 1979	0.001	0	0.001	**0.002**
	1980-1989	0.004	0.007	0.001	**0.012**
	1990-1999	0.005	0.001	0.001	**0.007**
	2000-2009	0.007	0.008	0.006	**0.021**
	2010-	0.002	0.002	0.002	**0.007**
	Total	**0.019**	**0.019**	**0.012**	**0.050**

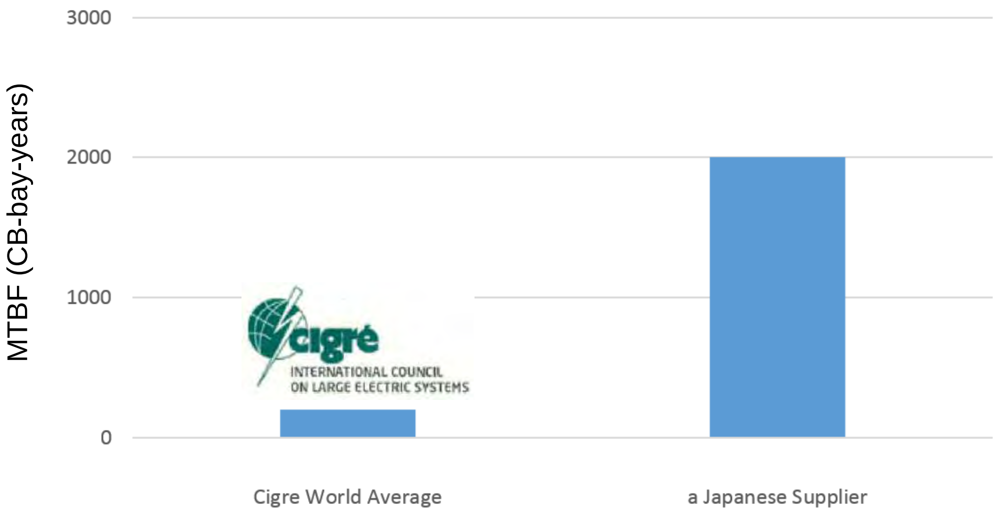
MaF Frequency = **0.050 MaF / 100CB-bay-years**

Source : Cigre Technical Brochure No.513 "Final Report of the 2004-2007 International Enquiry on Reliability of High Voltage Equipment"(2012)
Mitsubishi Electric Corporation.

GIS (Gas Insulated Switchgear)

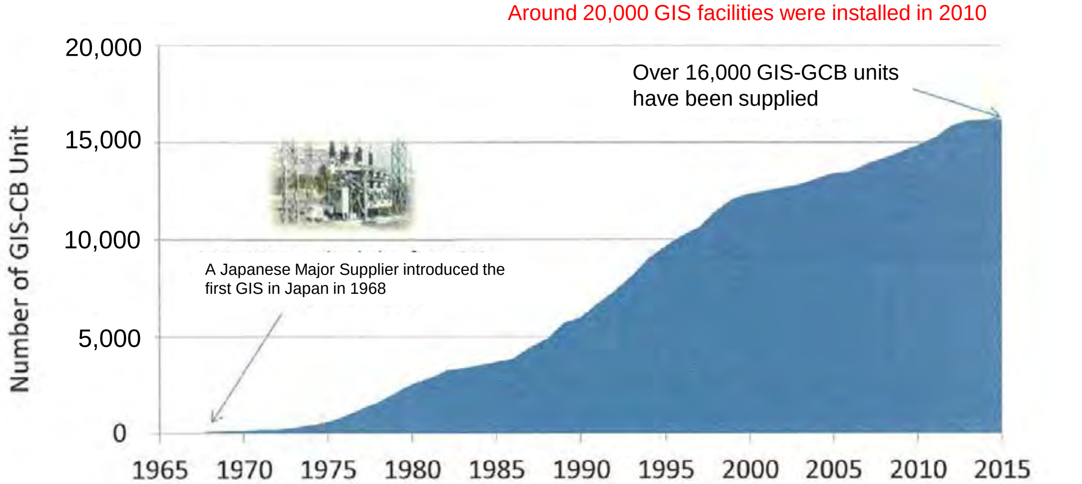
$$\text{MTBF(Mean Time Between Failure)} = \frac{1}{\text{MaF Frequeny}}$$

MTBF : Gigre Averrage vs. a Japanese Supplier



Source : Cigre Technical Brochure No.513 "Final Report of the 2004-2007 International Enquiry on Reliability of High Voltage Equipment"(2012)
Mitsubishi Electric Corporation.

GIS Substation - Trace of installation



Source : Electric Technology Research Association "Integration of GIS"(2014)
Mitsubishi Electric Corporation.

Japan introduced GIS facilities in 1968, and these are installed mainly at "Outdoor" with tuff durability against severe environmental condition.

For 50 years experience, Japanese technologies of GIS is sure to improve the substation all over the world.

GIS Substation - Japanese technologies in the world

The first GIS in Japan
Himeji 84kV GIS
Kansai Electric Power co.
(Japan)

The world first 550kV Full-GIS
Ohi Nuclear Power Plant (1976)
Kansai Electric Power co.
(Japan)

Chizu 550kV GIS
Chugoku Electric Power co.
(Japan)

Black Point 420kV GIS
CLP Power
(Hong Kong)

550kV Hybrid-GIS (H-GIS)
China Southern Power Grid
(China)

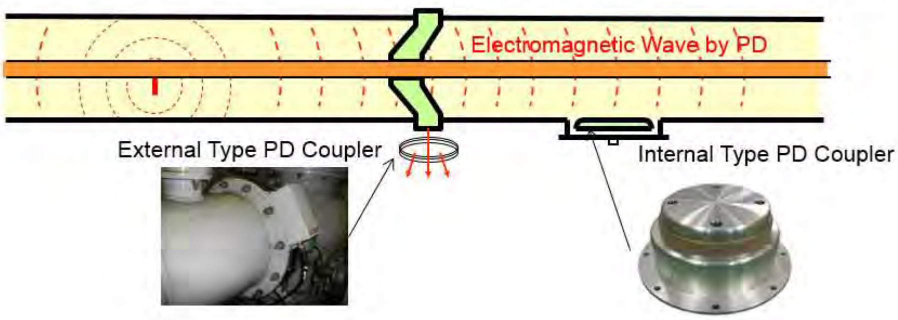
Source : Mitsubishi Electric Corporation.

2. Operation assisting equipment for substation

O & M for GIS - Remote sensing led to IoT

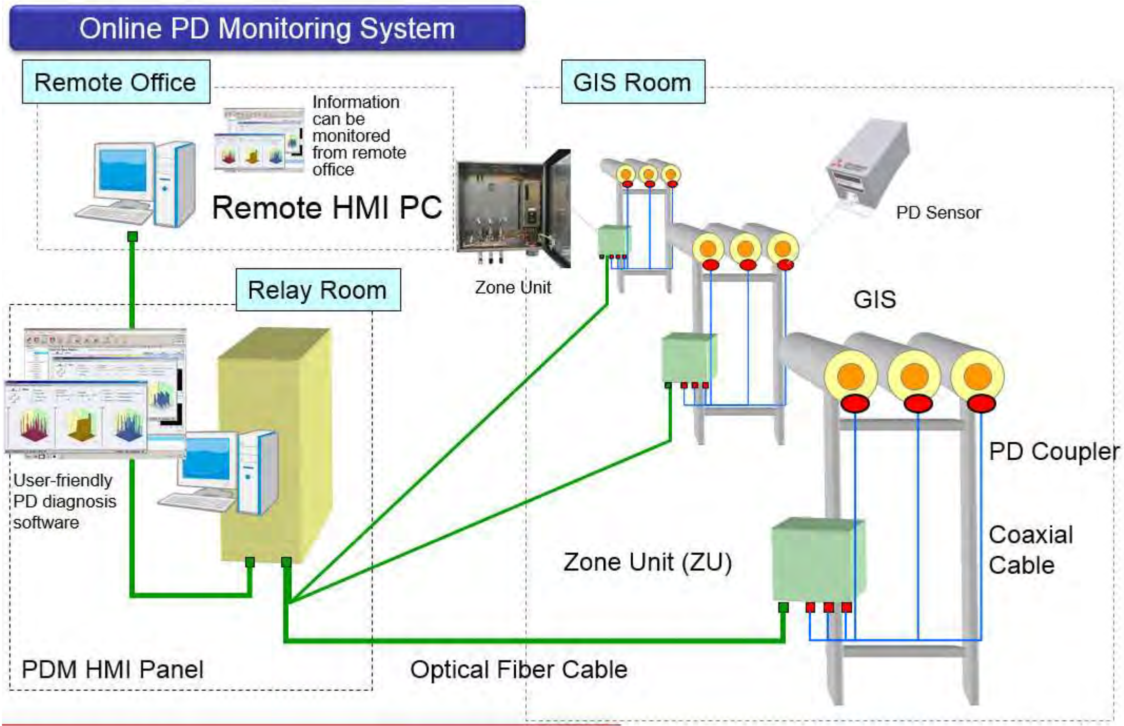
UHF Partial Discharge Sensors & Detection method

	Internal Type	External Type	
		Permanent Type	Portable Type
Appearance			
Sensitivity	0.1pC	0.1pC	0.1pC
Installation	Hand Hole	Spacer	Spacer



Source : Mitsubishi Electric Corporation.

O & M for GIS - Remote sensing led to IoT



Source : Mitsubishi Electric Corporation.

Maintenance for Oil-filled Transformer - Gas monitoring equipment

To keep log life time for Transformer, comprehensive analysis are needed….

Feature of DGA Monitor

- No need oil analysis at laboratory (No consumption of oil)
- Quick detection of abnormal symptom

N-TCG-6CM

Hydran 201Ti(GE)

		N-TCG-6CM	HYDRAN 201Ti (GE)	REMARKS
Detective Gas (Objective range) [Relative sensitivity to H2]	C2H2	O (0.5-500ppm)	× [8%]	-Monitoring TCG(*1) and 6 components gases & moisture. (*1):Total combustible gas -High sensitivity of the C2H2 (Acetylene) for partial discharge. -Very quick response. -Very high reliability. - Automatic operation at preset -HYDRAN report only H2 .
	H2	O (20-2000ppm)	O (0-2000ppm)	
	CH4	O (20-2000ppm)	× [No sensitivity]	
	CO	O (20-2000ppm)	× [18%]	
	C2H4	O (10-2000ppm)	× [1.5%]	
	C2H6	O (20-2000ppm)	× [No sensitivity]	
	TCG	O (20-9999ppm)	×	
Moisture		O (0-1000ppm) (0-100RH%)	×	
Diagnosis of Transformer Condition		O	×	Trend analysis is easily
Measuring Time		45 min (7~8min. Each)	10min(*1) (Response time to 90% of step change)	Hydran detect gas only(*1).

Source : Mitsubishi Electric Corporation.

3. Tips for maintenance of thermal power

Contents

- 1 Periodical Maintenance
- (1) Former Maintenance Method
- (2) Plant Maintenance Optimization
- 2 Thermal Facility Management System
- 3 Plant Performance Management System
- 4 Conclusion

1 Periodical Maintenance

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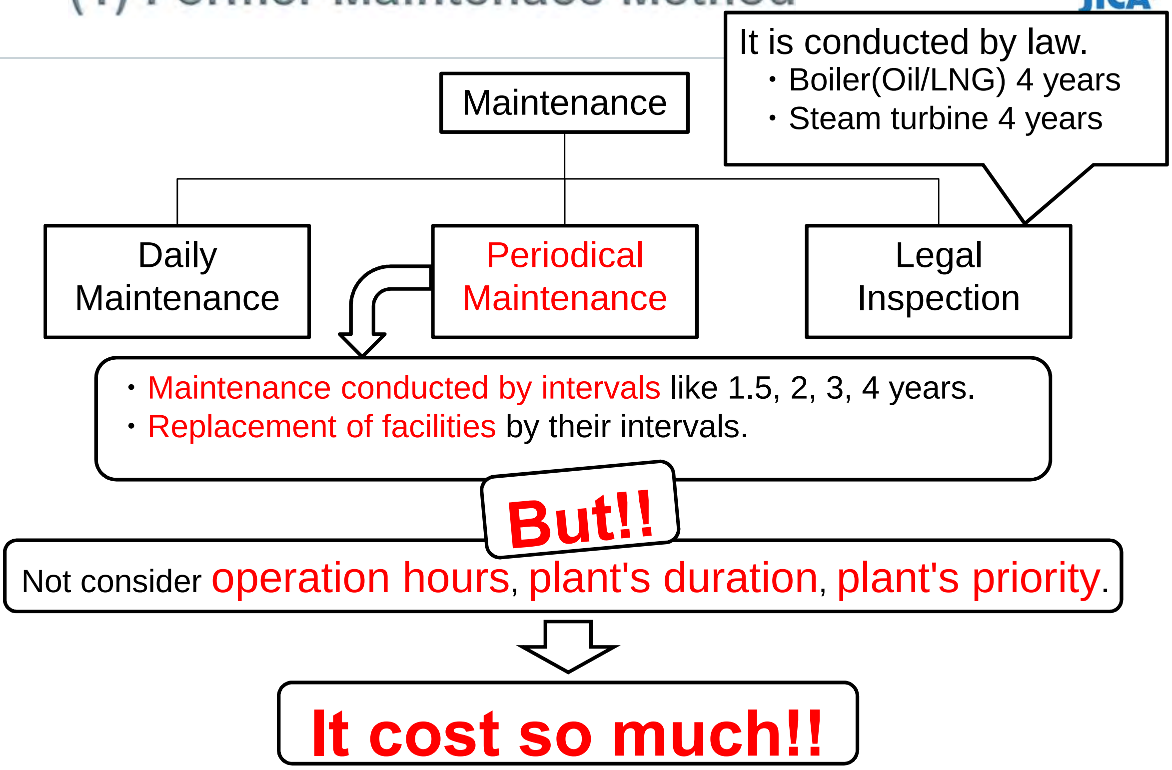
(1) Former Maintenace Method



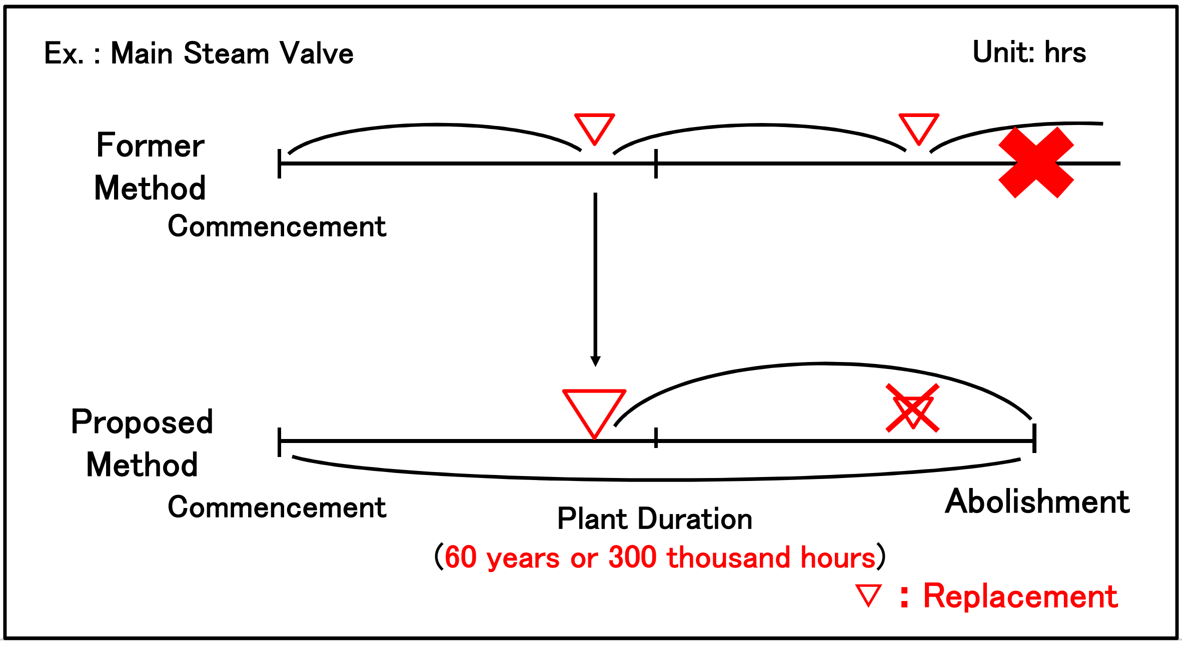
① Determination of Plant's Duration

② Reform Maintenance Method

③ Determination of Plant's Priority

Determination of Plant's Duration

◆Reduction of the Number of Replacement by the Facility's Life Extension



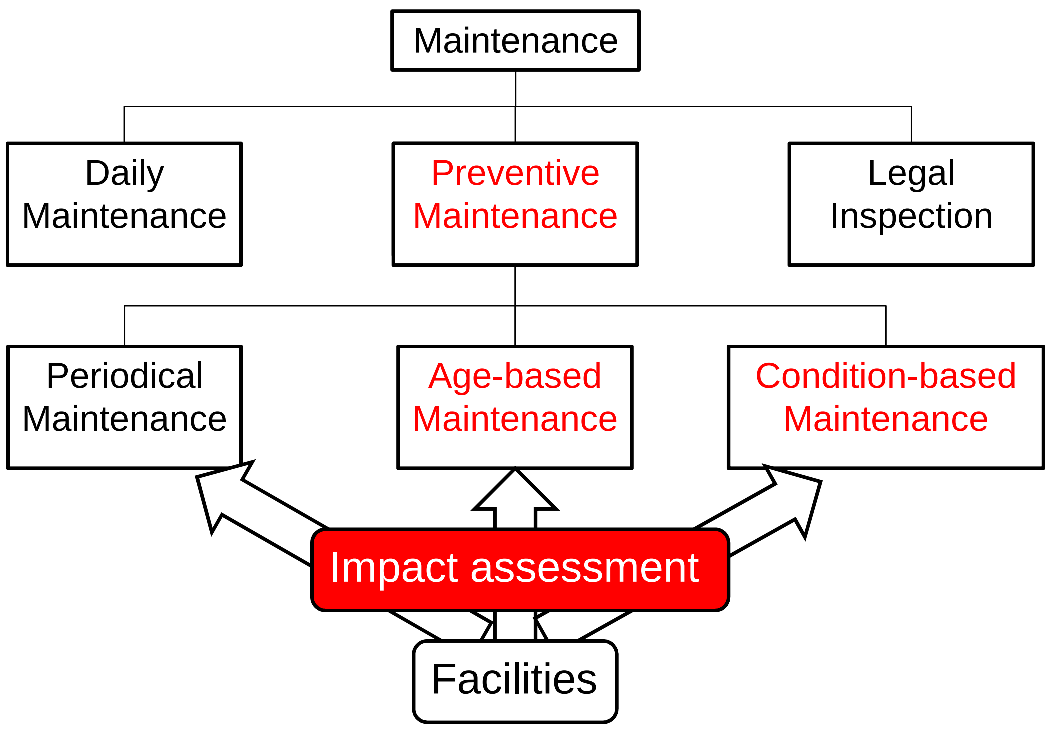
(2) Plant Maintenance Optimization

① Determination of Plant's Duration

② Reform Maintenance Method

③ Determination of Plant's Priority

Reform maintenance method



Preventive Maintenance

◆Periodical Maintenance
- By intervals considering plant's duration, our knowledge, manufacturer's recommendation.

◆Age-based Maintenance
- Based on operation hours, Plant's start- and-stop, plant's duration.

◆Condition-based Maintenance
- Monitoring the state of facilities.
- Symptoms appears, we fix them.

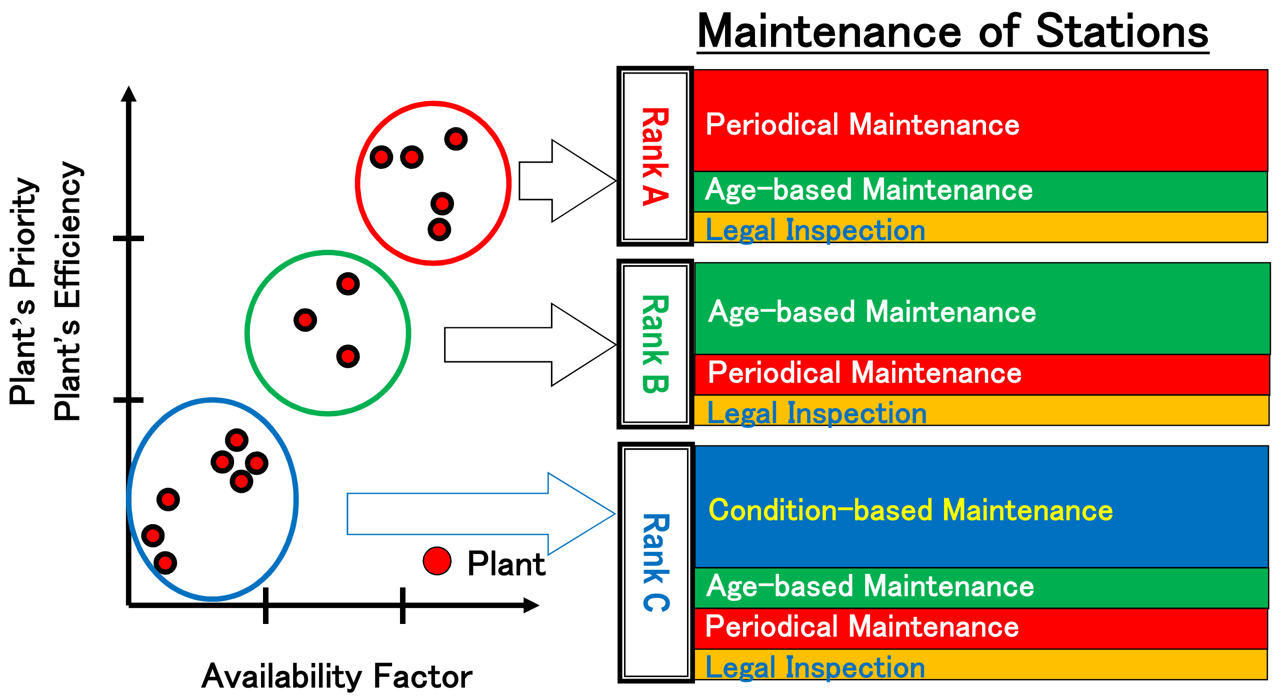
(2) Plant Maintenance Optimization

① Determination of Plant's Duration

② Reform Maintenance Method

③ Determination of Plant's Priority

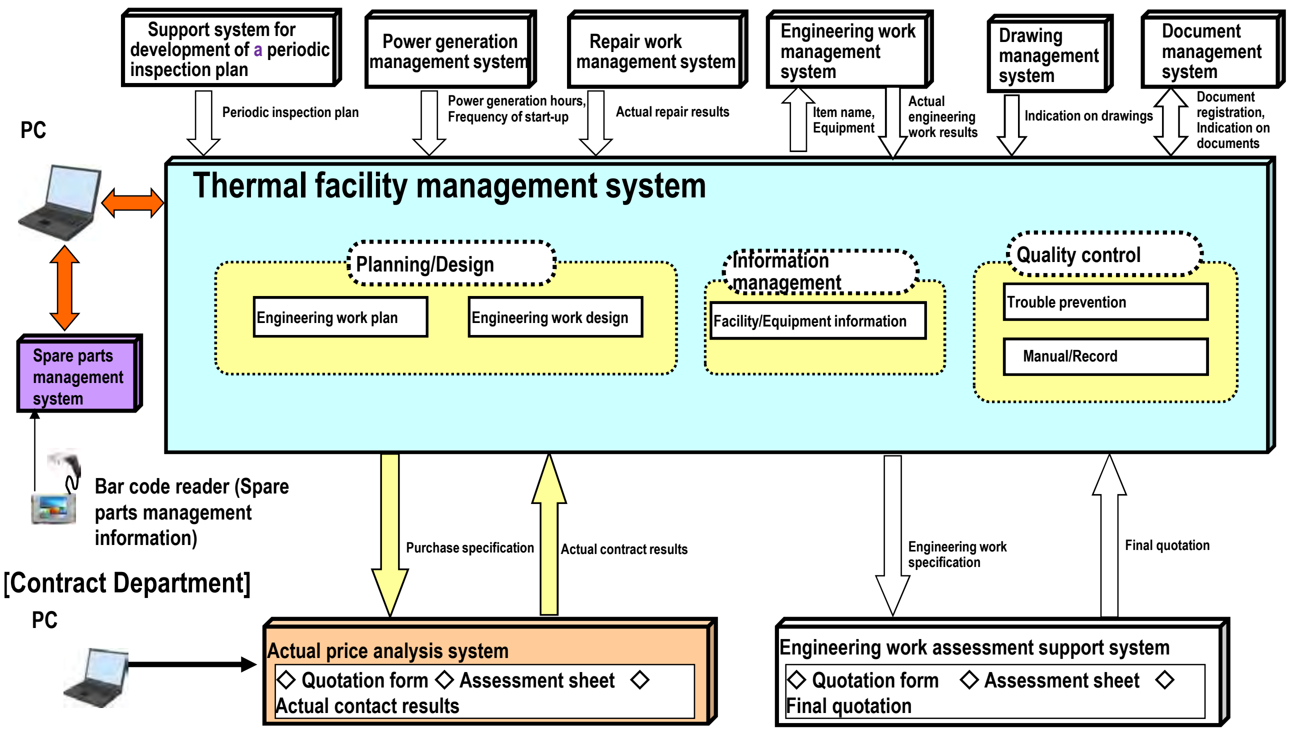
Determination of Plant's Priority



2 Thermal Facility Management System

Thermal Facility Management System

[Maintenance Department]



3 Plant Performance Management System

Plant Performance Management System

The necessity of performance test

Performance gets lowered

Fuel consumption increases

Generating Cost increases

Find any declines in performance → Minimize Loss

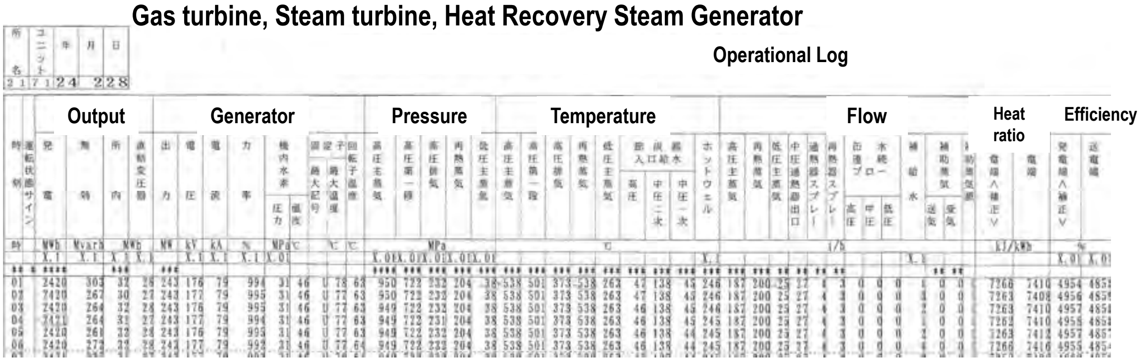
Plant Performance Management System

Daily performance management

Confirm the state of the equipment by a Log sheet.

- Plant Thermal Efficiency, Generator output.
- Operating state for each equipment

Gas turbine, Steam turbine, Heat Recovery Steam Generator



If we confirm the performance decline,

- Plan stopping it for repair (Wash GT compressor with hot water)
- Plan repair simultaneously with periodical inspection

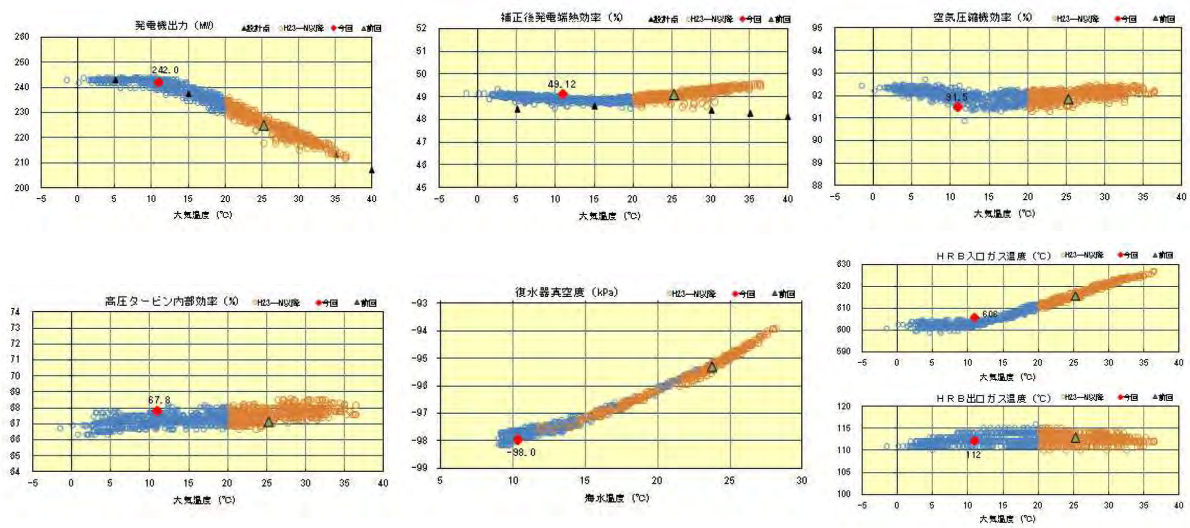
Recover the performance

Plant Performance Management System

Performance test after periodical inspection

Confirm the effects of the works during periodical inspection

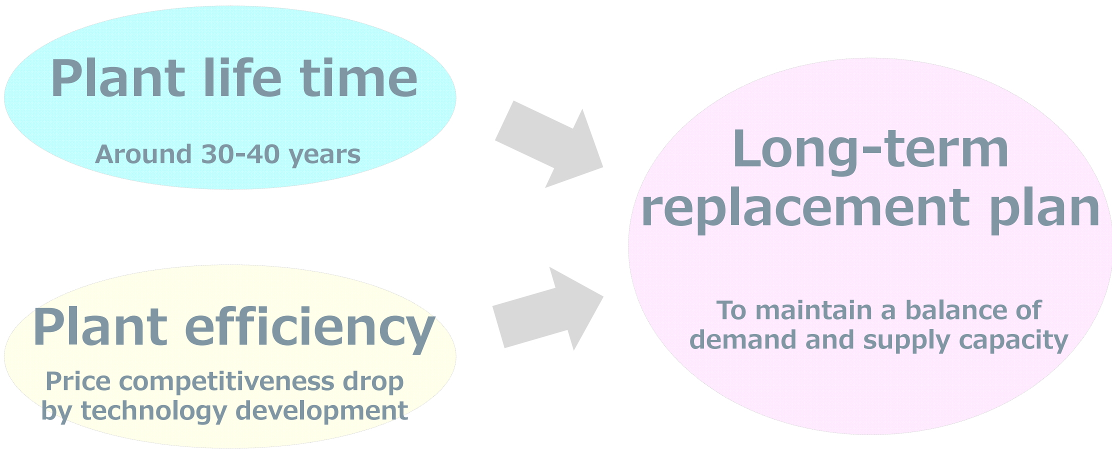
Compare the result with the past one year data.



Session 2: Special technique for construction of thermal power

1. Necessity of Plant Replacement

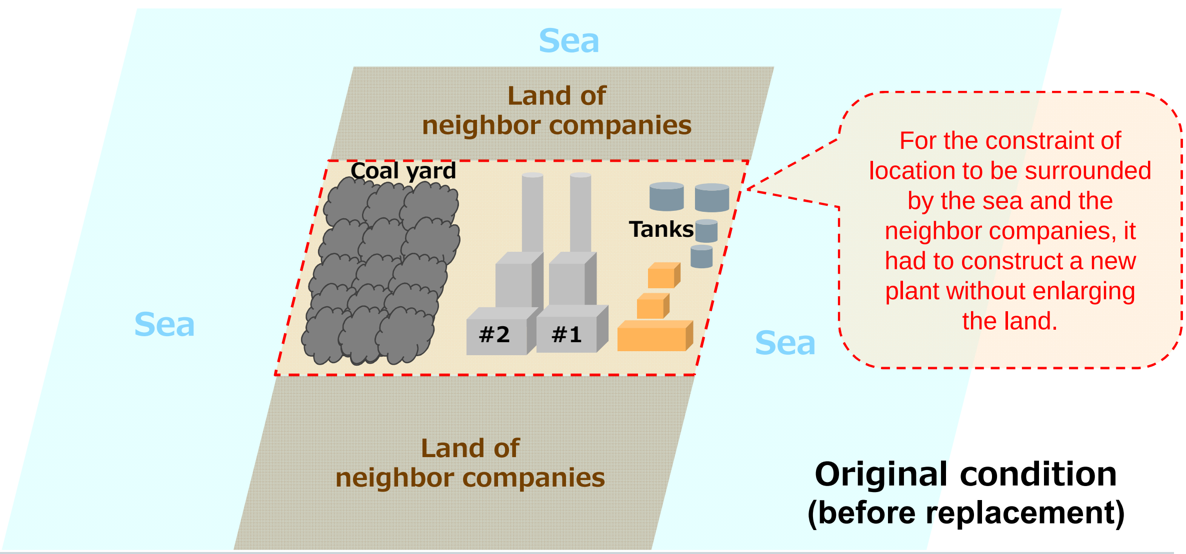
Generally, the life time of thermal power plant is considered to be around 30-40 years. In addition, from the point of view as price competitiveness drop by new technology development (such as plant efficiency improvement), planning the long-term plant replacement is necessary to maintain a balance of the electricity demand and supply capacity.



2. Introduction of Reference Case

Though there are several kind of plant replacement scenarios, especially we would like to introduce one reference case that achieved plant replacement under the following two constraints.

1) To maintain power supply capacity during the construction of a new plant
2) To use only same land area for constructing a new plant

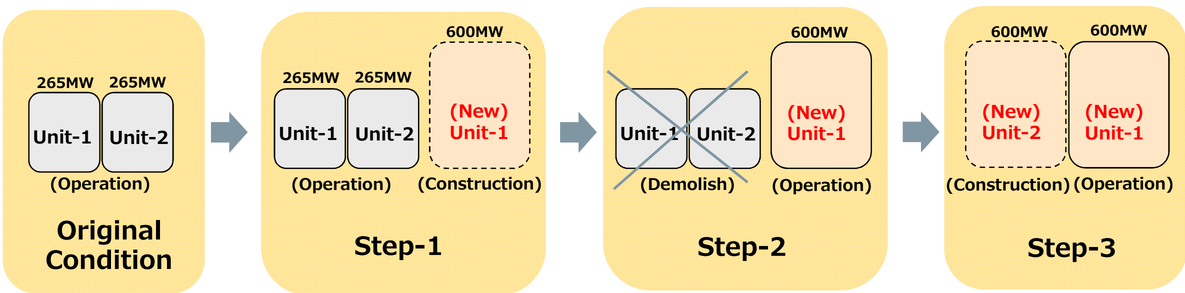


3. Outline of Replacement Process

<Step-1>
To maintain the required power supply capacity during the construction of a new generating facility, it was built the new Unit-1 while operating the old generating facility.

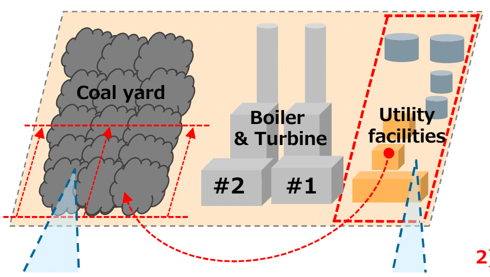
<Step-2>
After the new Unit-1 was commissioned, the old generating facility was decommissioned and demolished.

<Step-3>
Then, new Unit-2 was constructed on the site.

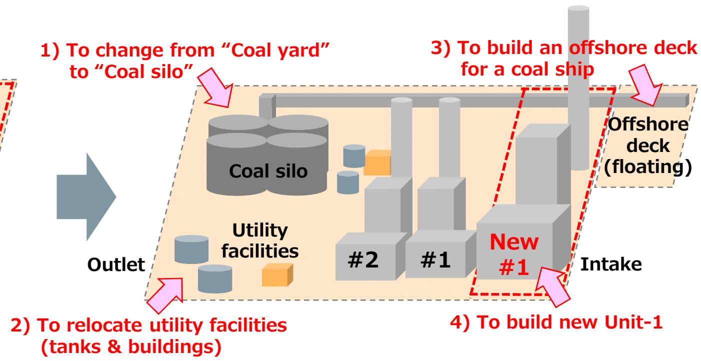


4. Step by Step Process

<Original Condition>



<Step-1>



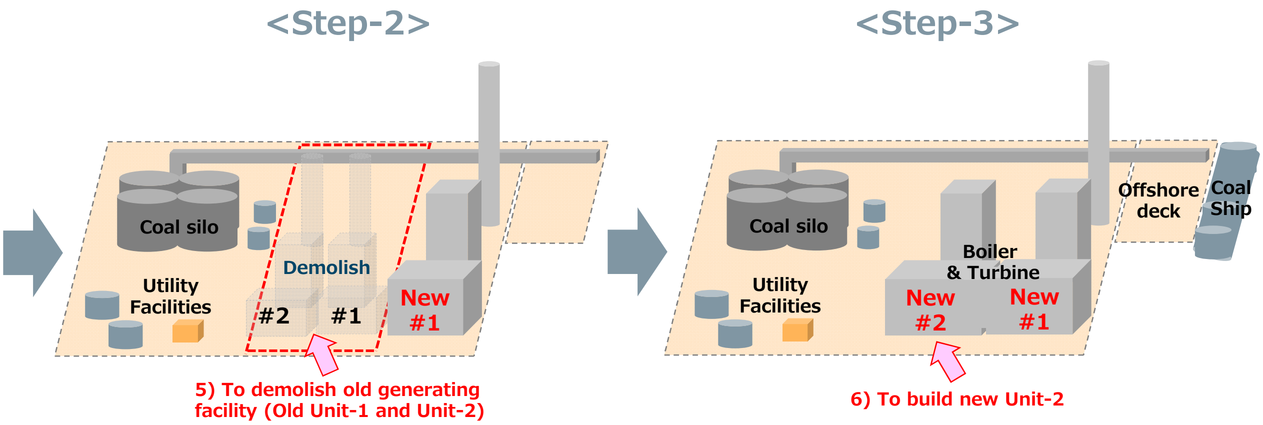
Key concept of this replacement

By changing the coal storage method from the outdoor yard type to indoor silo type, making an extra space.

By using the extra space, relocating utility facilities and making an area for new Unit-1.

- The extra space made available by reducing the outdoor coal yard provided room for building an indoor coal silo and other utility facilities.
- The space that was made available as a result was used for building new Unit-1.
- In conjunction with new Unit-1, an offshore deck and new water intake & outlet were constructed.

4. Step by Step Process

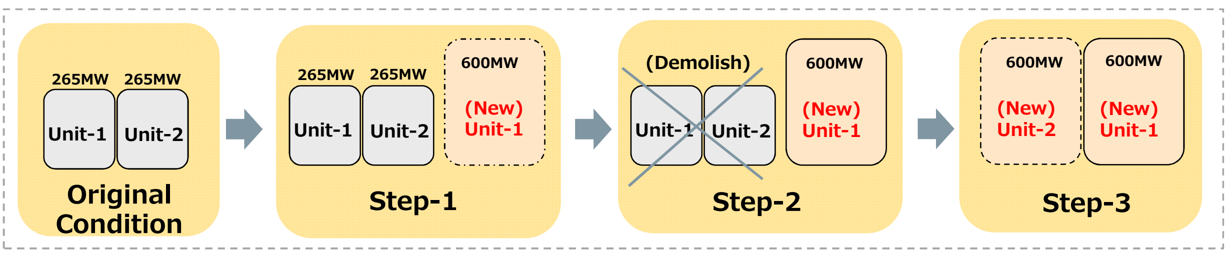


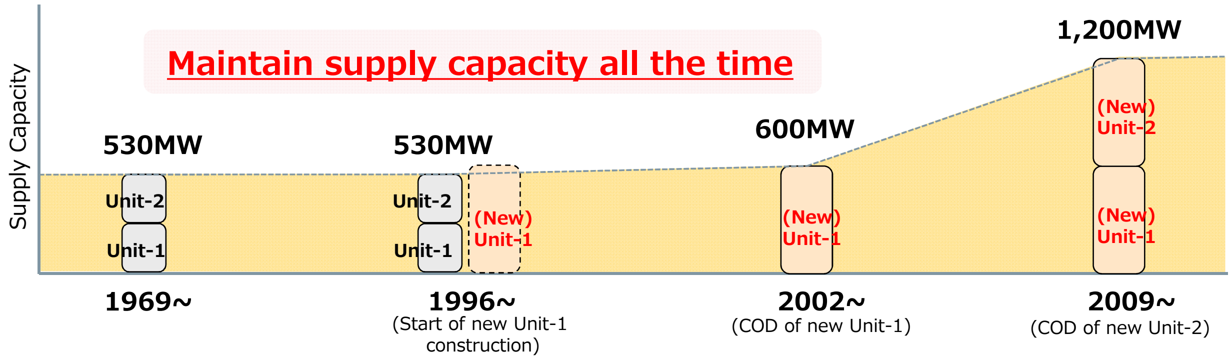
- In line with commissioning new Unit-1, old generating facility was demolished, and the cleared space was secured as the site for new Unit-2.
- New Unit-1 has an output of 600MW and maintain almost the same power supply capacity as older generating facility (530MW).

- New Unit-2 was built at site where old generating facility used to be located.
- The power generating capacity of new Unit-1 and Unit-2 is total 1,200MW, more than double the capacity of old generating facility.

5. Maintaining Supply Capacity

The required power supply capacity was being maintained during the construction of new generating facility.



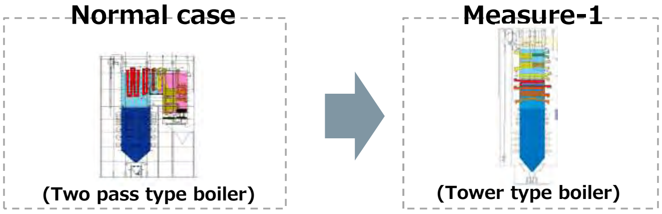


6. Measures for minimizing plant area

Since there were two heavy constraints against this plant replacement, the following two measures were applied to minimize plant area.

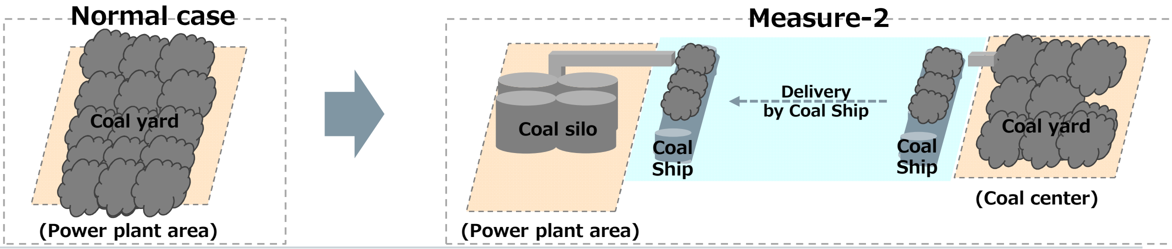
<Measure-1>

To apply tower type boiler instead of normal type boiler.
It can assist to minimize power plant area.



<Measure-2>

To apply a coal center with a coal delivery ship near power plant.
It can assist to minimize power plant area.



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7. Summary

The plant replacement from old units to new units was successfully done under two constraints that is using a limited land area and maintaining the original supply capacity (530MW).

Furthermore, exhaust emission was reduced by using high performance environmental facilities (SCR, ESP and FGD) through this plant replacement.

SCR: Selective Catalytic Reduction
ESP: Electro Static Precipitator
FGD: Flue gas Desulfurization

	Old Unit-1&2	New Unit-1&2
NOx	159ppm	33ppm
SOx	60ppm	30ppm
Dust	50mg/m3N	15mg/m3N

Reference

Source of data & figures in this report

-Literature
(日本電気協会新聞部　火力発電カギのカギ)

-Brochure
(Isogo Thermal Power Station, for public)

Session 3: Integration with up-to-date techniques and knowhow

1. Overhead transmission line

Demand for High Temperature Low Sag Conductor

Recent situation in OHTL

- Antiquated and overworked
- Objection from inhabitants to construct New T/L
- Unexpected growth in electricity consumption due to recent economy expansion (commercial, industrial & residential)

↓

Increasing transmission capacity of existing T/L by replacing conductor

↓

HTLS(High Temperature Low Sag) conductor

Lineup of HTLS

◆ Gap type conductor

The combination of the thermal resistant aluminum alloy and the Gap construction offers excellent sag and current-carrying characteristics
It was developed more than 30 years ago and used in the world include Japan

◆ Invar core conductor

The combination of thermal resistant aluminum alloy and the aluminum-clad invar which has small thermal expansion coefficient offers excellent sag and current-carrying capacity characteristics
It was developed more than 30 years ago and used in the world include Japan

◆ PS(Pre-stressed steel core) conductor

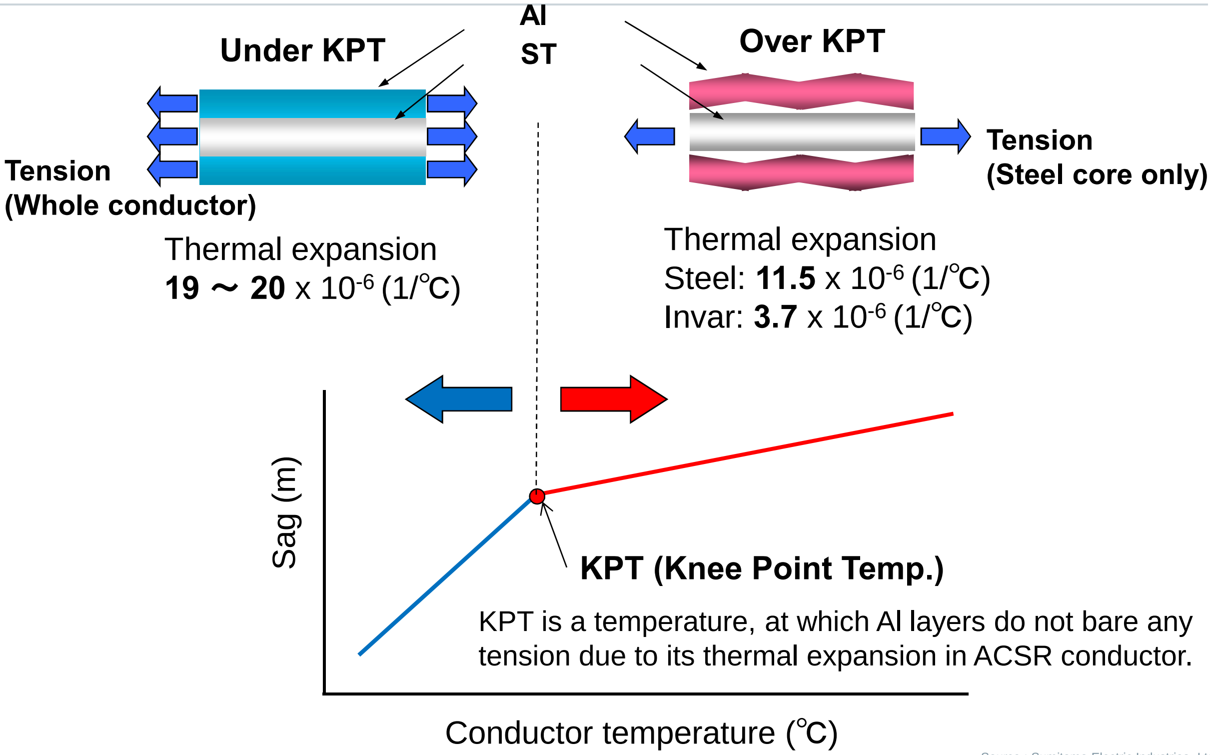
PS conductor has some excess length in Aluminum layers compared with steel core length
This construction offers excellent sag and current-carrying capacity characteristics
It was developed more than 10 years ago and used in the world include Japan

◆ ACFR(Aluminium Conductor Fiber Reinforced)

The combination of thermal resistant aluminum alloy and carbon fiber composite cable core which is light and has extremely small thermal expansion coefficient offers excellent sag and current-carrying capacity characteristics
It was developed more than 10 years ago and used in the world include Japan

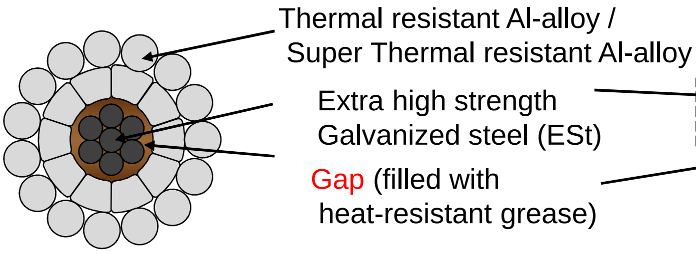
Source : Sumitomo Electric Industries, Ltd., TOKYO ROPE MFG. CO., Ltd

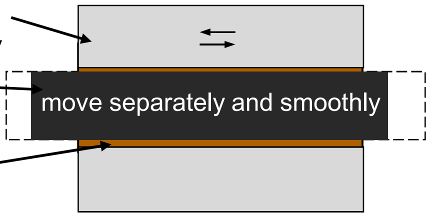
Design concept of HTLS conductors (KPT)



Source : Sumitomo Electric Industries, Ltd.

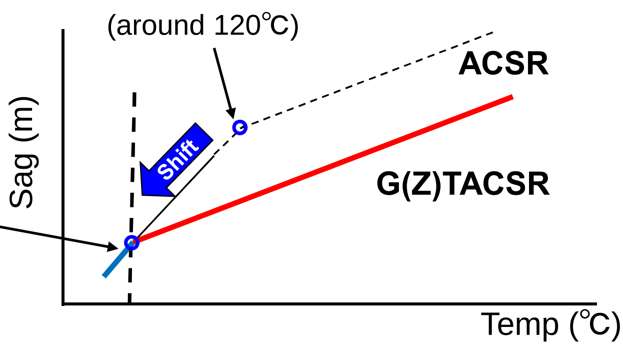
Gap type conductor





At the time of sagging, all tension is applied to the steel core by a special stringing method.

Sagging Temp. = Knee Point Temp.

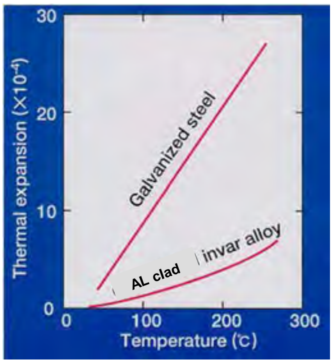


Thermal expansion

ACSR:**19 ～ 20** x 10^{-6} (1/℃)
Steel: **11.5** x 10^{-6} (1/℃)

Source : Sumitomo Electric Industries, Ltd.

Invar core conductor



Invar alloy

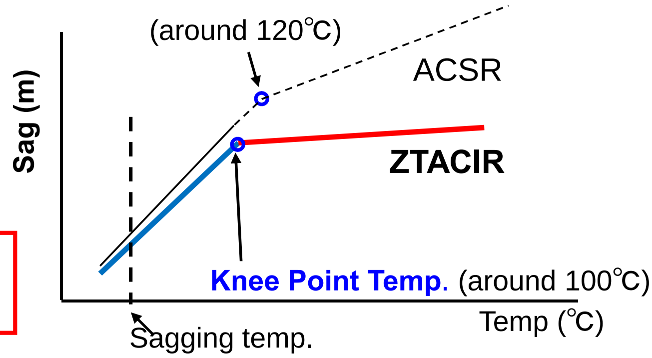
- Fe-36%Ni alloy
- Very small coefficient of thermal expansion
- "Invar" is an abbreviation of invariable

[Thermal expansion]
Invar alloy : 3.7 x 10^{-6} (1/℃)
Steel : 11.5 x 10^{-6} (1/℃)

Thermal expansion

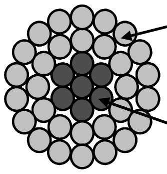
ACSR:**19 ～ 20** x 10^{-6} (1/℃)
Invar: 3.7 x 10^{-6} (1/℃)

Installation method is exactly the same as that of ACSR



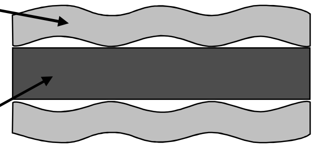
Source : Sumitomo Electric Industries, Ltd.

PS conductor

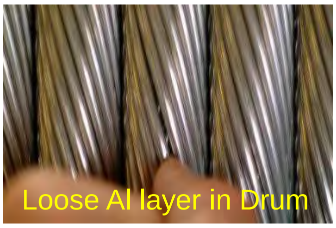


Thermal resistant Al-alloy / Super Thermal resistant Al-alloy

14% conductivity High strength AL-clad steel (14AC)



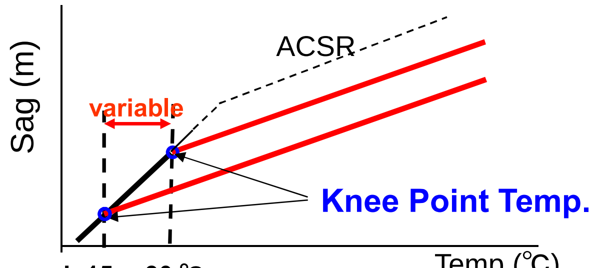
AL length > Steel length



- Some excess length is provided to Al layer.
- **Unique manufacturing method** is applied.

Thermal expansion

ACSR:**19 ～ 20** x 10^{-6} (1/℃)	
14AC: **12.0** x 10^{-6}	(1/℃)



KPT depends on
- Pre-stress for core
- Sagging condition
- Line condition

Cradle pulley method or low tension stringing (less than 1.0 ton) is required.

Source : Sumitomo Electric Industries, Ltd.

Characteristics and advantage of ACFR

ACFR stands for
"Aluminum Conductor Fiber Reinforced"

Core : CFCC(Carbon Fiber Composite Cable)
■Stranded CFRP cable

Conductor : Trapezoidal Shaped Aluminum Conductor

CFCC

Characteristic of ACFR
- Large Cross Section Area
- Non Magnetic Core
- Light Weight
- Low Creep
- Low Thermal Expansion
- Anti-Corrosion
- Stranded CFCC Core

Advantage of ACFR
- Reduction of Transmission Loss — 27% Less(※)
- OR
- Increase of Transmission Capacity — X 2 More Capacity(※)
- AND
- Less Sag — 20% Less(※)
- Long Material Life
- Easy Handling — Less Complicated

(※) These figure depends on conditions

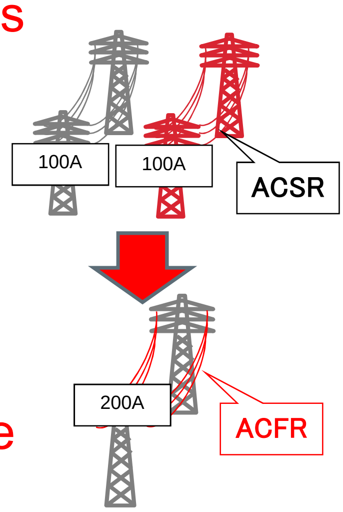
Source : TOKYO ROPE MFG. CO., Ltd.

Design example of ACFR

■Reduction of Transmission Loss

		ACFR 540/55	ACSR 430/55
Core		CFCC	Steel Wire
Diameter	[mm]	28.62	28.62
Electric Current	[A]	700	
Operation Temperature	[℃]	66.55	72.8
Resistance per Length	[Ω/km]	0.0623	0.0851
Transmission Loss per Circuit Length	[kW/km]	91.6	125.1
	Ratio	0.73	1

27% Less
than ACSR



■ Increase of Transmission Capacity

		ACFR 540/55	ACSR 430/55
Core		CFCC	Steel Wire
Diameter	[mm]	28.62	28.62
Electric Current	[A]	1643	729
Operation Temperature	[℃]	175	75
Resistance per Length	[Ω/km]	0.0847	0.0858

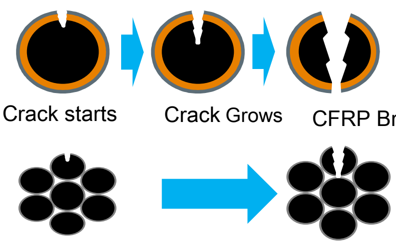
X 2 More
than ACSR

【Capacity Upgrade Image】

Source : TOKYO ROPE MFG. CO., Ltd.

Benefit of ACFR using stranded CFCC core

①Core Durability/Reliability



② Flexibility

ACFR can utilize the same reel and stringing equipment as ACSR.

③Installation Efficiency

Install Time	ACSR	ACFR	ACCC
	10 Min	10 Min	30 Min

ACFR has compatibility to the conventional installation procedure.

Better grip strength of the stranded core surface requires only one additional device.

Source : TOKYO ROPE MFG. CO., Ltd.

Track record of HTLS conductors

Conductor	Gap type	Invar core	PS	ACFR
Records	●Africa (1): Libya ●Middle east (6): Kuwait, Oman, Saudi Arabia, etc. ●Europe (5): UK, Ire land, Russia, etc. ●Asia (9): China, Vietnam, India, Japan, etc. ●Other countries (4): USA, Brazil, etc. 25 countries, From Japan	●Africa (1): Egypt ●Middle east (1): UAE ●Europe (2): France, Italy ●Asia (8): China, Korea, Japan, etc. ●Other countries (1): USA 13 countries, From Japan	●Asia (2): Vietnam, Japan 2 countries, From Japan	●Asia (4): Korea, China, Indonesia, Japan From Korea, From China, From Indonesia, From Japan
Developed in	1971 (Japan)	1981 (Japan)	2002 (Japan)	1997 (Japan)

Source : Sumitomo Electric Industries, Ltd.

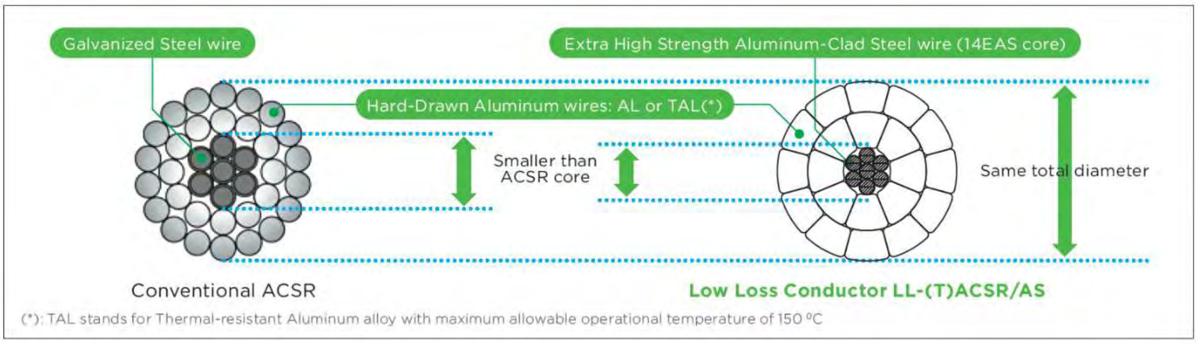
Characteristics of LL conductor

Clear advantage

- Reduction of transmission losses in the range of 10-25%
- Almost the same tower loading as convetional ACSR (same diameter, same tensile strength)
- Same installation and maintenance procedure as conventional ACSR

Technical construction

- Adoption of trapezoidal shaped wires instead of round wires
- Adoption of 14EAS(tensile strength: 1770MPa) instead of normal galvanized steel wires(1290-1340MPa)

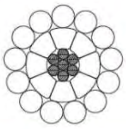
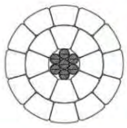


Source : Sumitomo Electric Industries, Ltd.

Characteristics of LL conductor

Design type

Low loss conductor can have two design types, depending on the purpose or specific project requirements.

Type 1	Type 2
Use AL(TAL) round and trapezoidal shaped wires:  ■ **Same diameter** ■ **Same weight** No tower load increase	All aluminum wires are trapezoidal shaped wires:  ■ **Same diameter** ■ **Have maximum aluminum area** Achieve highest power saving
■ Reduce power loss by **roughly 10-15%** ■ No sag increase ■ No need to reinforce nor to modify the existing towers Recommended for re-conductoring of existing lines, or for new lines construction	■ Reduce power loss by **roughly 20-25%** ■ Slight sag increase (because of slight weight increase) ■ Tower reinforcement or modification may be necessary Recommended for construction of new lines

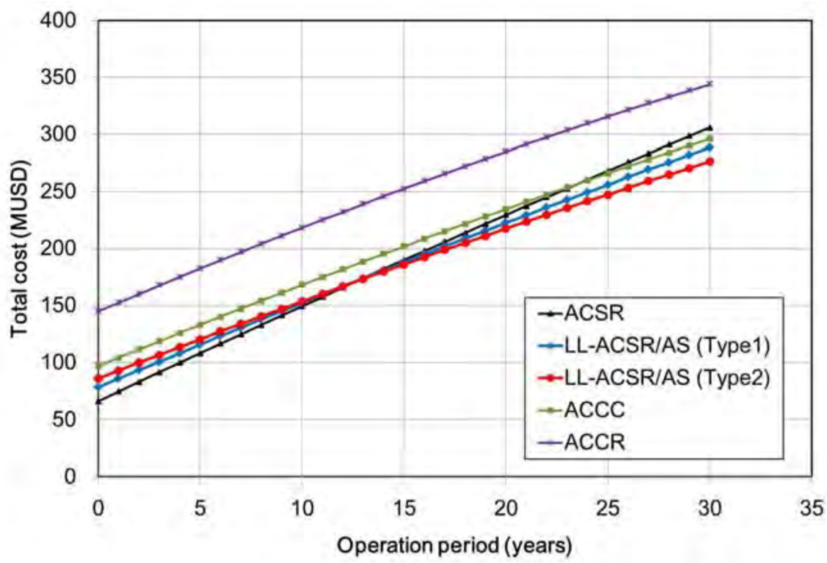
Source : Sumitomo Electric Industries, Ltd.

Characteristics of LL conductor

Economic comparison

Condition of the comparison:

- Line volatage:400kV
- Numbers of circuit:1
- Bundle: 4 conductor/phase
- Load factor: 0.5
- Route length: 200km
- Generation cost: 0.07USD/kWh



In this case, low loss conductor(Type 2) can recover the difference of initial cost in 15 years

Source : Sumitomo Electric Industries, Ltd.

Overseas projects –LL conductor

TNB / Malaysia	——	**Standardize Low Loss conductor for 275 ～ 500kV OHTLs.**

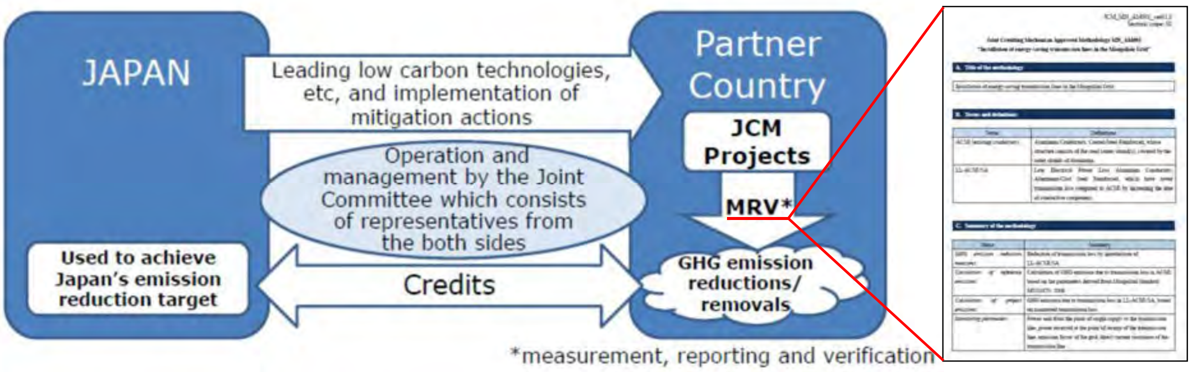
JICA Loan Projects

CEB / Sri Lanka	——	**220kV Havarana – Veyangoda** **220kV Polpitiya – Havarana**
Tan Transco / India	——	**Tamil Nadu Transmission System Improvement Project (110kV and 230kV)**
PGCB / Bangladesh	——	**230kV Hathazari - Sikalbaha**
PNGP / Papua New Guinea	——	**132kV Ramu Transmission System Reinformcement Project**

Source : Sumitomo Electric Industries, Ltd.

JCM Project –LL conductor

JCM concept
[citation: Web site of New Mechanisms Information Platform (http://www.mmechanisms.org/index.html)]

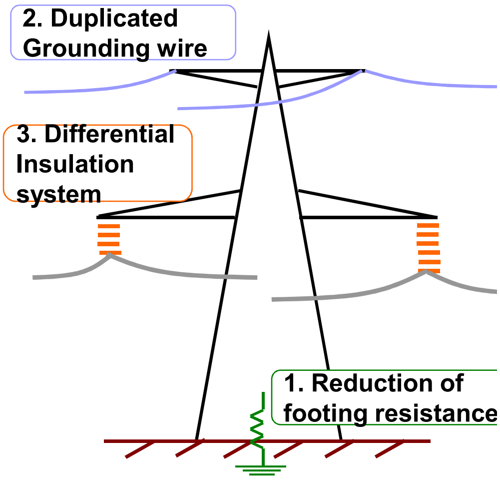


MRV about calculation of GHG emission reduction by using Low Loss conductor has been established in Mongolia.

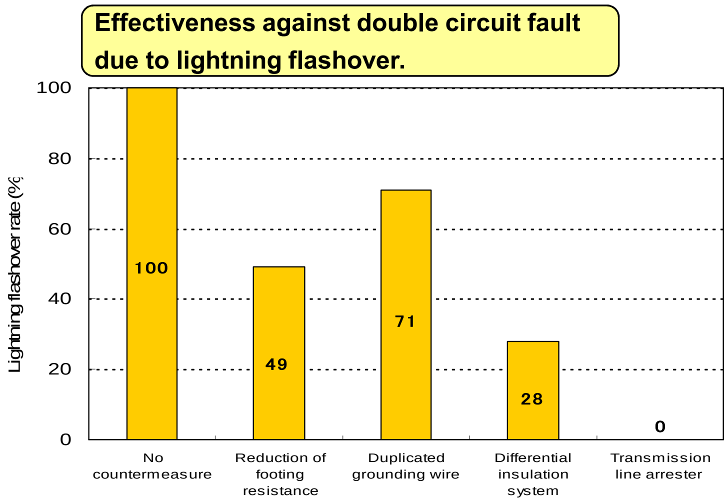
[Title: Joint Crediting Mechanism Approved Methodology MN_AM001 "Installation of energy-saving transmission lines in the Mongolian Grid"]

Source : Sumitomo Electric Industries, Ltd.

Lightning countermeasure of the transmission line

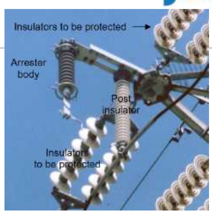


Source : Toshiba Corporation



Source:
"Experience and Effectiveness of Application of Arresters to Overhead Transmission Lines" (CIGRE 33-301, 1998)

History of development of EGLA



1986-1990 Development of EGLA for 33- 500kV

1999-2009 Development of arcing horn type EGLA for 33- 500kV

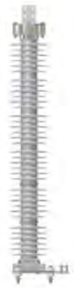
2011 Standardized IEC 60099-8 Surge Arresters Part8
: Metal-oxide surge arresters with external series gap (EGLA) for overhead transmission and distribution lines of a.c. systems above 1kV

EGLA has been used not only in Japan but also in Korea, China, Hong Kong, Vietnam, Thailand, Malaysia, Indonesia, Mexico, Russia

Source : Toshiba Corporation

Advantage of EGLA(Externally Gapped Line arresters)

Comparison between EGLA and gapless type arresters
Both for a 145kV system as an example

Item	EGLA	Gapless type (Station type for reference)
Schematic illustration		
Size	Length of one arrester unit : 400 mm Mass of arrester units per phase : 10 kg (Mounting parts and balance weight are not included.)	Height : approx. 1200 mm Mass : 45 kg
Duty to be withstand	Only lightning overvoltage (Key factor to the compactness)	Lightning overvoltage Switching surge overvoltage, Power freq. overvoltage
Deterioration	Electrical stress free Maintenance free	Always electrically stressed Disconnector needed

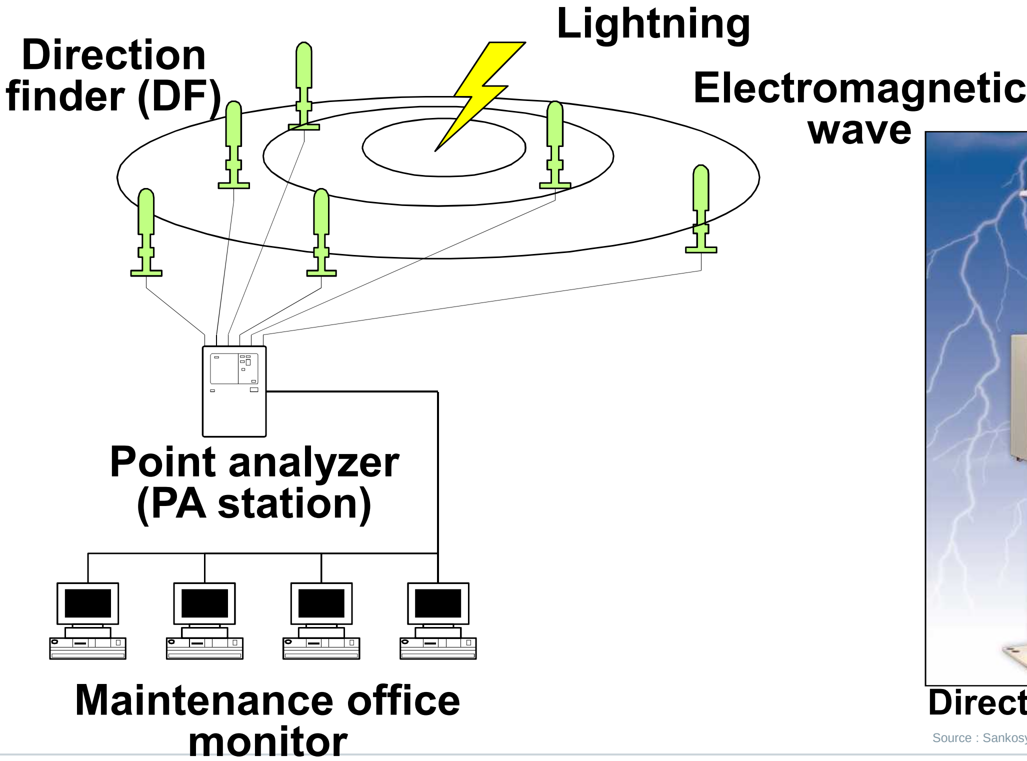
Source : Toshiba Corporation

Advantage of EGLA(Externally Gapped Line arresters)

Comparison between EGLA and gapless type arresters(Image)
Both for 245kV system as an example

Source : Toshiba Corporation

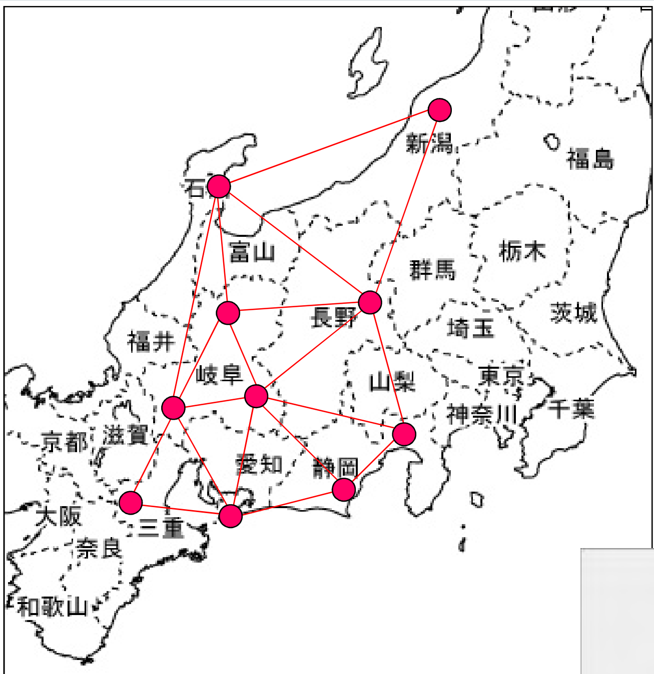
Application of LLS(Lightning Location System) in Japan

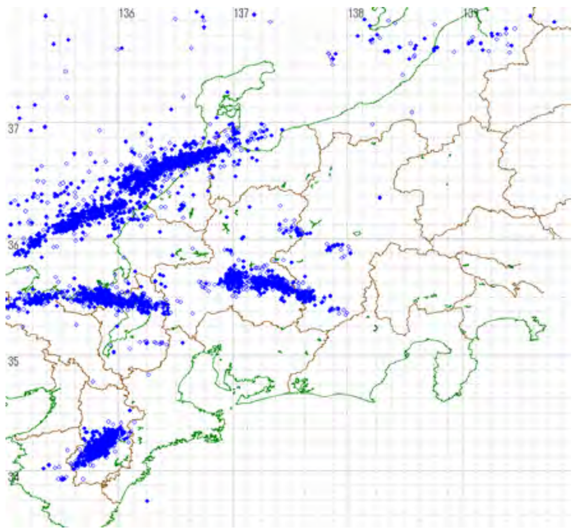


Direction finder

Source : Sankosya Corporation

Application of LLS(Lightning Location System) in Japan

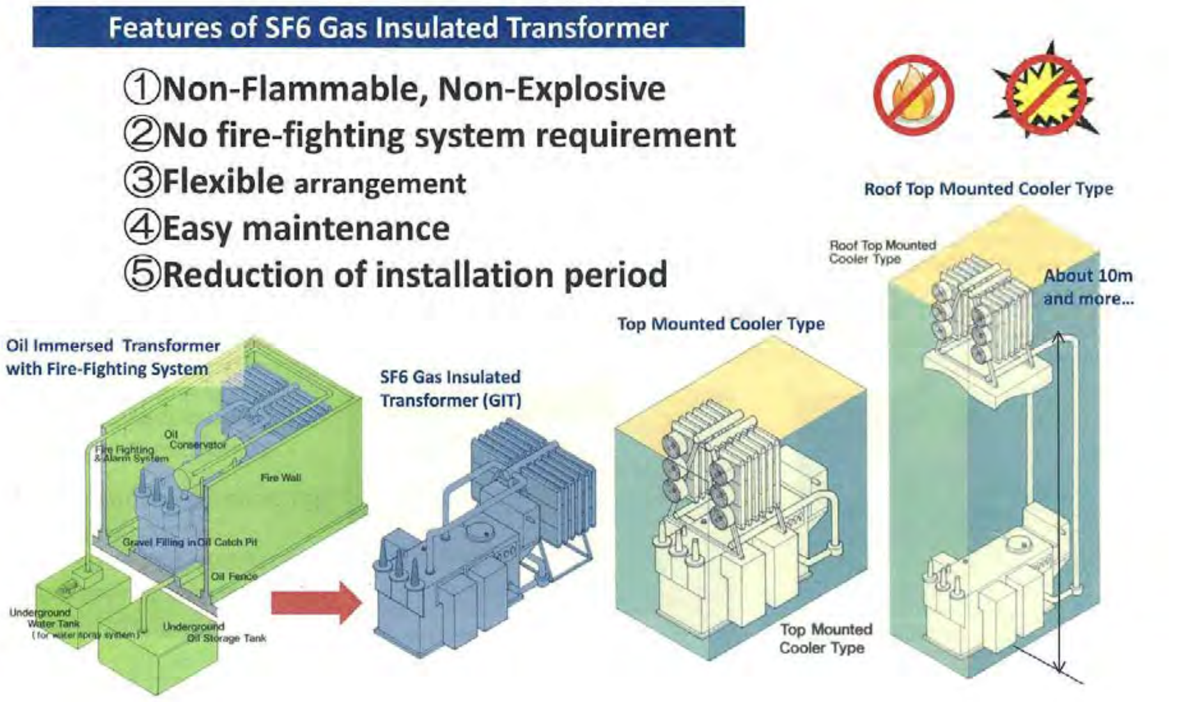




Source : Chubu Electric Power Co., Inc.

2. Substation equipment

Gas Transformer - to meet metropolitan integration



Source : Mitsubishi Electric Corporation.

Gas Transformer - to meet metropolitan integration

TRANSFORMER MAIN BODY

OIT
- OXIDIZATION OF OIL (Requirement of DGA test periodically)
- CHECK OIL TEMP.
- CHECK OIL LEVEL
- CHECK BREATHER
- CHECK OIL PUMP

→ **Less Maintenance Item**

GIT
- SF6 GAS (No maintenance)
- CHECK GAS TEMP.
- CHECK GAS PRESSURE
- CHECK GAS BLOWER

ON LOAD TAP CHANGER

OIL TYPE
- OIL CONTAMINATION
- AVE. LIFE TIME
  EITHER EVERY 7 YEARS or 200,000 TIMES OPERATION

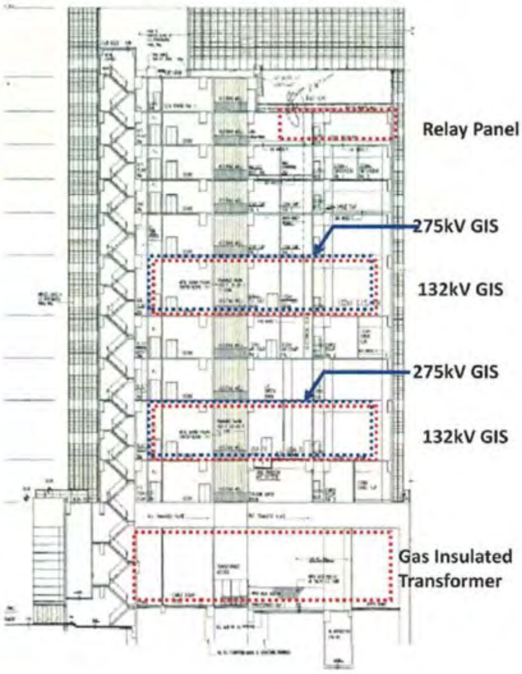
→ **Long Maintenance Interval**

VACUUM SWITCH TYPE
- NO-CONTAMINATION
- AVE. LIFE TIME
  EITHER EVERY 10 YEARS or 500,000 TIMES OPERATION

Source : Mitsubishi Electric Corporation.

Gas Transformer - to meet metropolitan integration

S/S in the building of Hong Kong besides commercial building (2000)



Source : Mitsubishi Electric Corporation.

Gas Transformer - to meet metropolitan integration

110/10.5kV 50MVA GIT FOR BEIJING ELECTRIC POWER Co.

FOR UNDER GROUND SUBSTATION

50MVA, Three phase, 50Hz,
Continuous Rating,
Core-Form, Type GUB-VSG,
Forced-Gas Natural Air,
with On-Load Tap Changer
GNAN/GDAF

H.V.	110kV +10/-10%	Star
L.V.	10.5kV	Delta

Shipping Year 2007

Beijing 2008

Source : Mitsubishi Electric Corporation.

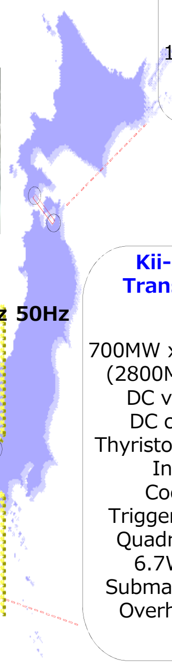
HVDC - experience of Japanese technologies

Shin-Shinano Frequency Converter Station

300MW-Year 1977/2009
600MW-Year 1992
DC voltage: 125kV
DC current: 2,400A
Thyristor: LTT 7.5kV-2440A
Cooling: Water
Insulation: Air

Hokkaido-Honshu DC Transmission Line

150MW – Year 1979
300MW- 1980
600MW - 1993



Minami-Fukumitsu Back to Back Converter Station

300MW – Year 1993

Sakuma Frequency Converter Station

300MW–Year 1993/1965

Higashi-Shimizu Converter Station

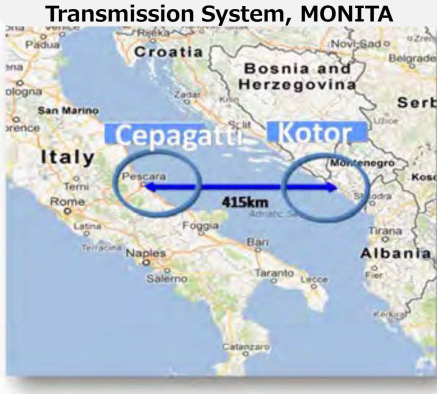
300MW – Year 2006

Kii- Channel DC Transmission Line

700MW x 2 pole-Year 2000
(2800MW in the future)
DC voltage : 250kV
DC current: 2800A
Thyristor: LTT 8kV-3500A
Insulation: Air
Cooling : Water
Triggering: Direct Light
Quadruple valve size:
6.7W-3.7D-8.75H
Submarine cable: 50km
Overhead line: 50km

"Year" indicates Commissioning Year

Italy-Montenegro HVDC 1GW ±500kVdc Transmission System, MONITA



Uruguaiana Back to Back Station, Uruguay

Source : Toshiba Corporation

HVDC - with technologies of thyristor valves

jica

Year: 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2001 2006 2009

Project

- 125kV 37.5MW — **Sakuma FC** (Prototype)
- 125kV 300MW — **Shin-Shinano FC No.1**
- 250kV 300MW — **Hokkaido-Honshu HVDC Pole1**
- 125kV 300MW — **Shin-Shinano FC No.2**
- 250kV 300MW — **Hokkaido Honshu HVDC Pole2**
- 125kV 300MW — **Sakuma FC**
- 125kV 300MW — **Minami Fukumitsu BTB**
- 10.6kV 53 MW — **Shin-Shinano Experimental FC system (VSC)**
- 250kV 1,400MW — **Kii Channel HVDC**
- 125kV 300MW — **Higashi-Shimizu FC**
- 125kV 300MW — **Shin Shinano FC No.1 (replace)**

Thyristor Valves

- 125kV 300A, Air Cooled
- 125kV 1,200A, Oil Cooled
- 250kV 1,200A, Air Cooled
- 125kV 1,800A, Water Cooled, Light Triggered
- 500kV 3,000A, Water Cooled, Light Triggered
- 125kV 2,400A, Water Cooled, Light Triggered
- 250kV 1,200A, Water Cooled, Light Triggered
- 250kV 2,800A, Water Cooled, Light Triggered

Sakuma FC
(ASEA)
125kV 1200A

Hokkaido-Honshu HVDC
Air Cooled, Light Triggered Thyristor Valve
250kV 1200A

Shin-Shinano FC
Water Cooled, Light Triggered Thyristor Valve
125kV 2400A

Hokkaido-Honshu HVDC
Water Cooled, Light Triggered Thyristor Valve
250kV 1200A

Kii Channel HVDC
Water Cooled, Light Triggered Thyristor Valve
250kV 2800A

Source : Hitachi Co., Ltd.

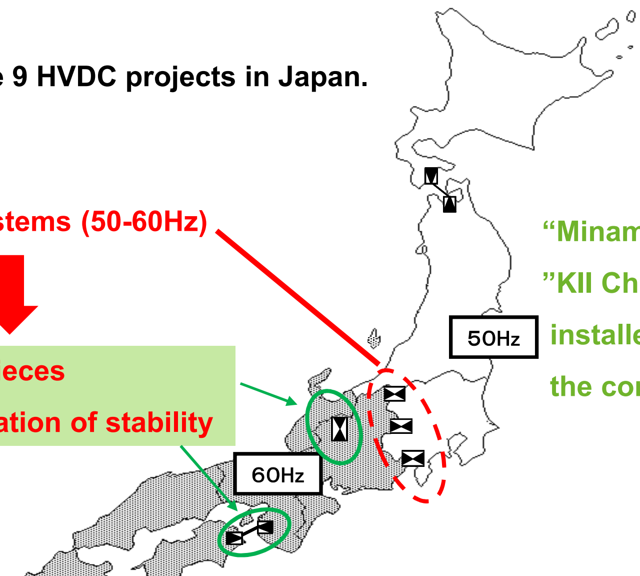
HVDC - enhancement of installation purpose of HVDC

jica

-There are 9 HVDC projects in Japan.

To connect different systems (50-60Hz)

To divide into pieces in consideration of stability



"Minami Fikumitsu BTB" and "KII Channel HVDC" are installed based on the concept of simplification for system stability

HVDC can control power flow rapidly (ms) at any value within the range of rated capacity.

Therefore, Network Stabilizing Function can be applied in accordance with requirement from AC network.

Source : Hitachi Co., Ltd.

Advanced Control Technology applied to Kii-Channel HVDC

1) HVDC Power Modulation Control for AC power swing damping

This method controls DC power with using frequency deviation between both ends of HVDC converter station.

2) Emergency Frequency Control

This method controls DC power with using frequency deviation between both ends of HVDC converter station.

3) DC Continuous Operation Control during and after AC fault

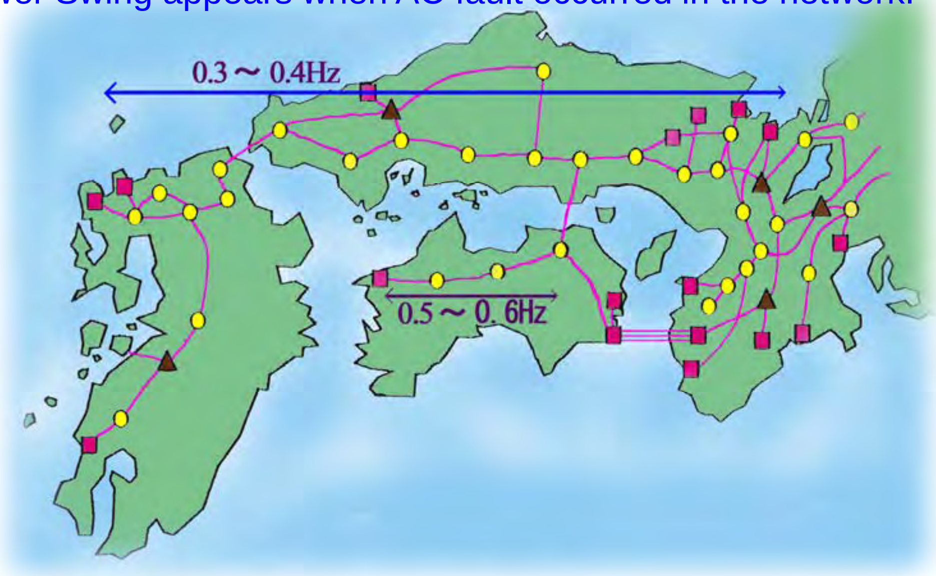
This method mitigates communication failure and recovers transport power faster during and after AC circuit fault.

Source : Hitachi Co., Ltd.

Power Modulation (PM) for AC Power Swing Damping

Power Oscillation Mode exists in western Japan AC network.

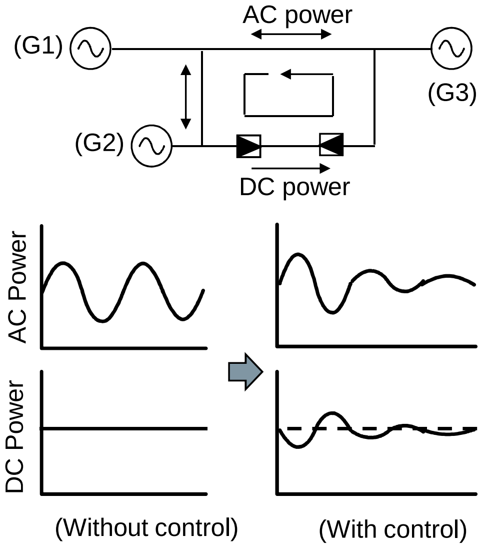
- Frequency mode: 0.3~0.4Hz and 0.5~0.6Hz
- Power Swing appears when AC fault occurred in the network.

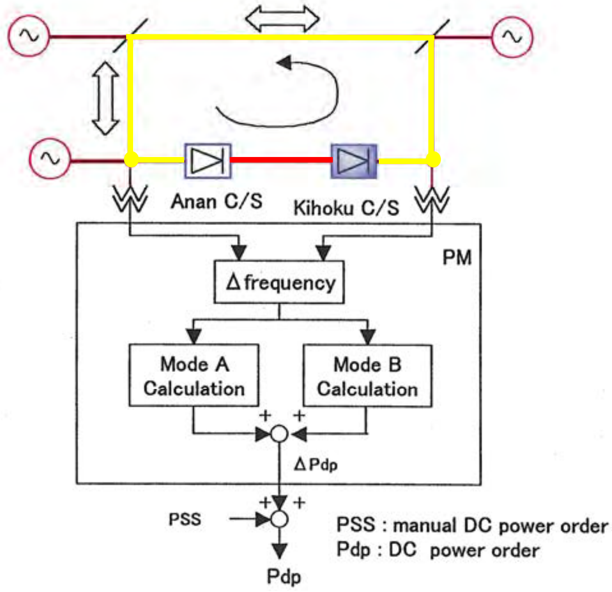


Source : Hitachi Co., Ltd.

Power Modulation (PM) for AC Power Swing Damping

In order to keep network stability, **Power Modulation Control Function** was applied to Kii-Channel HVDC project

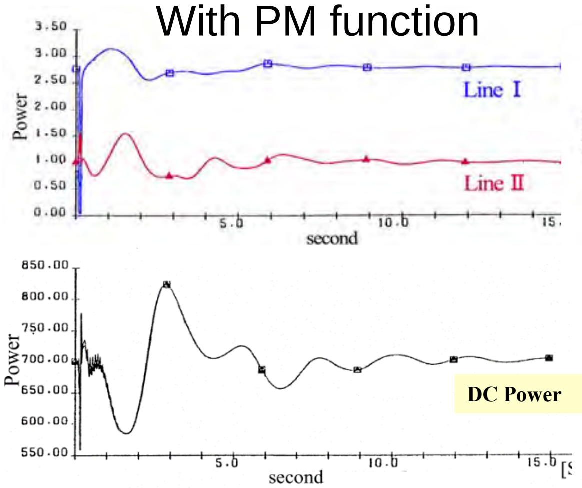




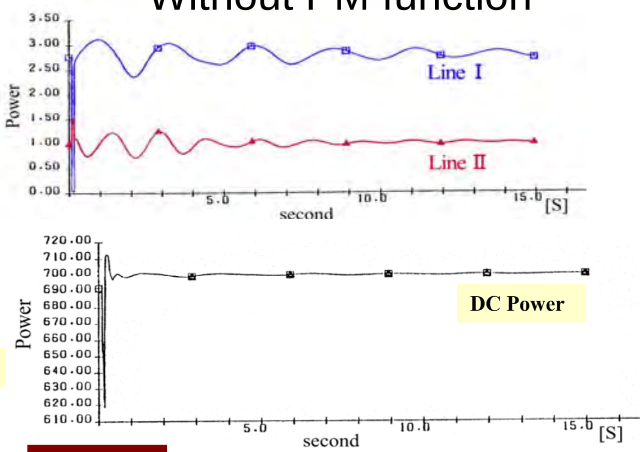
Source : Hitachi Co., Ltd.

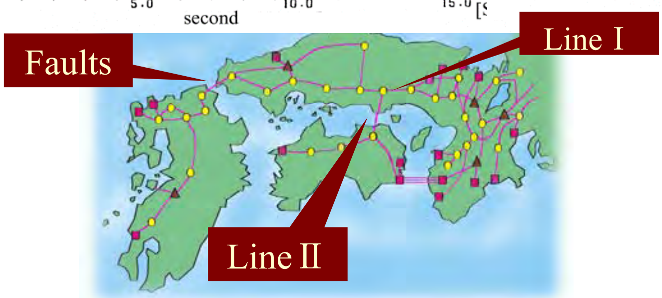
HVDC - Case of KII Channel HVDC – to reduce damping

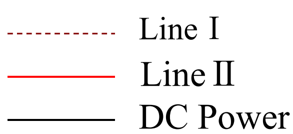
With PM function



Without PM function



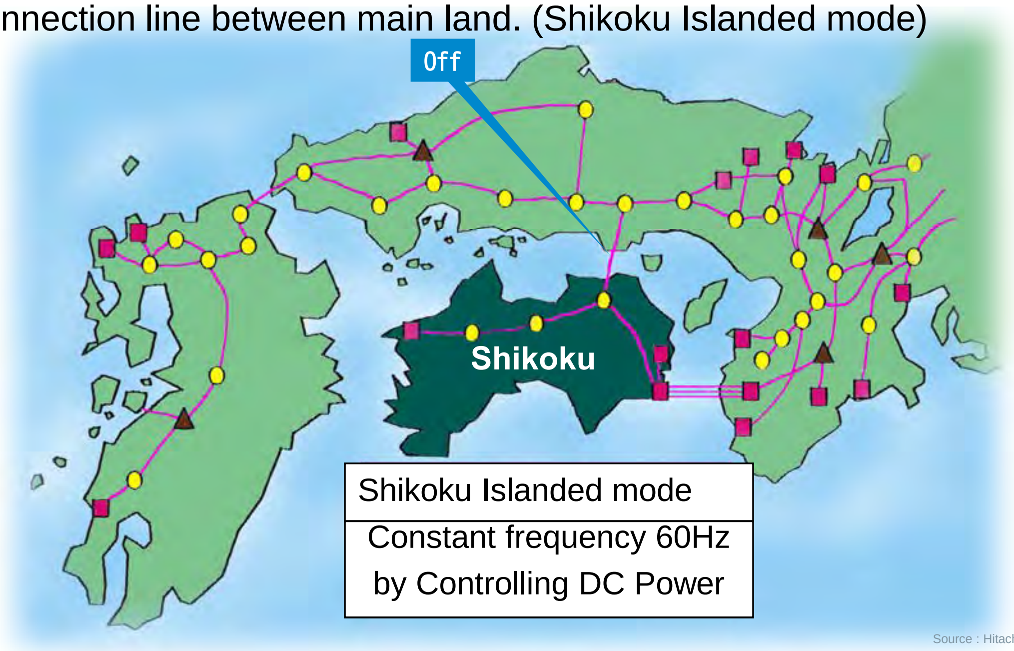




Source : Hitachi Co., Ltd.

Emergency Frequency Control (EFC)

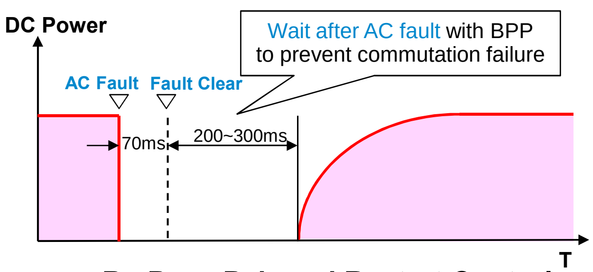
Frequency of Shikoku Island becomes unstable when AC fault occurred in interconnection line between main land. (Shikoku Islanded mode)



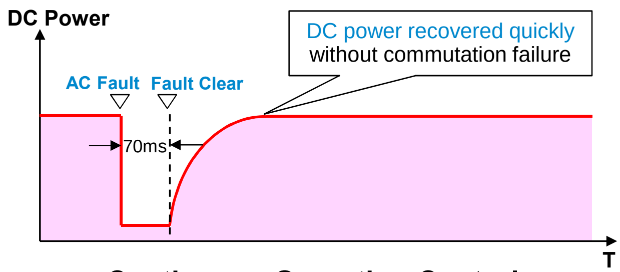
Source : Hitachi Co., Ltd.

DC Continuous Operation Control during & after AC Falut

- In order to ensure stable power supply as an interconnection, HVDC system is required to be stable to AC fault without commutation failure.
- The continuous operation control makes HVDC system capable to maintain stable commutation even under AC fault close to converter station.
- The continuous operation control can;
  - prevent temporally overvoltage caused by reactive power unbalance
  - enable the AC power system to be stable caused by power unbalance



By-Pass Pair and Restart Control (Conventional)



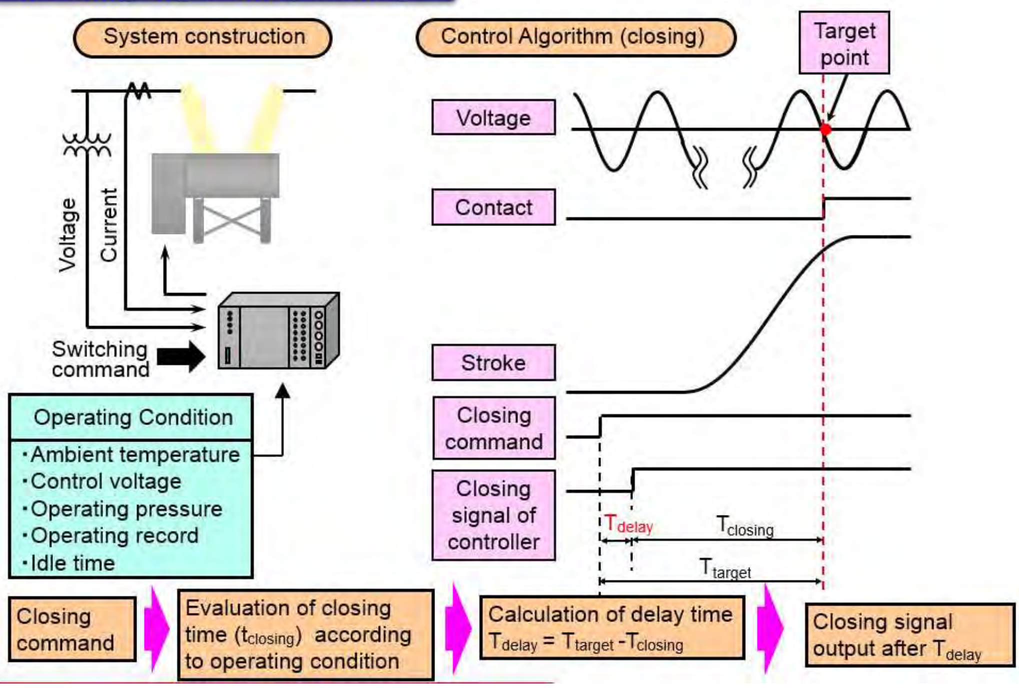
Continuous Operation Control

Source : Hitachi Co., Ltd.

Operating equipment - Synchronous Switching GCB

To reduce the stress of contacts and enhance its life time

Controlling Algorithm (Closing)



Source : Mitsubishi Electric Corporation.

Operating equipment - Synchronous Switching GCB

To reduce the stress of contacts and enhance its life time

Low wear of contacts and nozzle

Measurement of wear of contacts and nozzles for GCB which has been operated 2300 times.

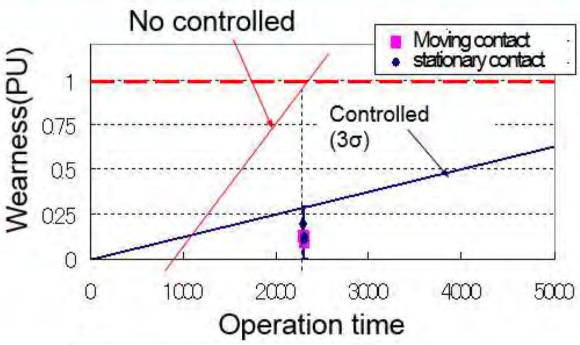
■ Prevention of re-ignition

⇩

○Little wear of contacts
○Decrease of contamination nozzle surface

⇩

Replace Interval for Nozzle will be increased.



Nozzle

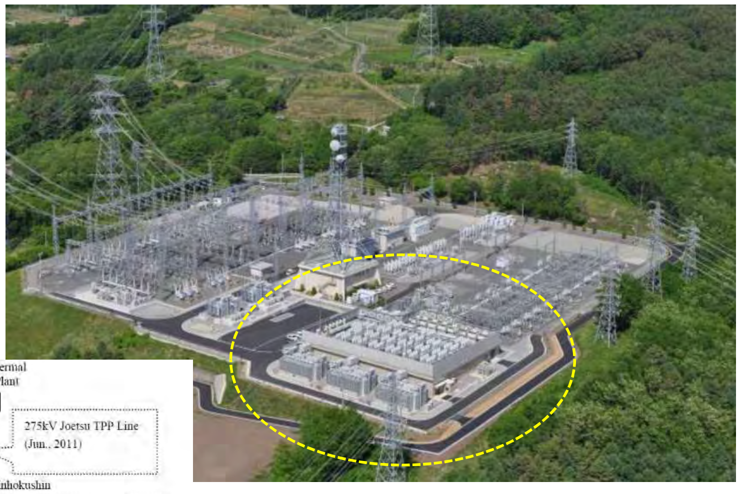
Stationary arc contact

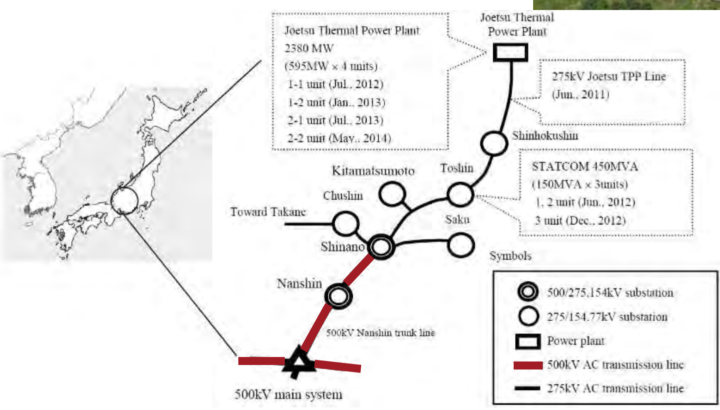
Source : Mitsubishi Electric Corporation.

3. Power System Stabilization

STATCOM- In Chubu Electric Power Co. , the world's largest capacity

Measure for system stability and overvoltage occurred newly-built gas-fired PP, 450MVA STATCOM was installed at 275kV Substation in Chubu (Central Japan) area.

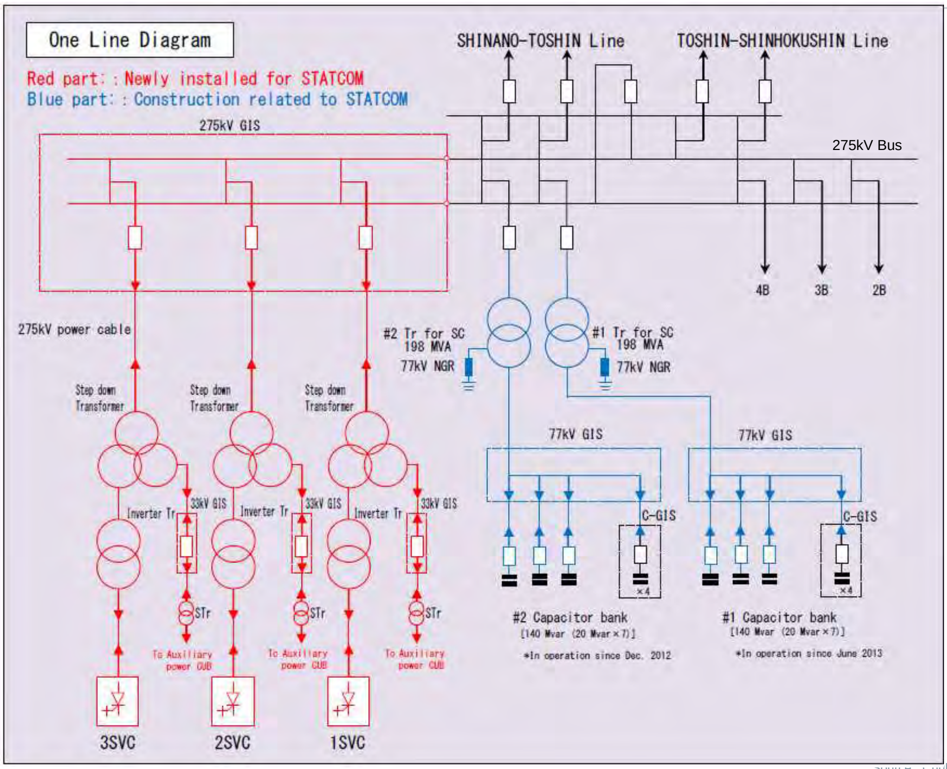




Chubu was introducing Rotary Condenser, SVC and STATCOM with changes across the ages

Source : Chubu Electric Power Co.,

STATCOM - Single line diagram of TOSHIN Substation (275kV)



Source : Chubu Electric Power Co.,

STATCOM - its feature

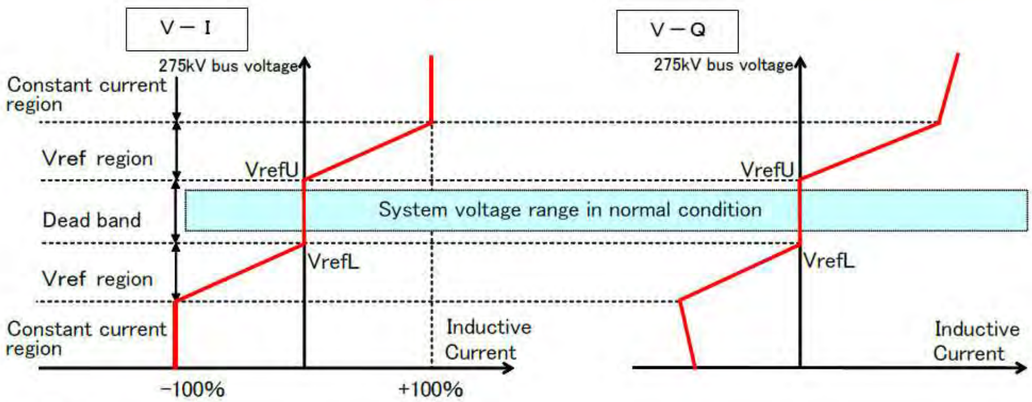
Operation modes

① AVR mode ··· 275kV bus Voltage control of TOSHIN Substation
Output reactive power is controlled according to the 275kV bus voltage
→ Regular Operation Mode

② ACR mode ··· Output reactive power is controlled by reference value (*)
→ Operation mode for system test

(*) Current reference value corresponding to the reactive power reference is used in STATCOM control.

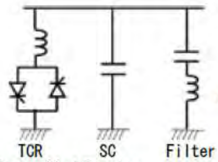
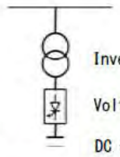
AVR control with Dead band



Dead band : Dead band reduces operation loss in normal voltage condition

V_{ref} Region : Output reactive power is propotional to the voltage deviation between system voltage and reference values ($V_{ref}U$, $V_{ref}L$)

Source : Chubu Electric Power Co.,

	SVC (TCR+SC+Filter)	STATCOM
Principle	・Turn off is done by system voltage ・Semiconductor device: Thyristor ・ Inductive reactive power is controlled continuously by reactor current control ・ Capacitive reactive power is controlled by capacitor ・Fast response and continuous control ・Harmonic generation is absorbed by filters ・Higher no-load loss	・Commutation by semiconductor device ・Semiconductor device: GTO, GCT, IGBT, IEGT etc. ・ Inductive and Capacitive reactive power is continuously controlled by output voltage of VSC. ・Faster response time by power device switching ・No harmonic filters are needed by multiplexed composition of inverters ・Lower no-load loss ・Smaller installation space than SVC
Circuit	 ＊This type is installed in CHUSHIN substation TCR: Thyristor Controlled Reactor	＊this type is installed in TOSHIN substation 

GTO : (Gate Turn-Off thyristor)
GCT : (Gate Commutated Turn-off thyristor)
IGBT : (Insulated Gate Bipolar Transistor)
IEGT : (Injection Enhanced Gate Transistor)

Source : Chubu Electric Power Co.,

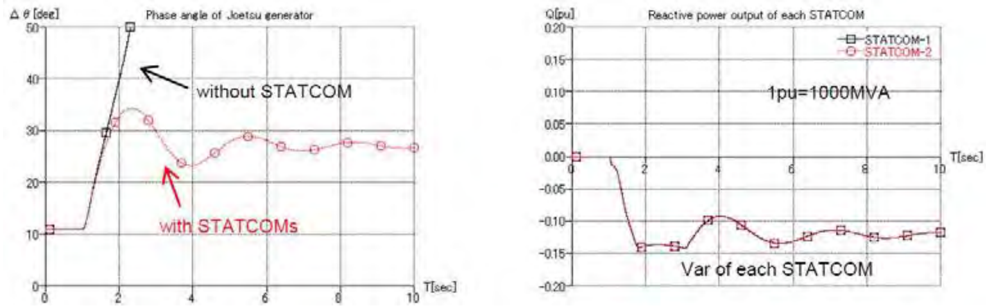


Figure : Stability Enhancement at one-line fault on Power line

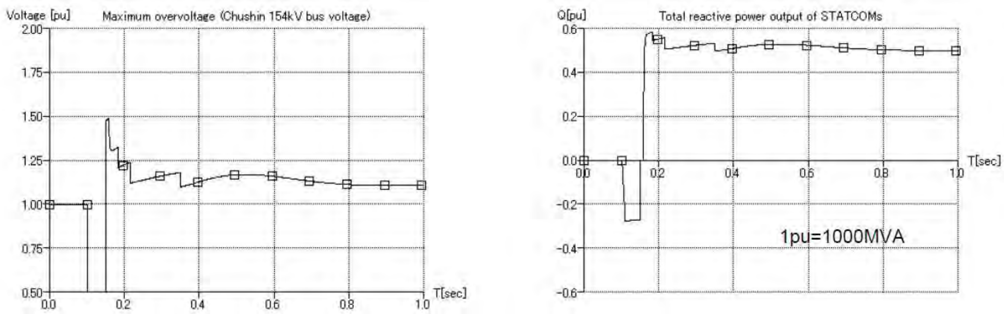


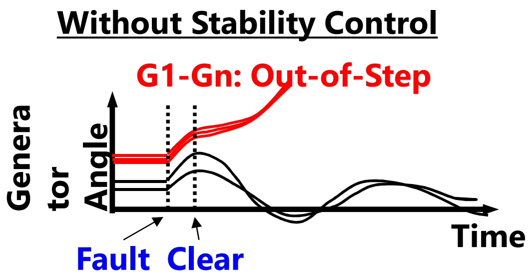
Figure : Overvoltage control by STATCOM on a route fault of 500kV trunk line

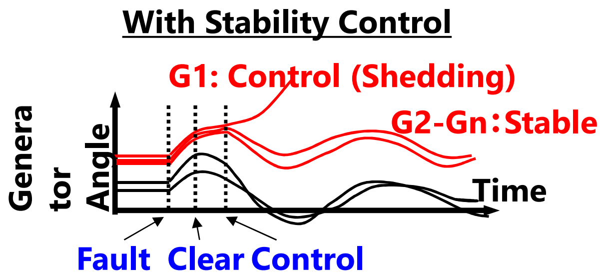
Source : Chubu Electric Power Co.,

Transient Stability Control

Purpose :

- Without stability control, G1 to Gn accelerate during the fault, an out-of-step will occur
- With stability control, provided that G1 is tripped following fault clearance, stable operation will be maintained for the remaining generators

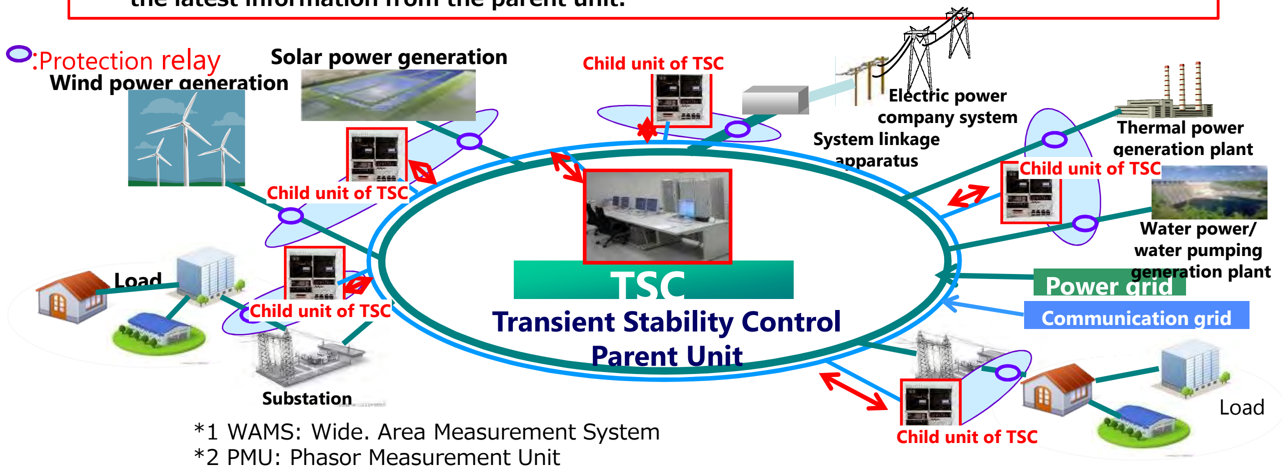




Source : Chubu Electric Power Co.,

Transient Stability Control - Overview

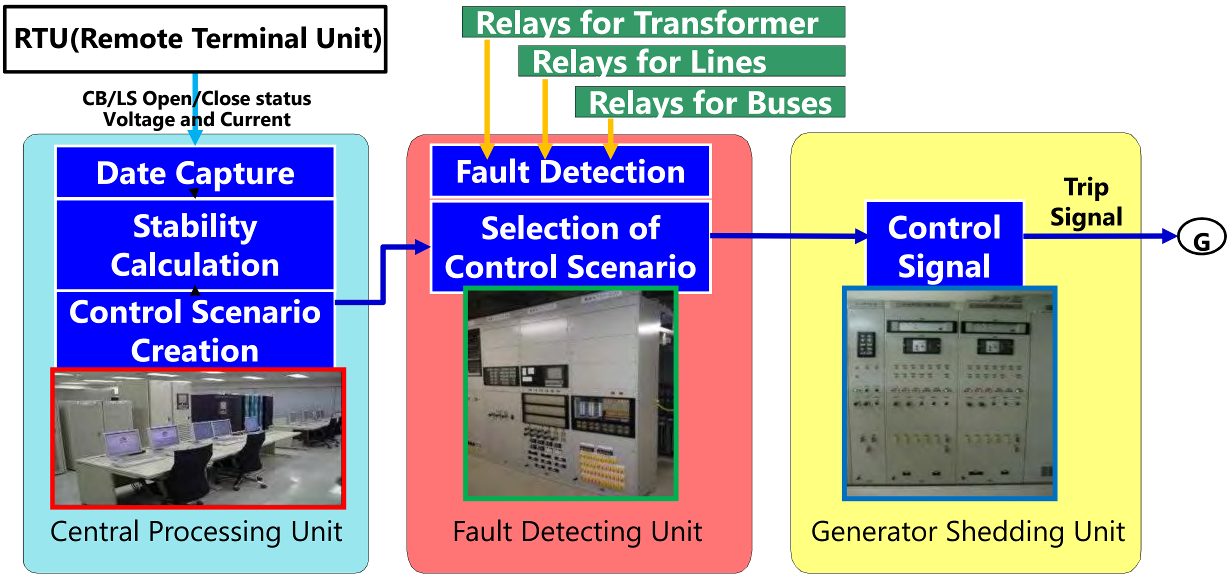
1. TSC system will be implemented based on the WAMS*1 .
2. IEDs and PMUs*2 are added receiving function that is to receive information from upper system of TSC (upper system of TSC is called "parent unit" of TSC, and developed IED + PMU is called "child unit" of TSC).
3. When the child units of TSC would find the accident, they shed the loads/generators based on the latest information from the parent unit.



*1 WAMS: Wide. Area Measurement System
*2 PMU: Phasor Measurement Unit

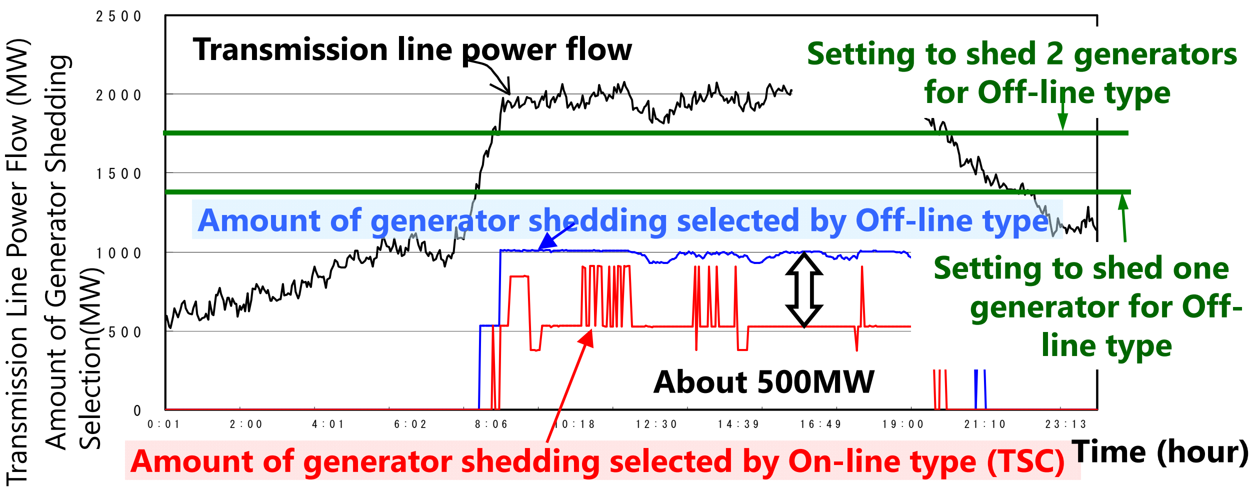
Source : Toshiba Corporation

Transient Stability Control - Configuration



Source : Toshiba Corporation

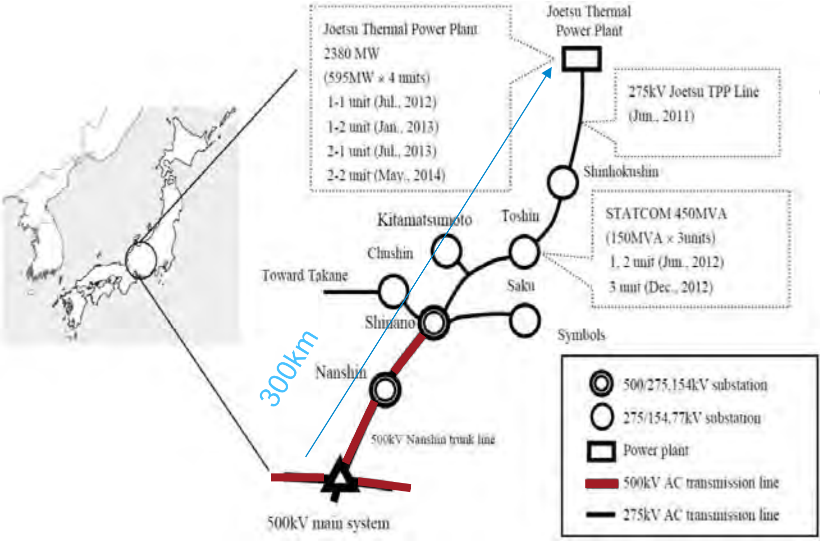
Transient Stability Control – Optimal Control



TSC enables optimal control of network operation which is changing

Source : Toshiba Corporation

Integrated Stability Control - Beyond the TSC



System phenomenon

Case : Single line trip in heavy power flow

↓

Generator will accelerate

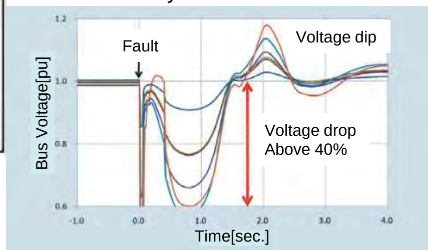
↓

Transient Stability Problem

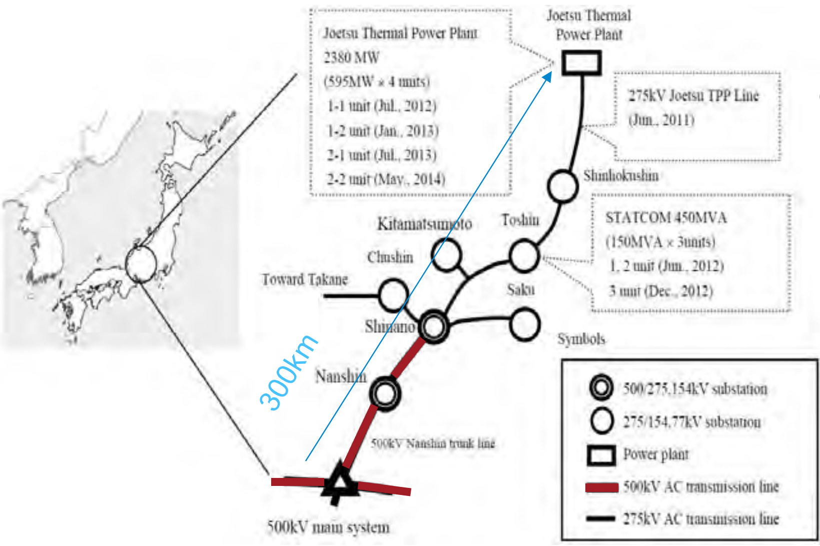
Voltage Phase difference will enlarge

↓

Complicated voltage fluctuation will occur by TSC's Generator control



Integrated Stability Control - Beyond the TSC



System phenomenon

Case : Single line trip in heavy power flow

↓

Generator will accelerate

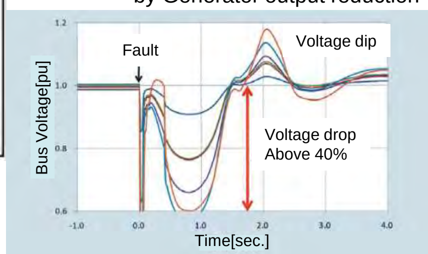
↓

Transient Stability Problem

Voltage Phase difference will enlarge

↓

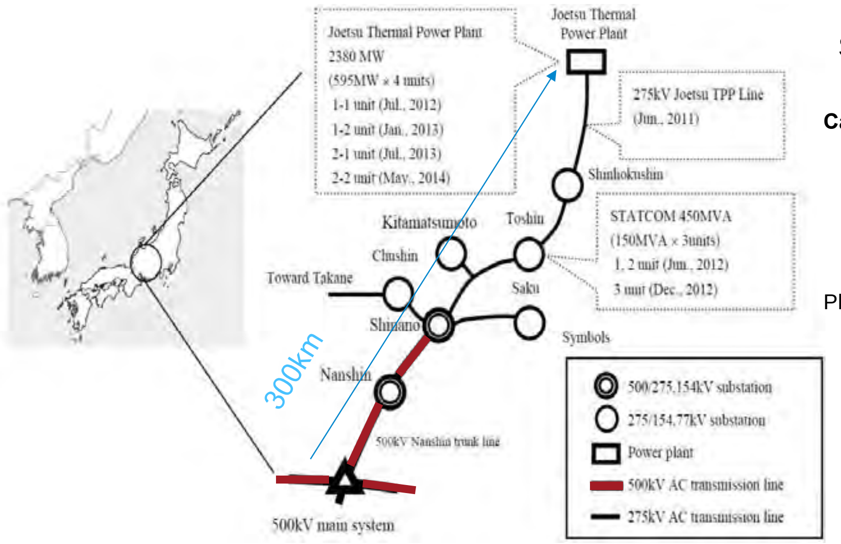
Complicated voltage fluctuation will occur by Generator output reduction



↓

Reactive Power loss Problem

Integrated Stability Control - Beyond the TSC (contd.



System phenomenon

Case : Route trip

↓

Islanding

↓

Load Frequency Control Problem

Plus…

Normal Condition

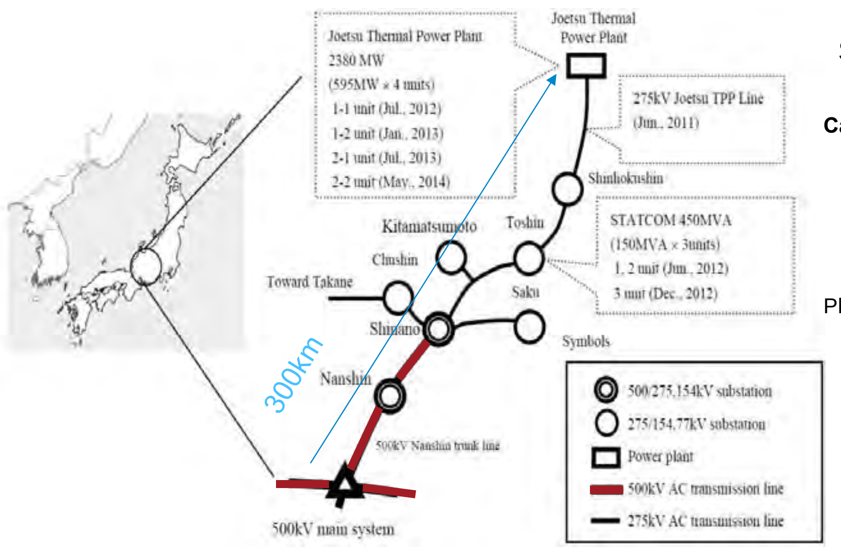
↓

Active Power flow variation will cause drastic change of reactive power loss

↓

Voltage Stabilization Problem

Integrated Stability Control - Beyond the TSC (contd.



System phenomenon

Case : Route trip

↓

Islanding

↓

Load Frequency Control Problem

Plus…

Normal Condition

↓

Active Power flow variation will cause drastic change of reactive power loss

↓

Voltage Stabilization Problem

TSC + VQC(Voltage – Reactive Power(Q) Control system) drives mutually

↓

ISC(Integrated system stability control system) installed in Chubu area.

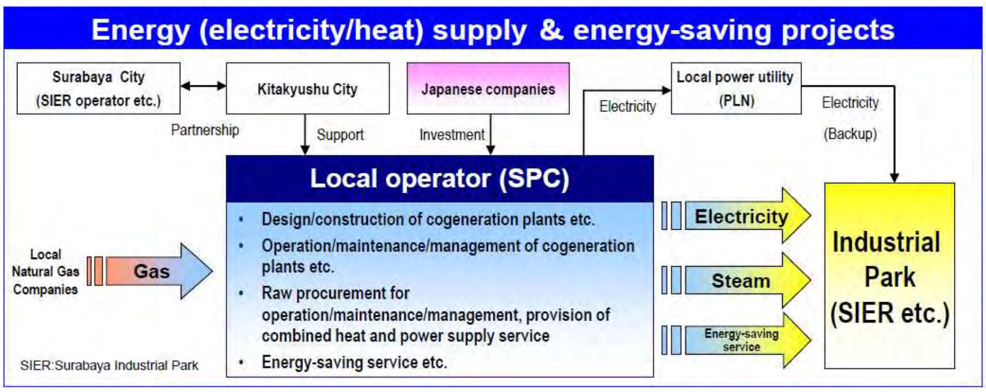
4. Power System Integration - Smart Grid

Smart Grid - case in Indonesia with Japanese technology

- Ministry of Economy, Trade and Industry (METI) implemented "**Export Promotion & Investigate Program of Infrastructure System**"
- **METI Feasibility Study (F/S) on Smart Community Business at SIER**
  (F/S members : 3 companies and a municipal organization in Japan)

[Source: Created from Google Maps]

- Utilization of the technologies and know-how of a pilot project in Japan
- **Provision of energy-related services to the tenant companies of SIER**
  - **Supply of heat (steam)**
  - **Supply of electricity**
  - **Energy-saving services**
  - **Reclaimed wastewater**
- **Sales of surplus power to the local power utility (PLN)**



Source : Fuji Electric Co., Ltd.

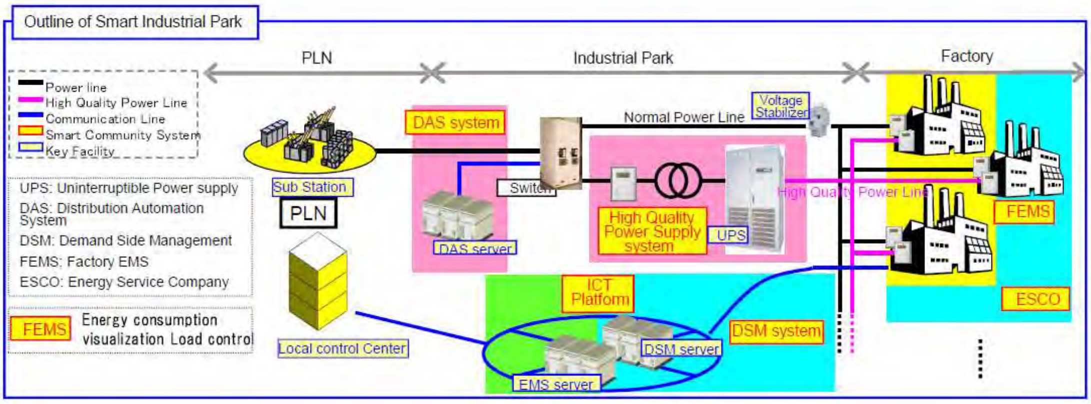
Smart Grid - case in Indonesia with Japanese technology

Project Description

Stabilization of power supply

Optimized energy management by the linkage of DSM and FEMS

Construction of smart community related basic infrastructure



Source : Fuji Electric Co., Ltd.

Smart Grid - Community Energy Management System(CEMS)

◆The Role of CEMS

New energy systems (soar and wind power) are not stable. Variation in electric power generated by the new energy systems cause the supply and demand imbalance. Demand for new energy is increasing significantly. A reverse power flow poses the voltage rise problem. CEMS plays a key role in solving these problems.

◆Key features

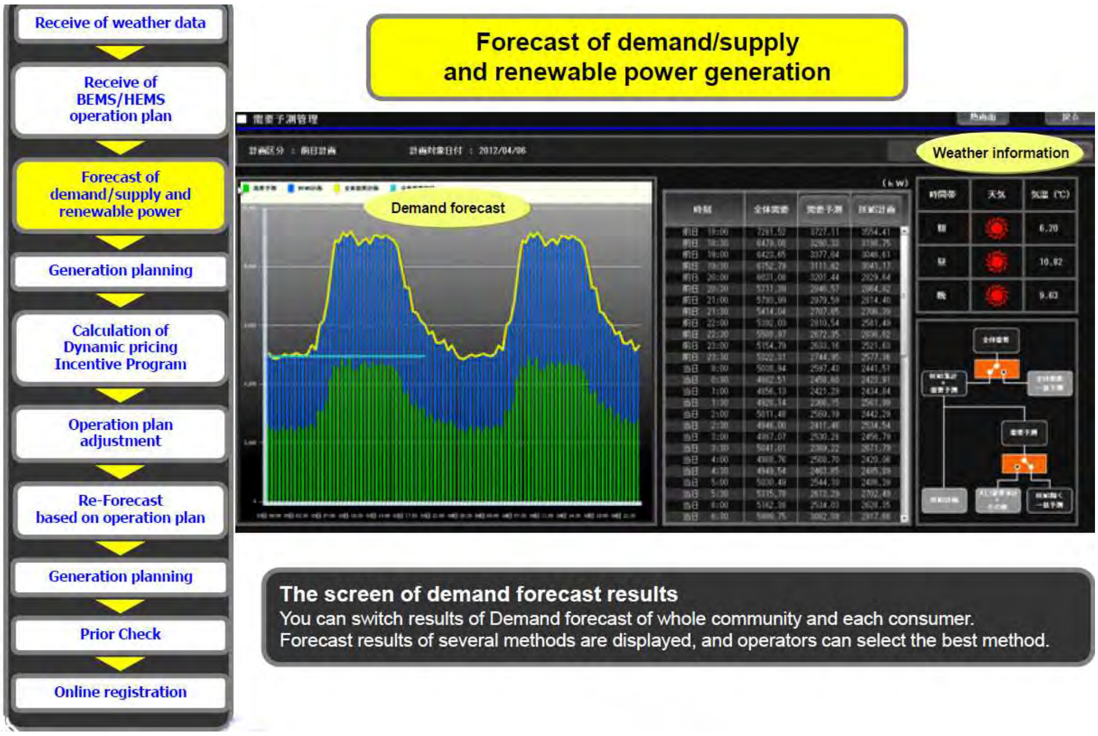
- Prediction of power generated by new energy (PV and Wind Turbine Generator)
- Optimized planning and control of supply and demand, and frequency control by utilization of storage batteries.
- Demand response service for balancing the load
- Smart meters for consumers

◆Extendibility

- Multi-languages (Japanese, English and Chinese)
- Control several regions by a single system
- All in one package

Source : Fuji Electric Co., Ltd.

Smart Grid - Example of CEMS Surface



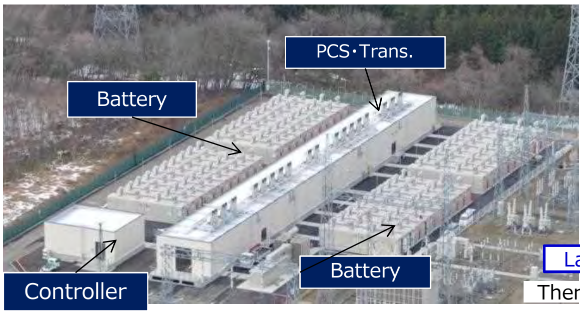
Source : Fuji Electric Co., Ltd.

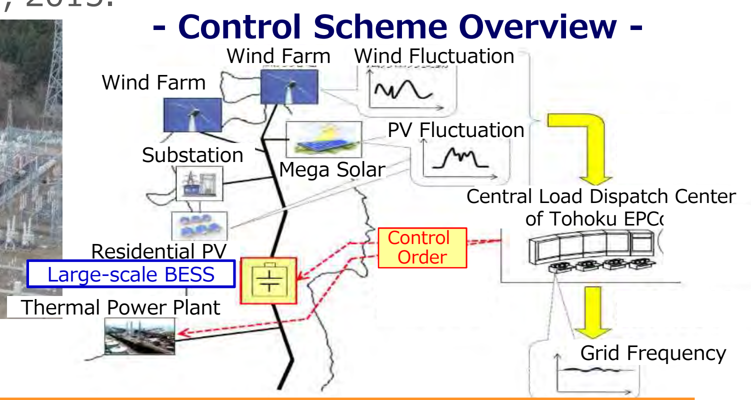
5. Power System Integration - Battery technologies

BESS - the would largest class installed in Japan with Lib(SCiB)

Nishi-Sendai Substation, Tohoku Electric Power Co.

- Construction started on Nov. 25, 2013
- Operation started in Feb. 20, 2015.

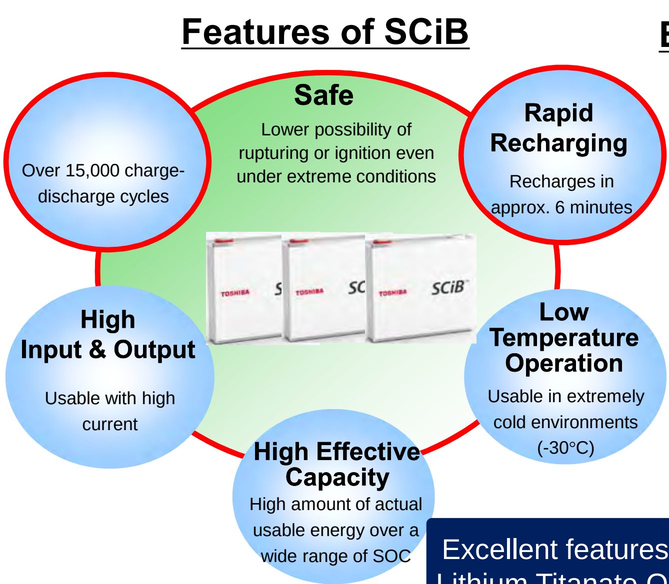


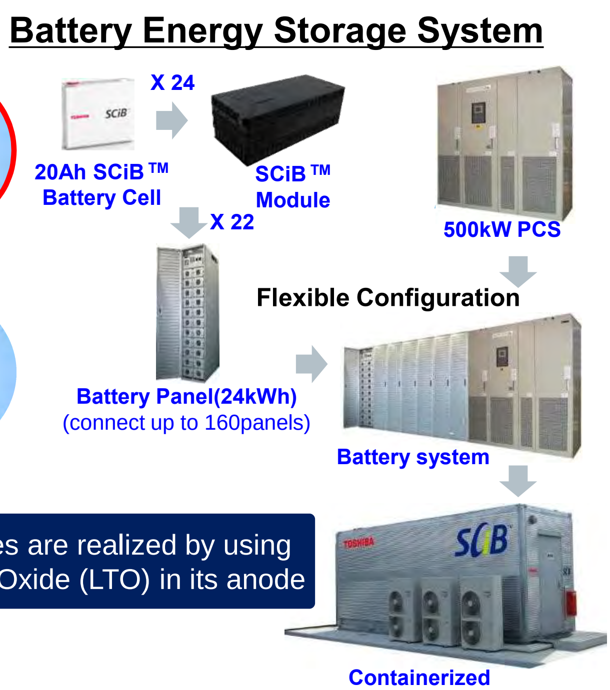


40MW-20MWh BESS for Frequency Regulation remotely controlled by central load dispatch center.

Source : Toshiba Cooperattion

Super Charge ion Battery (SCiB) – Hi-efficiency LiB



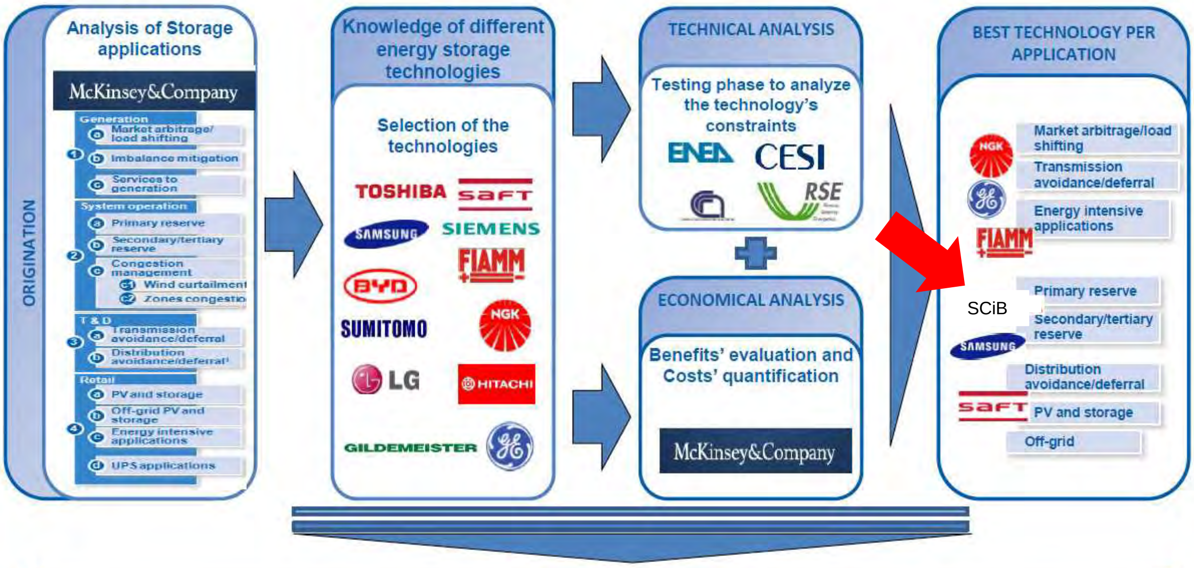


Excellent features are realized by using Lithium Titanate Oxide (LTO) in its anode

SCiB : Super Chargeable Li-ion Battery
SOC : State of Charge

Source : Toshiba Cooperation

Battery Characteristics – experiences in TERNA(Italy)



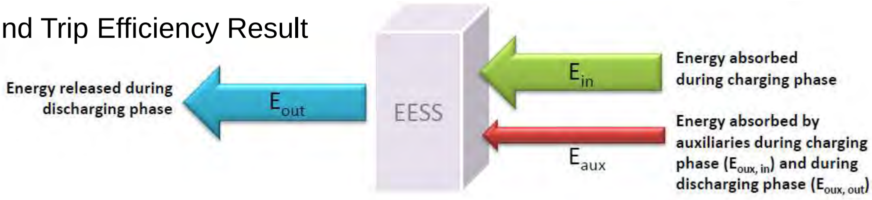
DEFINITION AND DEVELOPMENT OF A VIRTUAL STORAGE PLANT

A Platform capable of integrating the characteristics and limitations of each technology while maximizing their performance and reducing additional costs stemming from non-optimal usage

Source : **Experiences and Initial results from Terna's Energy Storage Projects (Terna-Itary)**

Battery Characteristics – experiences in TERNA(Italy)

AC/AC Round Trip Efficiency Result



$$\eta = \frac{E_{out} - E_{aux,out}}{E_{in} + E_{aux,in}}$$

System	Technology	AC/AC Efficiency
FIAMM	SODIUM NICKEL CHLORIDE	~ 80%
(*) GE	SODIUM NICKEL CHLORIDE	Data not available yet
SCiB	LITHIUM TITANATE	~ 86%
BYD	LITHIUM IRON PHOSPHATE	~ 83%
SAFT	LITHIUM NICKEL COBALT ALUMINA	~ 84% (**)
SAMSUNG	LITHIUM MANGANESE	~ 85%
(*) SIEMENS LG Batteries	LITHIUM NICKEL MANGANESE COBALT	Data not available yet

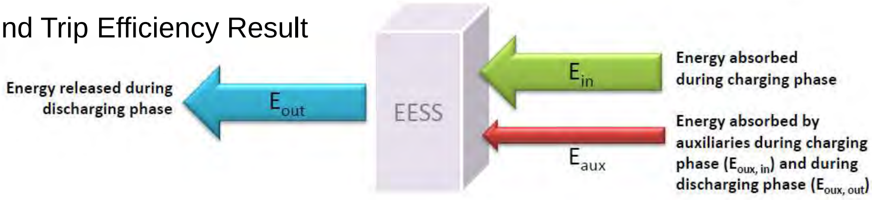
(*) Installed only in Sardinia

(**) Result obtained in Sardinia Site, in Sicily the efficiency is lower due to the different capacity of the system

Source : **Experiences and Initial results from Terna's Energy Storage Projects (Terna-Itary)**

Lib Battery Characteristics – experiences in TERNA(Italy)

AC/AC Round Trip Efficiency Result



$$\eta = \frac{E_{out} - E_{aux,out}}{E_{in} + E_{aux,in}}$$

System	Technology	AC/AC Efficiency
FIAMM	SODIUM NICKEL CHLORIDE	~ 80%
(*) GE	SODIUM NICKEL CHLORIDE	Data not available yet
SCiB	LITHIUM TITANATE	~ 86%
BYD	LITHIUM IRON PHOSPHATE	~ 83%
SAFT	LITHIUM NICKEL COBALT ALUMINA	~ 84% (**)
SAMSUNG	LITHIUM MANGANESE	~ 85%
(*) SIEMENS LG Batteries	LITHIUM NICKEL MANGANESE COBALT	Data not available yet

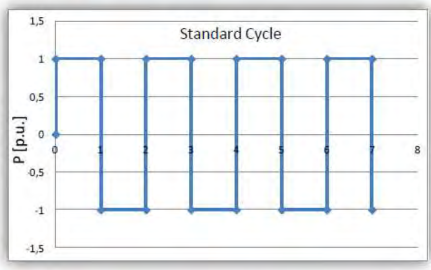
(*) Installed only in Sardinia

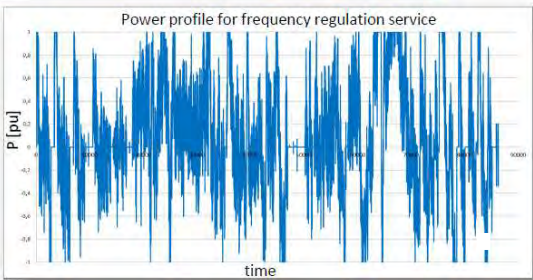
(**) Result obtained in Sardinia Site, in Sicily the efficiency is lower due to the different capacity of the system

Source : **Experiences and Initial results from Terna's Energy Storage Projects (Terna-Itary)**

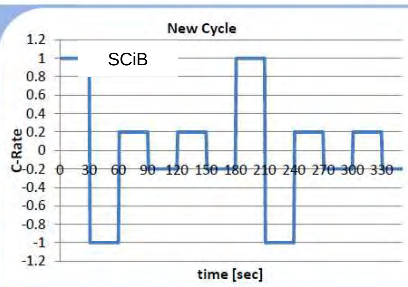
Lib Battery Characteristics – Next Aging Test

In order to verify if frequent and numerous power inversions impact the aging of the batteries more than heat or energy a new cycle has been defined





New test profile



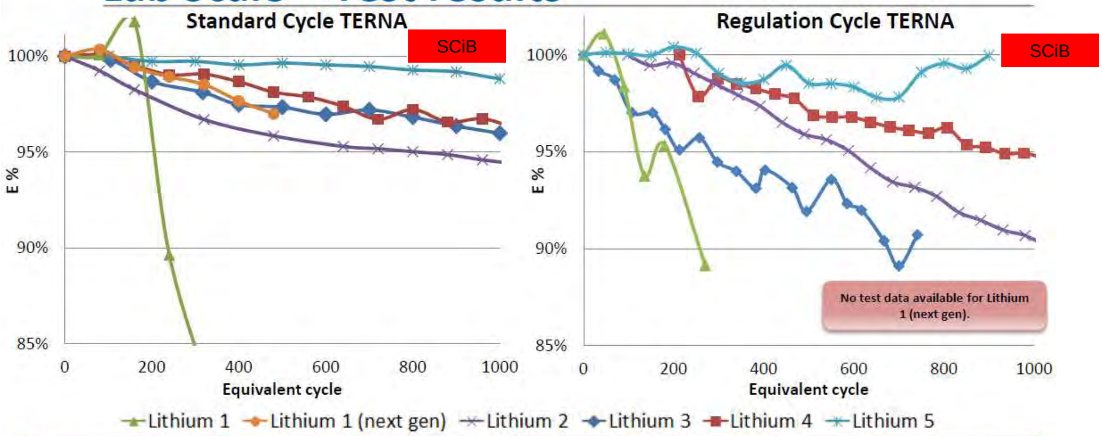
- Average C-rate: ≈ **0.46**
- Daily equivalent(*) cycles: **5.6**
- Daily power inversions: ≈ **2800**

Test initiated in 02/2016

Source : **Experiences and Initial results from Terna's Energy Storage Projects (Terna-Itary)**

Lib Battery Characteristics – Next Aging Test

Lab Scale – Test results



Module under test	Technology	Cycle	Number of cycles 100	200	300	400	500	1000	1500	2000	2500	3000	4000	5000	6000
Lithium 1	NCA	Standard Cycle Terna	100%	95%	85%	75%	-	-	-	-	-	-	-	-	-
		Regulation Cycle Terna	98%	95%	88%	-	-	-	-	-	-				
Lithium 2	NCM	Standard Cycle Terna	99%	98%	97%	97%	96%	94%	93%	92%	91%				
		Regulation Cycle Terna	100%	100%	98%	97%	96%	90%	-	-	-	-	-	-	-
Lithium 1 (next gen)	NCA	Standard Cycle Terna	100%	99%	99%	98%	97%	-	-	-	-	-	-	-	-
		Regulation Cycle Terna	-	-	-	-	-	-	-	-	-	-	-	-	-
Lithium 3	LFP	Standard Cycle Terna	100%	99%	98%	97%	97%	96%	-	-	-	-	-	-	-
		Regulation Cycle Terna	97%	95%	94%	94%	92%	-	-	-	-	-	-	-	-
Lithium 4	LMO	Standard Cycle Terna	100%	99%	99%	99%	98%	96%	96%	94%	93%	91%	-	-	-
		Regulation Cycle Terna	100%	100%	99%	98%	97%	95%	-	-	-	-	-	-	-
Lithium 5	LTO	Standard Cycle Terna	100%	100%	100%	100%	100%	99%	98%	97%	96%	96%	95%	95%	94%
		Regulation Cycle Terna	100%	100%	99%	99%	99%	99%	-	-	-	-	-	-	-

Data at Jenuary 2016

* Equivalent cycles are obtained dividing the daily energy discharged, by module's nominal energy

Source : **Experiences and Initial results from Terna's Energy Storage Projects (Terna-Itary)**

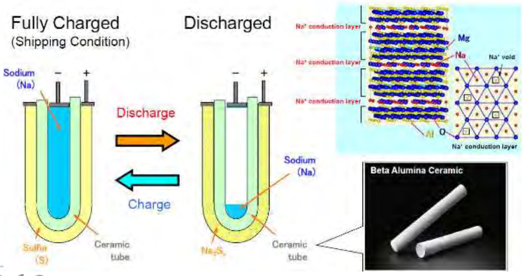
NAS Battery – principle

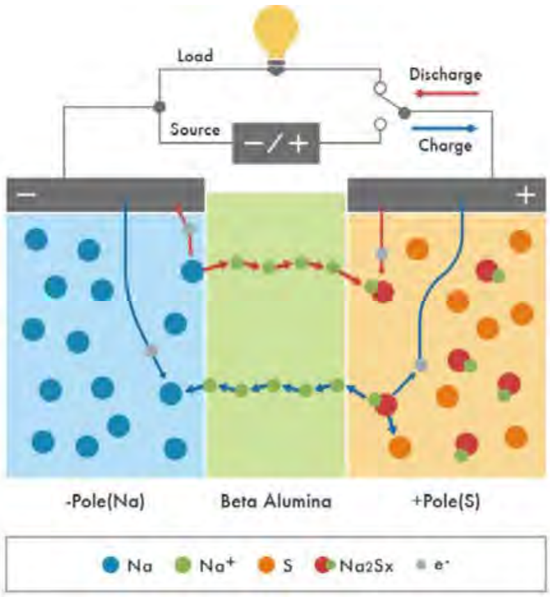
Discharge

If a load is connected to terminals, electric power is discharged through the load. During the discharge, sodium ions converted from sodium in a negative electrode pass through solid electrolyte then reach to sulfur in positive electrode.
The electrons finally flow to outside circuits. The electric power is generated by such current flow.
With the progress of the discharge, sodium polysulfide is formed in positive electrode; on the contrary, sodium in negative electrode will decrease by consumption.

Charge

During the charge, the electric power supplied from outside form sodium in negative electrode and sulfur in positive electrode by following the reverse process of the discharge. Because of this, the energy is stored in the battery.

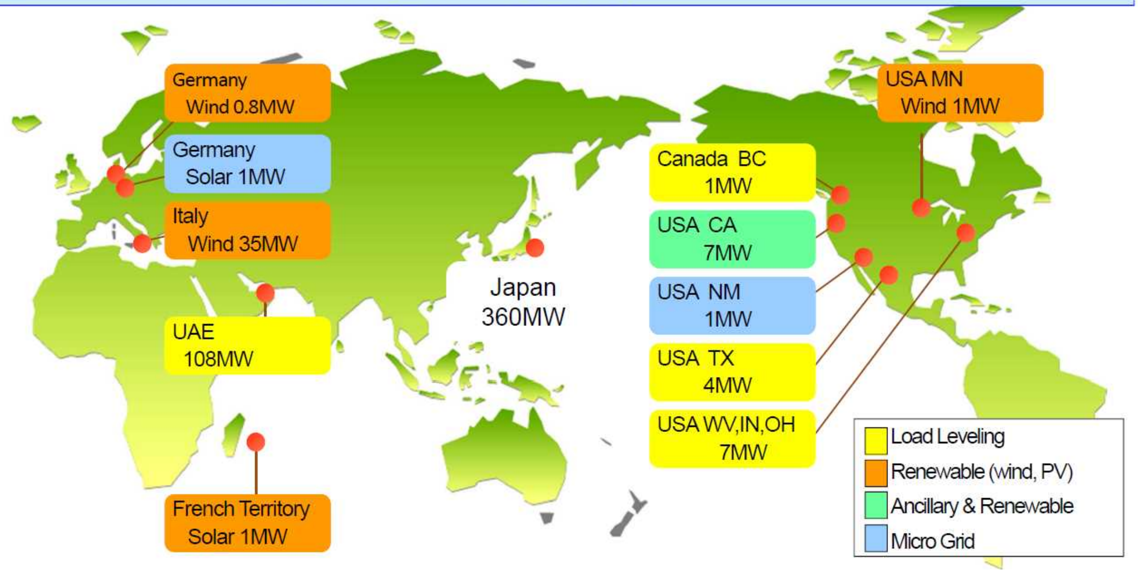




Source : NGK Insulators Ltd.

NAS Battery – footprint of NAS for multipurpose

■Outstanding supply record in Large Scale Battery Energy Storage
Total Installation Record of 530MW (3700MWh) (as of Oct. 2015, incl. under construction)
■Annual Production Capacity 150MW (1GWh)

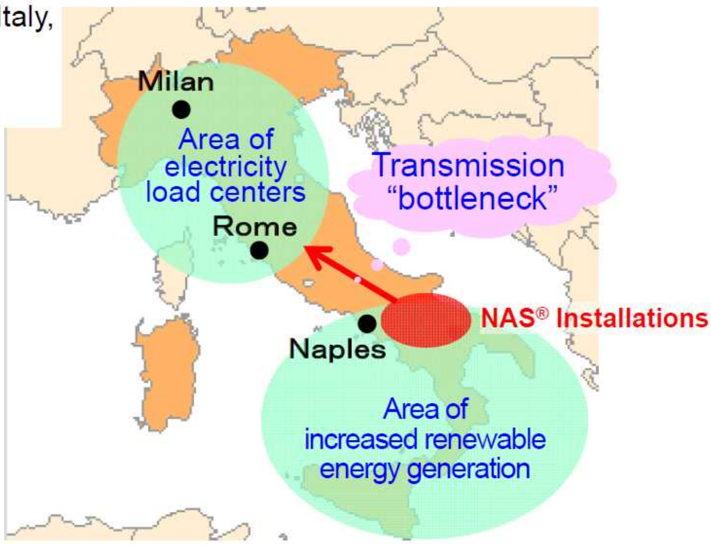


Source : NGK Insulators Ltd.

NAS Battery – footprint of NAS for multipurpose

■ Fast and massive growth of renewable energy in south region could not be transmitted to electrical load center in north due to transmission bottle neck.
■ NAS® Battery optimize integration of renewable energy and reduce transmission congestions, and allow investment deferral of new transmission line.

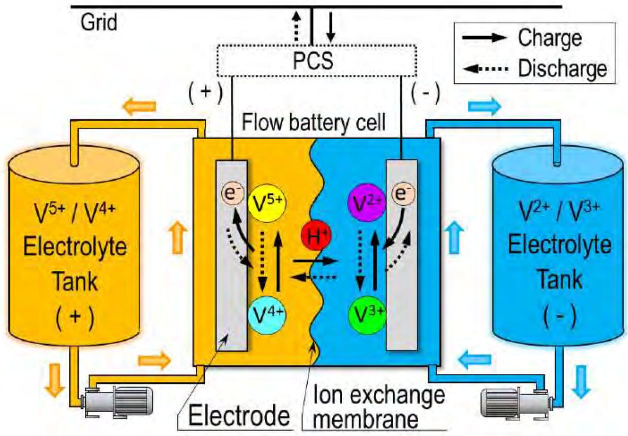
NAS® connected to transmission line in Italy, total 35MW/230MWh at 3 substations, started operation from 2015.



Source : NGK Insulators Ltd.

Vanadium Redox Flow Battery – principle

- Using the charge-state differences of vanadium ions dissolved in sulfuric acid
- No degradation of electrolyte occurs during charge / discharge cycle
  - → Long Lifetime: 20+ years
  - → No limit to the Number of Cycles
- Power (MW) and Energy (MWh) separately designed
  - → Simple BMS with long duration

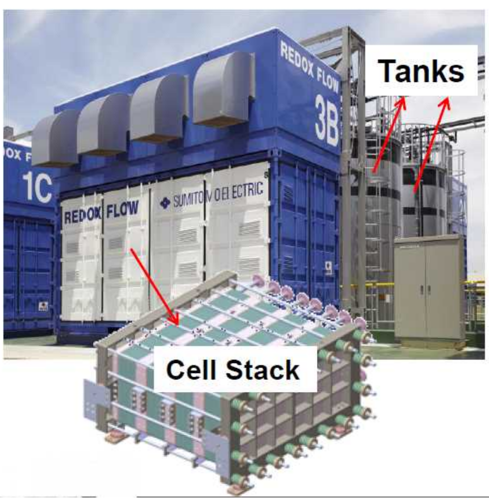


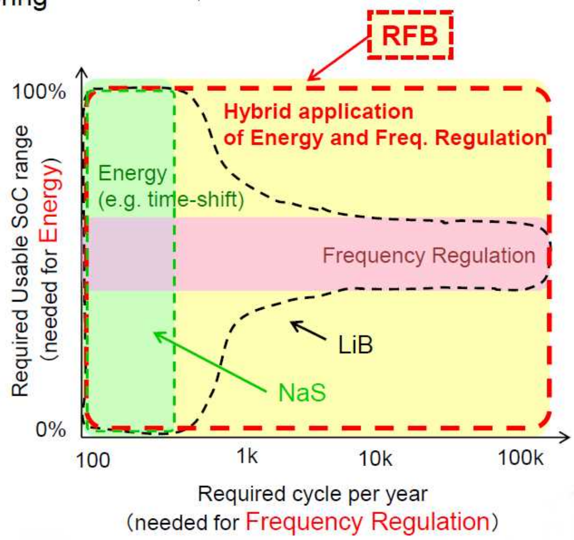
Source : Sumitomo Electric Industry Ltd.

Vanadium Redox Flow Battery – advantages

- Long lifetime (20+ years)
- No limit of cycles at full charge/discharge DoD=100%
- Long duration (up to several hours)
- Fast response (< 0.1 sec)
- Accurate SoC (State of Charge) monitoring
- Non-combustibility, Non-flammability

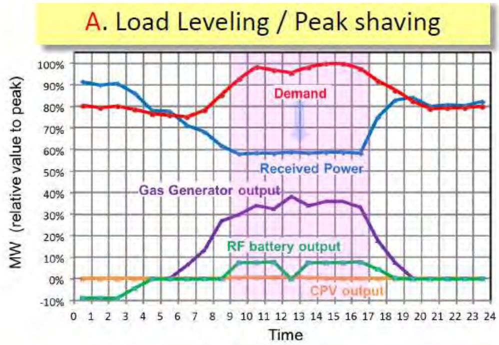
Ideal for Hybrid Applications: both Energy time-shift & Frequency Regulation

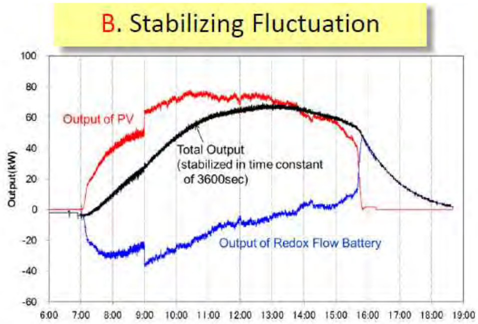


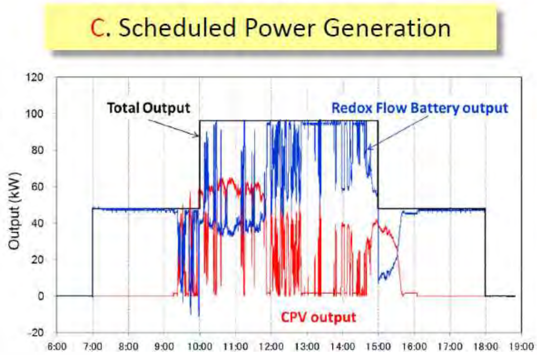


Source : Sumitomo Electric Industry Ltd.

Vanadium Redox Flow Battery – Multi purpose of usage





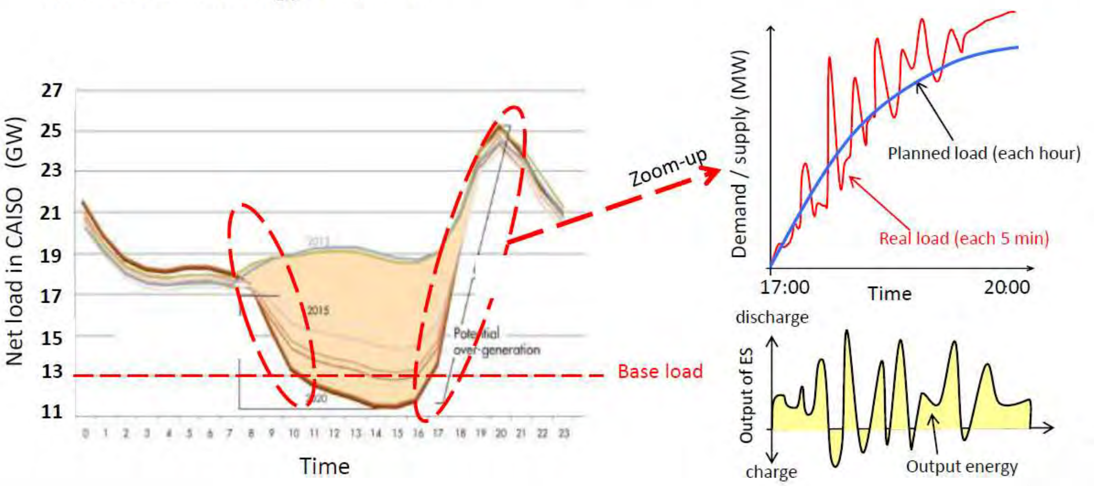


Please notice: in this test our RFB operates with CPV solar (not simply with standard PV). The CPV power output is highly dependent on strong solar radiation. These data were recorded in a cloudy day with rapid fluctuations of solar radiation, so that CPV output fluctuated dramatically. This figure confirms that our RFB can absorb the rapid CPV output fluctuations, ensuring the planned total output.

Source : Sumitomo Electric Industry Ltd.

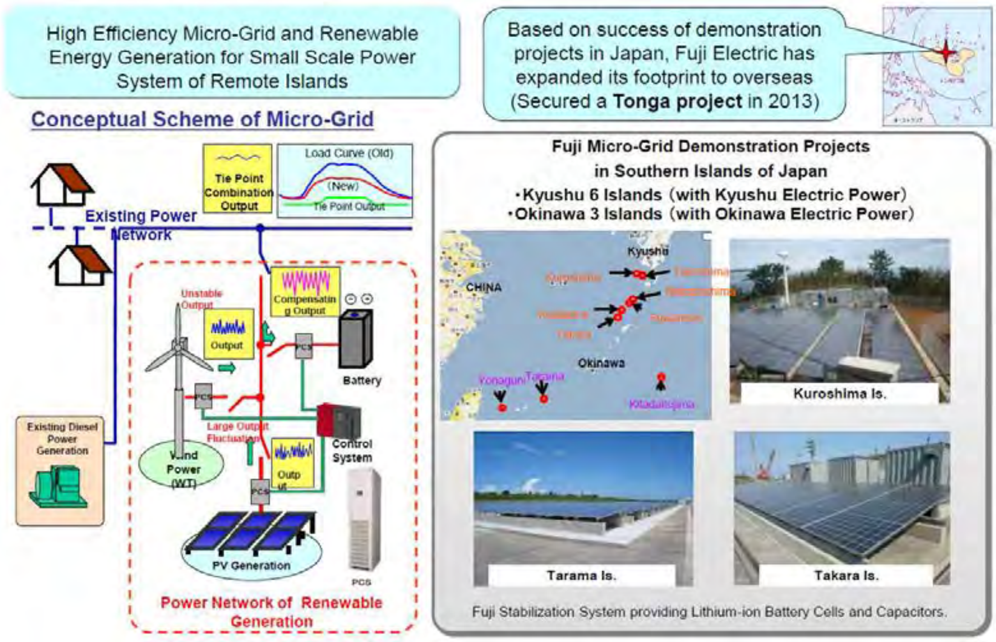
Vanadium Redox Flow Battery – highlighted in US

- Joint demonstration project with a utility in California
- **2 MW x 4h** system in utility's substation
- Expected to be commissioned in middle of 2016
- To demonstrate that RFB can be used for both fast response and long duration applications and it is the best solution to address issues caused by increased use of renewable energy resources



Source : Sumitomo Electric Industry Ltd.

Electrification – Micro grid technology to off-grid integration



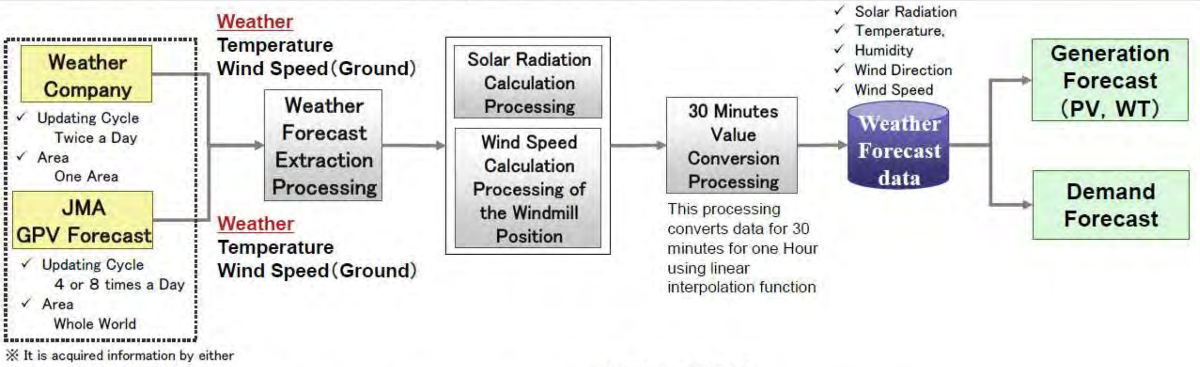
It's based on the smart grid's technology to stabilize the grid.

Source : Fuji Electric Co., Ltd.

6. To do the better system operations

Weather Forecast - to predict the output from REs

An Outline of the Function
This function can edit forecast data provided by Japan Meteorological Agency (JMA) or weather company, such as cloudiness, temperature, wind speed, as a weather forecast data format which EMS can utilize, and also, it can correct that data. This weather forecast data can utilize as generation and demand forecast function.



Conversion Method of the Solar Radiation

- ✓ Acquire cloudiness in GPV and convert it into solar radiation

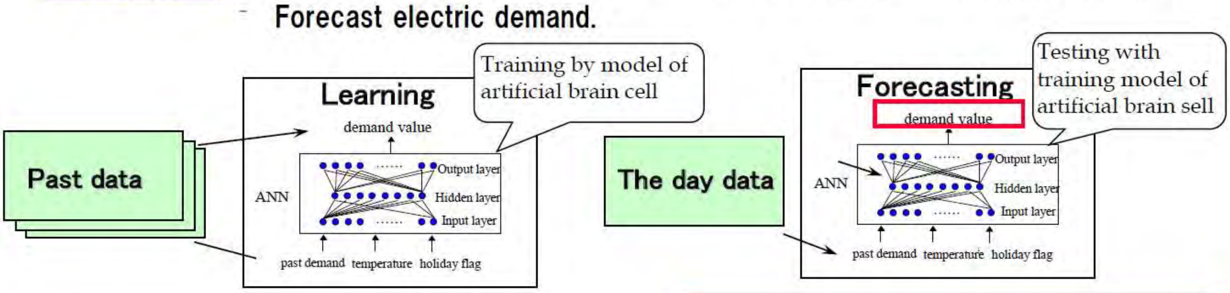
What is GPV ?

- ✓ Abbreviations of Grid Point Value.
- ✓ A weather forecast data of mesh space (e.g., 20km lattices) by JMA.
- ✓ This data is provided for a fee by Japan Meteorological Business Support Center.

Source : Fuji Electric Co., Ltd.

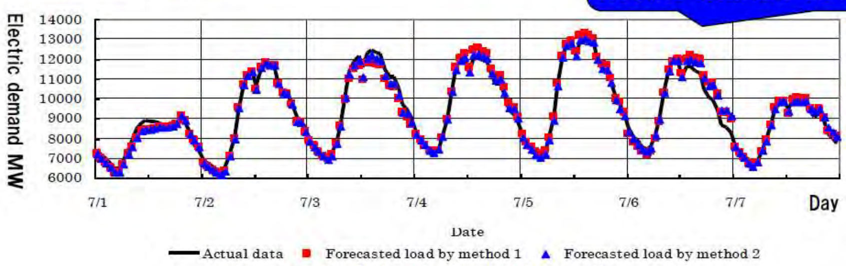
Demand Forecast - to make the better allocation of Generations

Outline
- Learn relation between weather condition/calendar and electric demand.
- Forecast electric demand.



Validation example

Confirm that it is possible to forecast electric demand of weekday and holiday.



An example of electric demand forecasting result

Source : Fuji Electric Co., Ltd.

7. Hydro power technique -Adjustable speed pumped storage plant

Hydropower technique

- ✓ Adjustable Speed Pumped Storage Power Plant
- ✓ River system Development

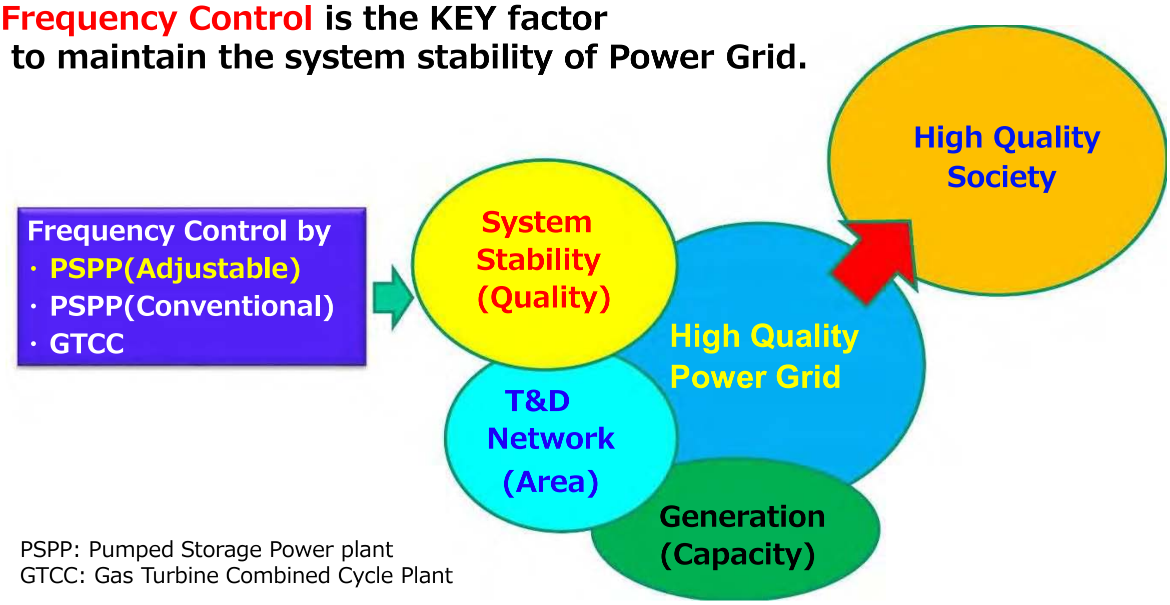
Brief introduction for Advantages of Adjustable Speed Pumped Storage Plant

1. Why is the Adjustable Speed PSPP recommended?
2. Economical benefit for utility
3. Back ground of development
4. How to change pumping input
5. Operation range of pump-turbine
6. Summary

1. Why is the Adjustable Speed PSPP recommended?

High Quality Power Grid is the foundation of High Quality Society

Frequency Control is the KEY factor to maintain the system stability of Power Grid.



PSPP: Pumped Storage Power plant
GTCC: Gas Turbine Combined Cycle Plant

1. Why is the Adjustable Speed PSPP recommended?

Comparison of Characteristic of Plant for Frequency Control

	Frequency Control Capability(*1)	Fuel Cost	O&M Cost	Emission	Erection Period
Adjustable Speed PSPP	Very Good	Good	Good	Good	Acceptable
Conventional PSPP	Acceptable	Good	Good	Good	Acceptable
GTCC	Acceptable	No Good	No Good	Acceptable	Good

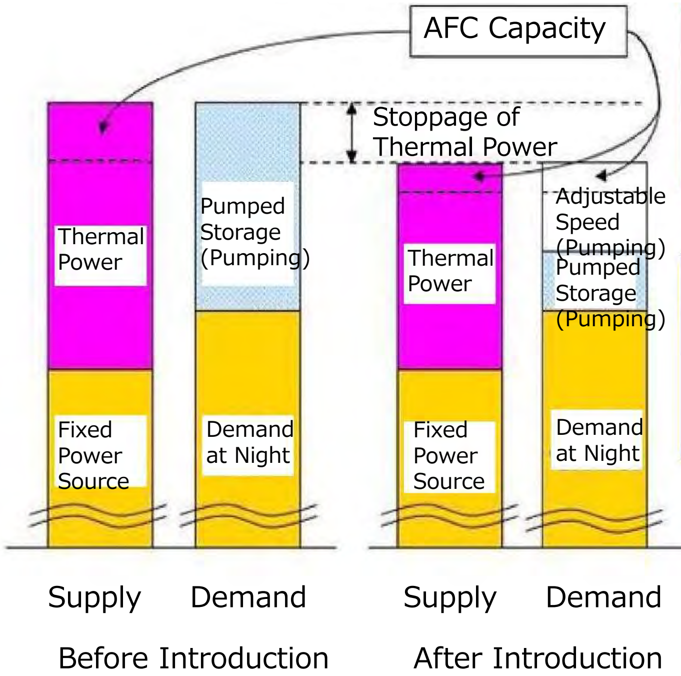
Note(*1) : Response Speed and Availability

1. Why is the Adjustable Speed PSPP recommended?

- Advantages
  1. Governor Free Operation
  2. Wide Operation Range and High Efficiency in Partial Load Operation
  3. Realizing Reduction of Operation Cost for Thermal Power Plant and Increase of Operation Profit for Pumped Storage Plant

- Disadvantages
  1. Larger size excitation system is required.
  2. Longer construction period (3 - 6 months for rotor assembling work) is required.

2. Economic benefit for utility



After introduction of Adjustable Speed System, AFC & GF capability at night is replaced from Thermal Power to Adjustable Speed System.

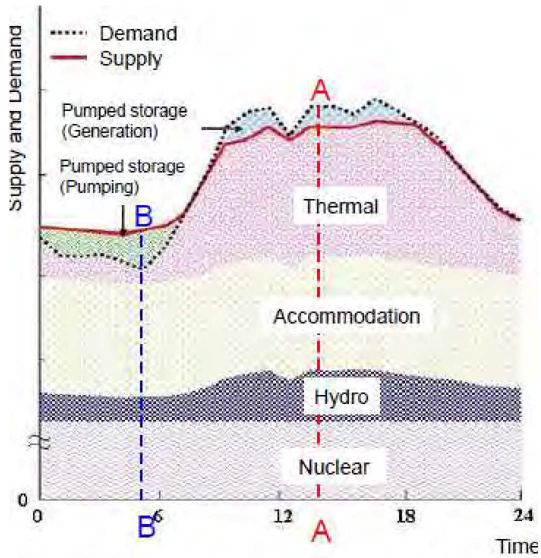
Advantage

Reduction of
- Thermal Power operation cost
- CO2 emission
- Pumping input

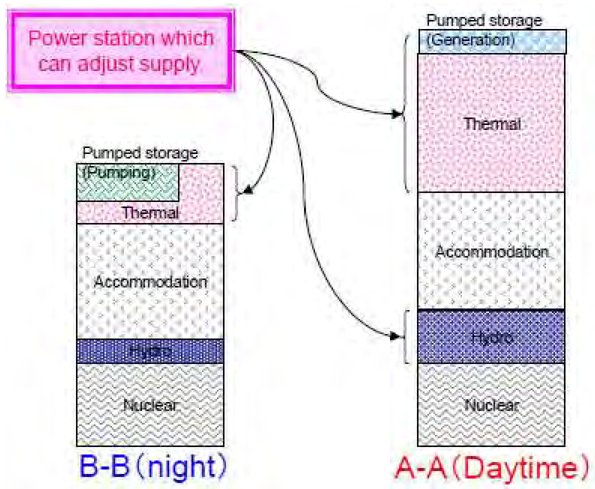
Additional Advantage

-Hydropower equipment are tougher than Thermal Power equipment to load variation. To concentrate supply and demand control to adjustable speed system, it will reduce total maintenance cost of other equipment.

3. Background of development



Typical daily supply and demand curve



At night, thermal power units stop due to demand reduction. It becomes difficult to maintain AFC & Governor Free capacity.

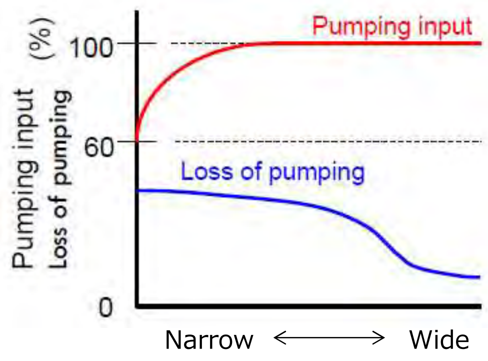
How can Pumped Storage work for AFC & GF at night ?

Development of the Adjustable Speed Pumped Storage System

4. How to change pumping input

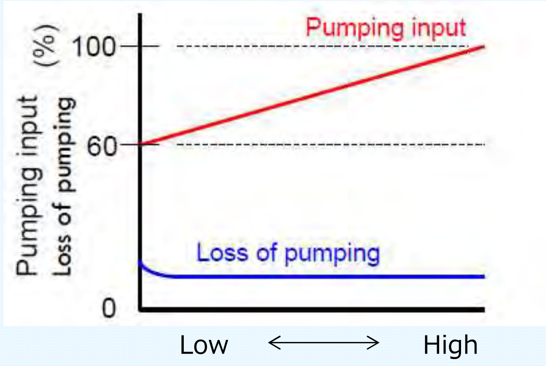
There are two methods to change pumping input.

① Changing of wicket gate opening



Loss of pumping and machine vibration increase at narrow area.

② Changing of rotating speed

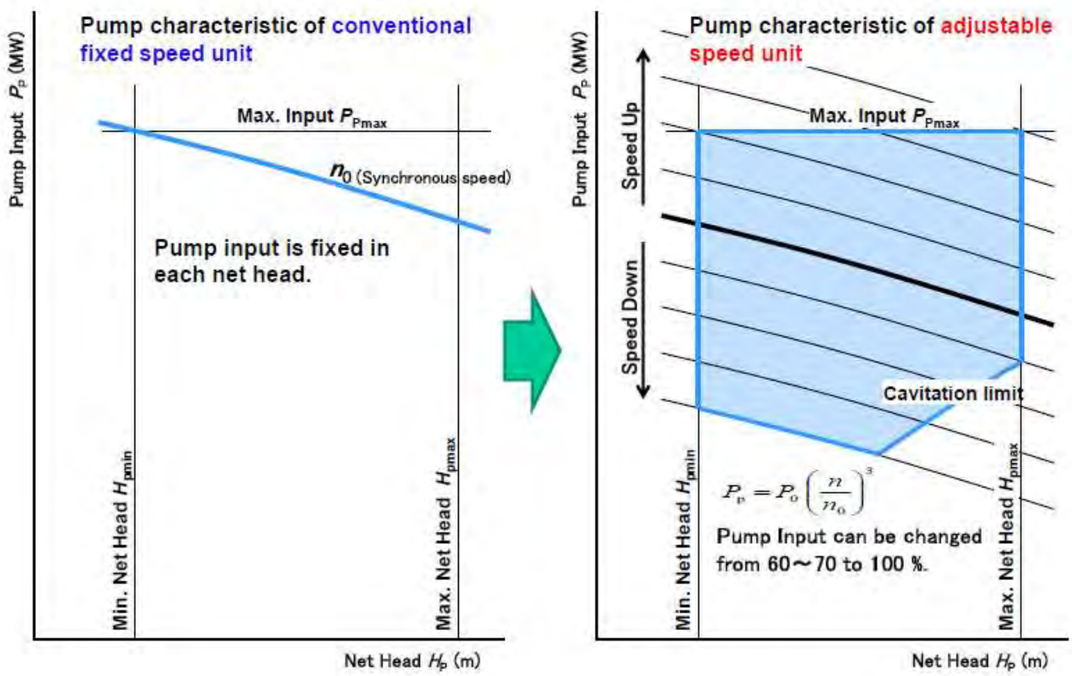


Pumping input can be changed smoothly and loss of pumping can be kept at low level.

Advantage of Speed Change

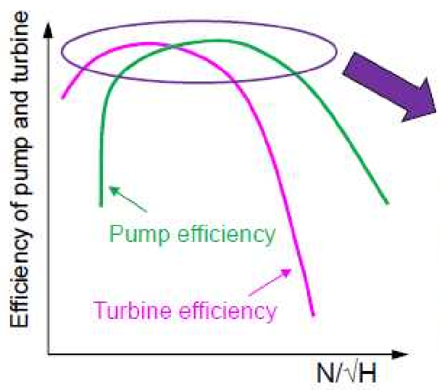
5. Operation Range of Pump-Turbine (Pump Operation)

Expansion of operation range

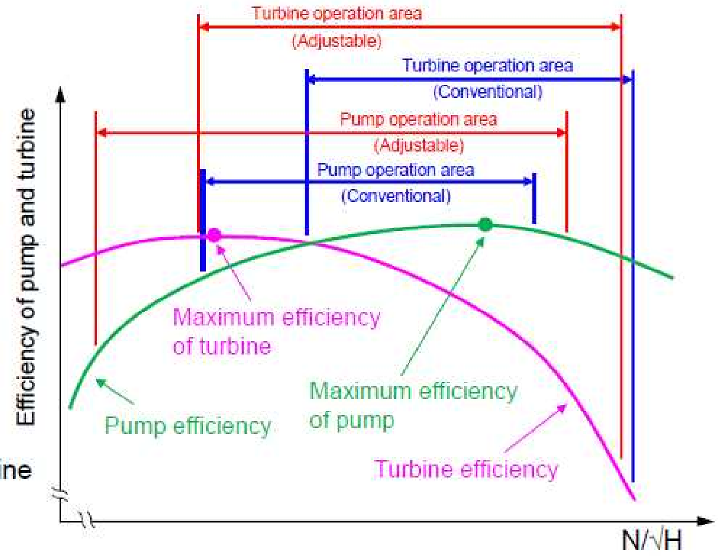


5. Operation Range of Pump-Turbine

- **Conventional System**
  Maximum efficiency speed of pump and turbine is not same. Pump characteristic is preceded. Actual operation speed does not provide maximum turbine efficiency.
- **Adjustable Speed System**
  Actual operation speeds of pump and turbine can approximate to each maximum efficiency speed. These speeds provide higher efficiency.

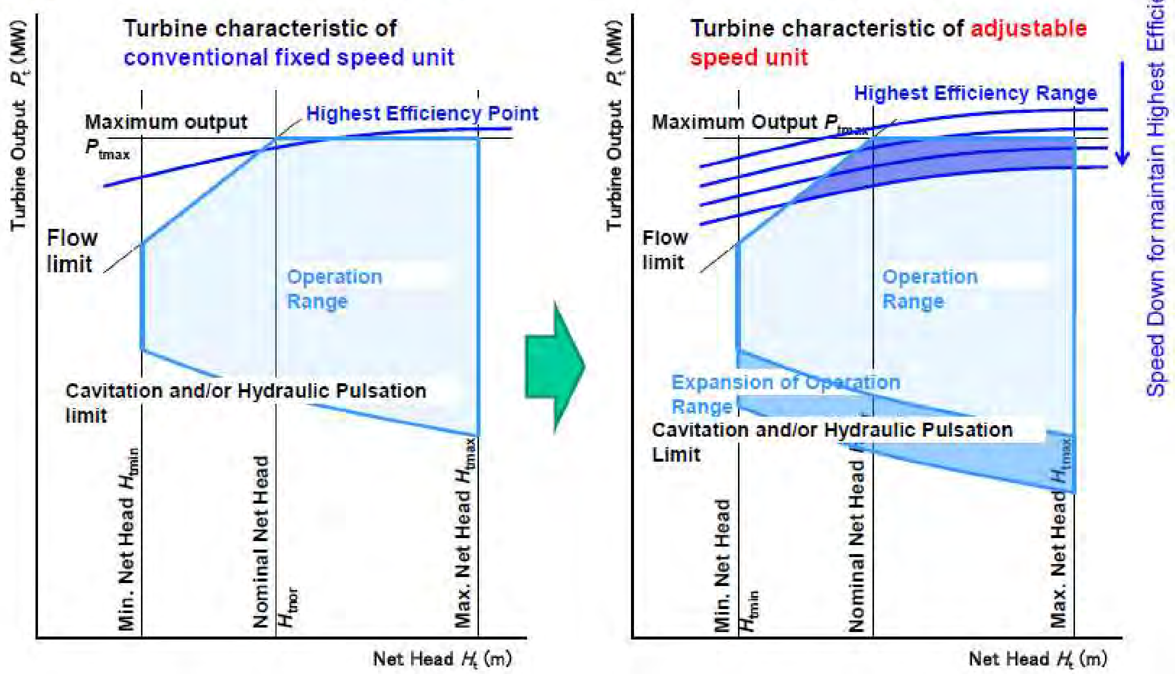


Efficiency characteristics of pump-turbine

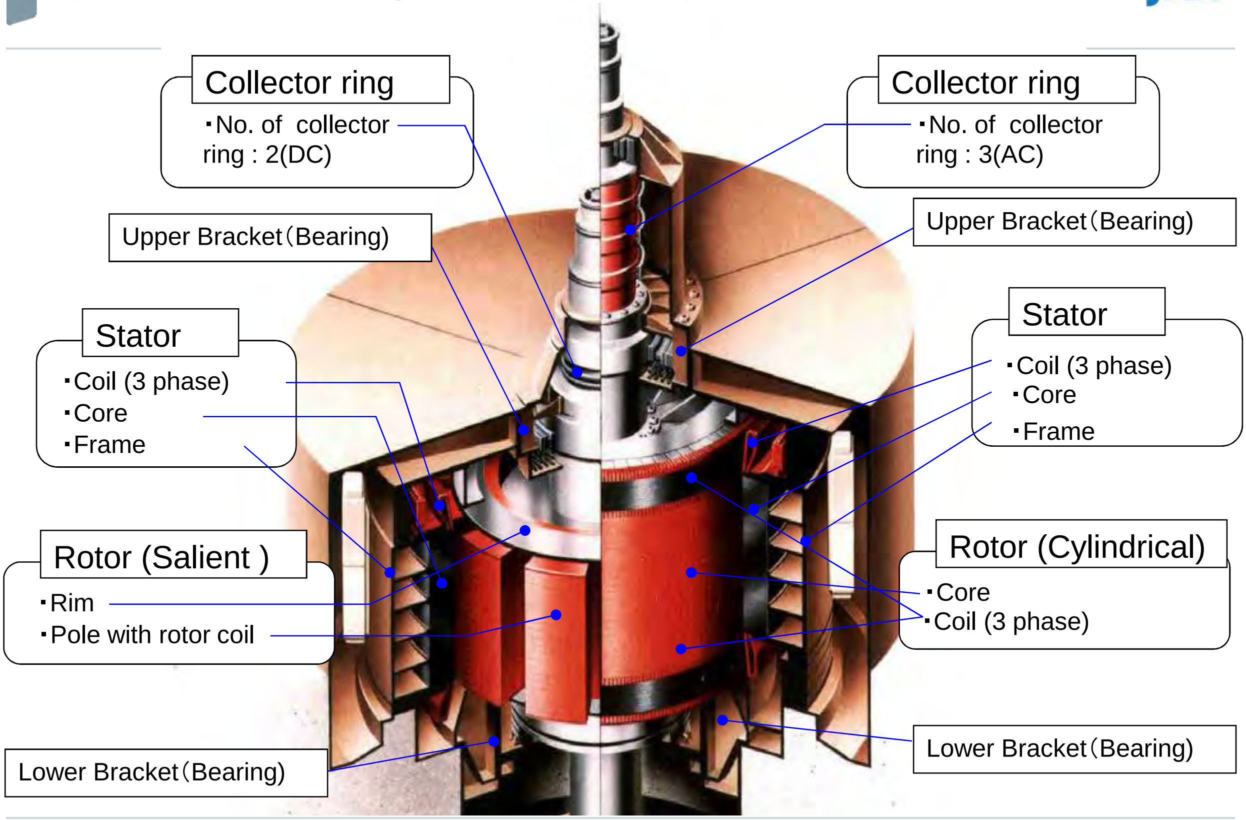


5. Operation Range of Pump-Turbine (Turbine Operation)

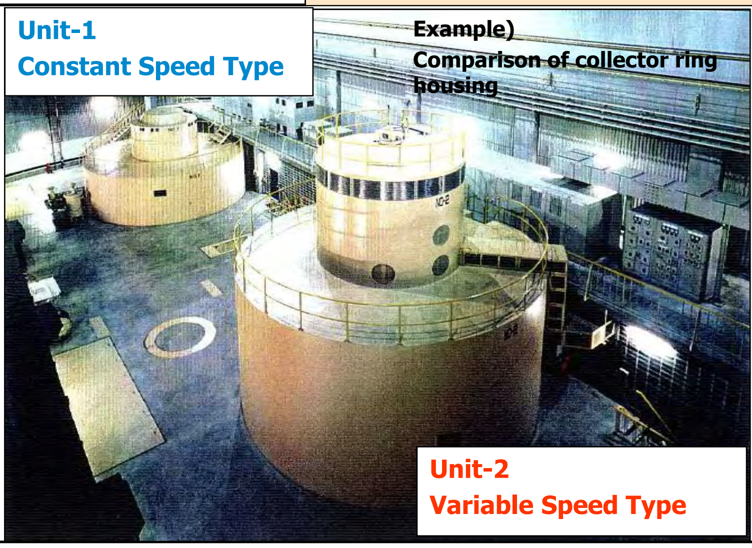
Expansion of operation range



[for Reference] Deference of Rotor Construction (Conventional & Adjustable Speed System)



[for Reference] Deference of Rotor Construction (Conventional & Adjustable Speed System)

Constant Speed Type Generator-motor	Collector ring	Variable Speed Type Generator-motor
		**AC excitation** @ No. of collector ring is 3 (each phase). ⬇ There are much more brushes than constant type. ⬇ @ Motor fan is set for carbon dust adsorbing

6. Summary

- AFC operation function at pumping
  - Adjustable-speed pumped storage can control pumping power by changing rotating speed, on the other hand conventional type can not.
- Quick response function
  - Adjustable-speed pumped storage can control active power instantly to convert rotational energy to electric energy with controlling AC excitation device at generating and pumping.
  - This characteristic contributes to the suppression of frequency and voltage fluctuations caused by RE.
- Improvement turbine efficiency and wide operational range
  - Adjustable rotating speed make turbine efficiency higher and operating condition better. Therefore the damage of turbine caused by cavitation is reduced and available head and output range are increased.

[for Reference] Adjustable Speed Pumped Storage System - Commissioned Project in the World -

Owner	Power Station	Capacity*Unit	Manufacturer	COD
Tokyo Electric Power Co.	Yagisawa	80MW*1	Toshiba	1990
Hokkaido Electric Power Co.	Takami	100MW*1	HM Hydro	1993
Kansai Electric Power Co.	Okawachi	320MW*2	HM Hydro	1995
Tokyo Electric Power Co.	Shiobara	300MW*1	Toshiba	1995
Electric Power Development Co.	Okukiyosu No.2	300MW*1	Toshiba	1995
Electric Power Development Co.	Yambaru sea water	30MW*1	Toshiba	1999
Germany	Goldisthal	300MW*2	ANDRIZ	2003
Kyushu Electric Power Co.	Omarugawa	300MW*4	HM Hydro	2007
Slovenia	AVCE	200MW*1	HM Hydro	2010
Tokyo Electric Power Co.	Kazunogawa	400MW*1	Toshiba	2014
Hokkaido Electric Power Co.	Kyogoku	200MW*2	Toshiba	2015
Kansai Electric Power Co.	Okutataragi	320MW*2	HM Hydro	Under Construction

Source: JICA Study Report 2012, Study team revised

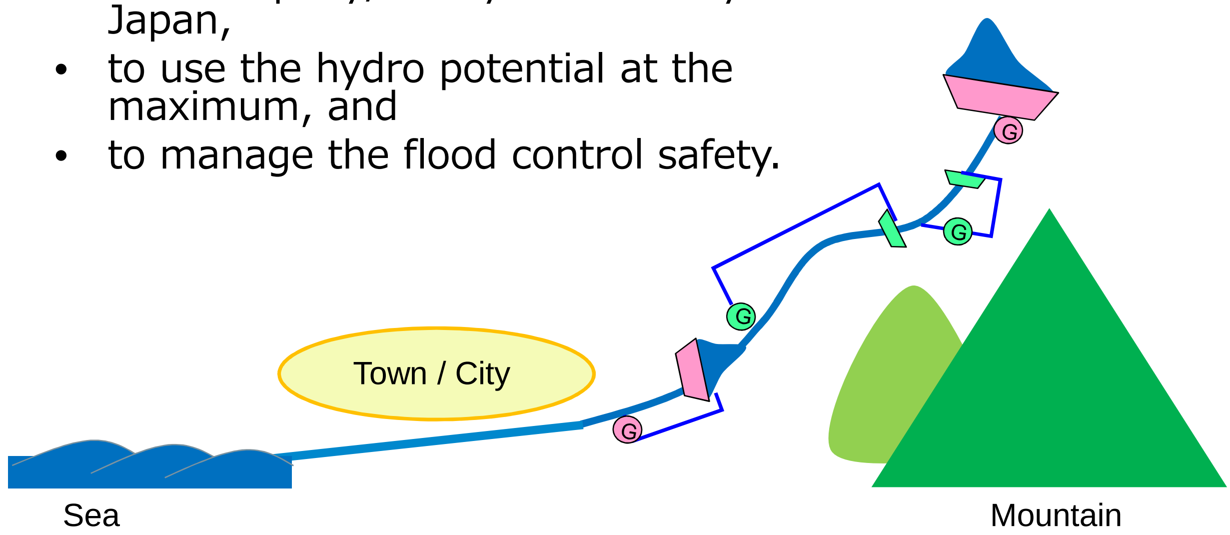
Brief introduction for River System Development

1. The way of development in river system in case of Japan
2. Optimum & safety operation
3. Optimization for Generation Plan
4. Safety Dam operation
   a. Safety dam control at flood period
   b. Simulation system for training
5. Summary

---

1. The way of development in river system

- One river system – One developer
  - One river system had been developed by one company/ utility traditionally in Japan,
  - to use the hydro potential at the maximum, and
  - to manage the flood control safety.



2. Optimum & Safety Operation

- Normal time
  - ✓ Operation controlled the guide vane according to the optimum generation plan
    - ➢ Optimum operation
- Flood time
  - ✓ Operation controlled the spillway gate according to the law/ rule, after reaching the full capacity
    - ➢ Safety operation

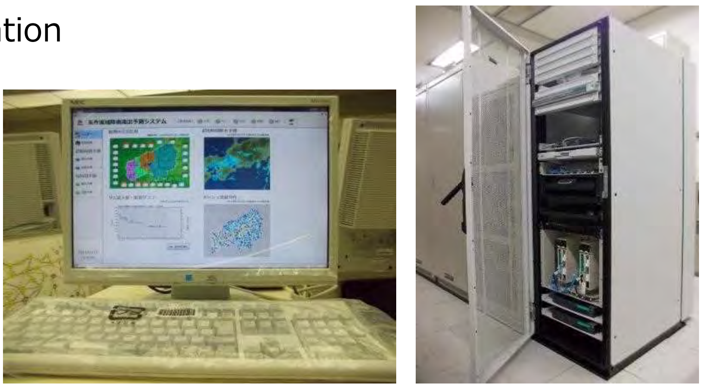
---

3. Optimization for generation plan

- Annual Plan
  - ➢ Operational cost, Efficiency, Rule curve, Inflow volume, Downstream requirement water volume, Outage plan at each PP, Time of arrival from upper dam
- Monthly plan
  - ➢ Breakdown of annual plan, considering the relevant information
- Daily Plan (One day before)
  - ➢ Input the latest information

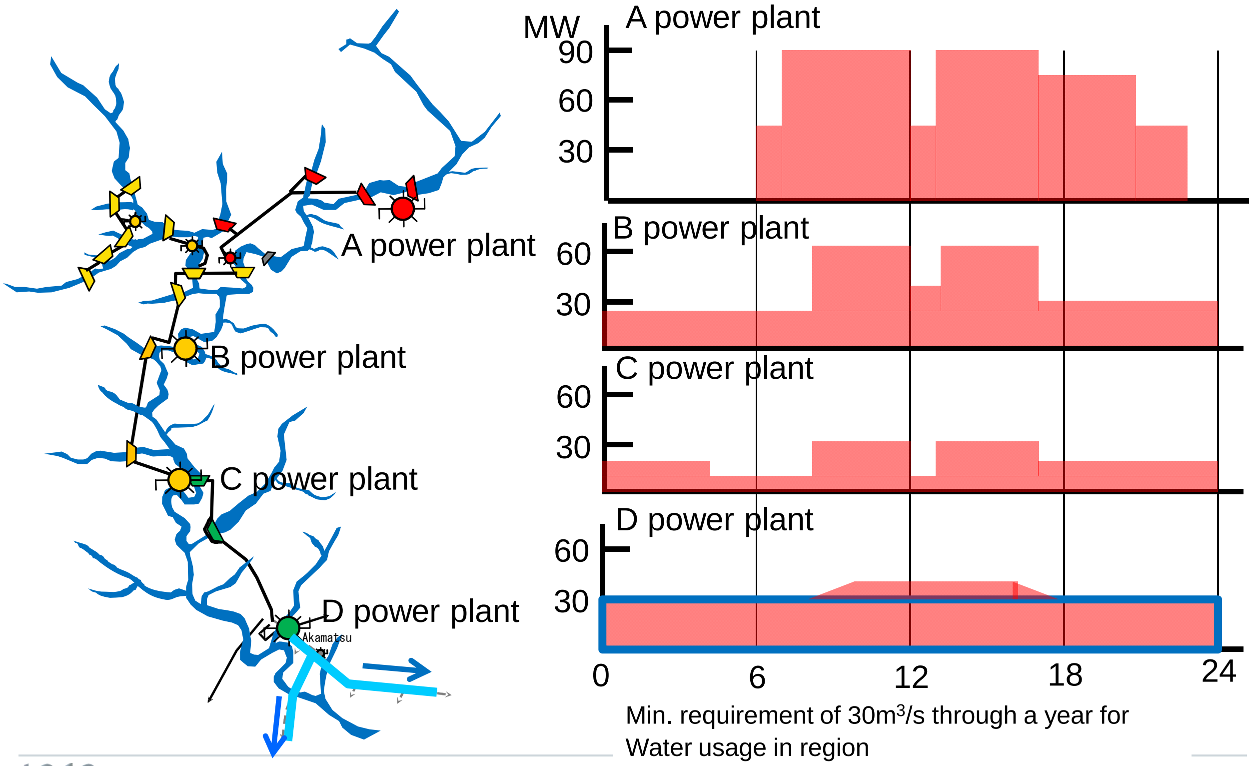
✓ Development of a support system for the hydropower plant operation in river system:

Calculate the operation plan at each power plant to be optimum by considering/ inputting such as operational cost and efficiency at each power plant, rain fall, inflow, reservoir conditions, and demand.



Support System PC & Server

3. Optimization for generation plan



Min. requirement of $30m^3/s$ through a year for Water usage in region

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Example

Example of Hida River

(Basic features)

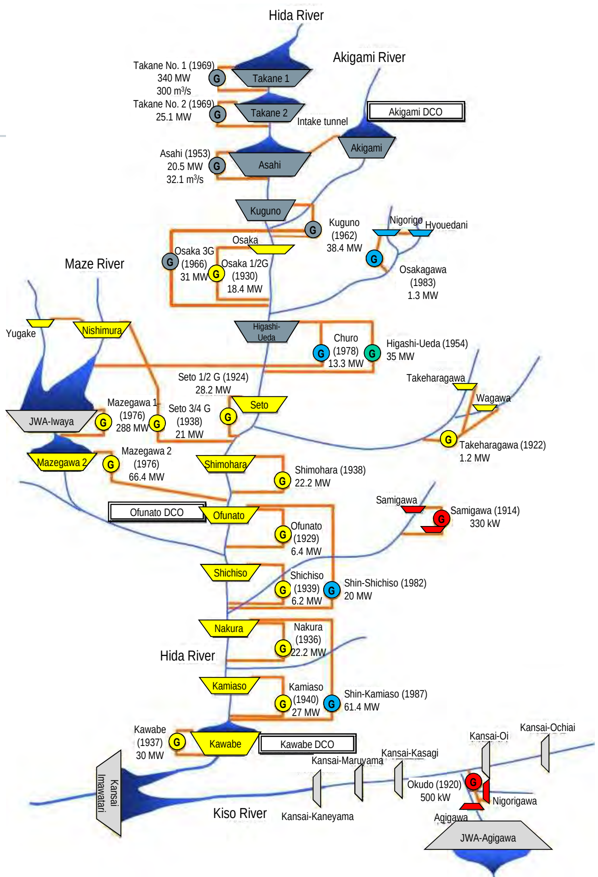
- Hida River (tributary of Kiso River): L=150 km, CA=2,160 sq.km
- 22 hydropower stations
- Total generation capacity: 1,145 MW

(Stages of development)

1. Early days: 1910s - 20s
2. ROR development period: 1920s - 40s
3. Large dam development period: 1950s - 70s
4. Re-development period: 1970s - 80s

(Centralization of operation)

- Three (3) Dam Control Offices (DCOs) are operating and maintaining 22 hydropower stations.



4. Dam operation

- Normal time
  - Maintaining of original function of river

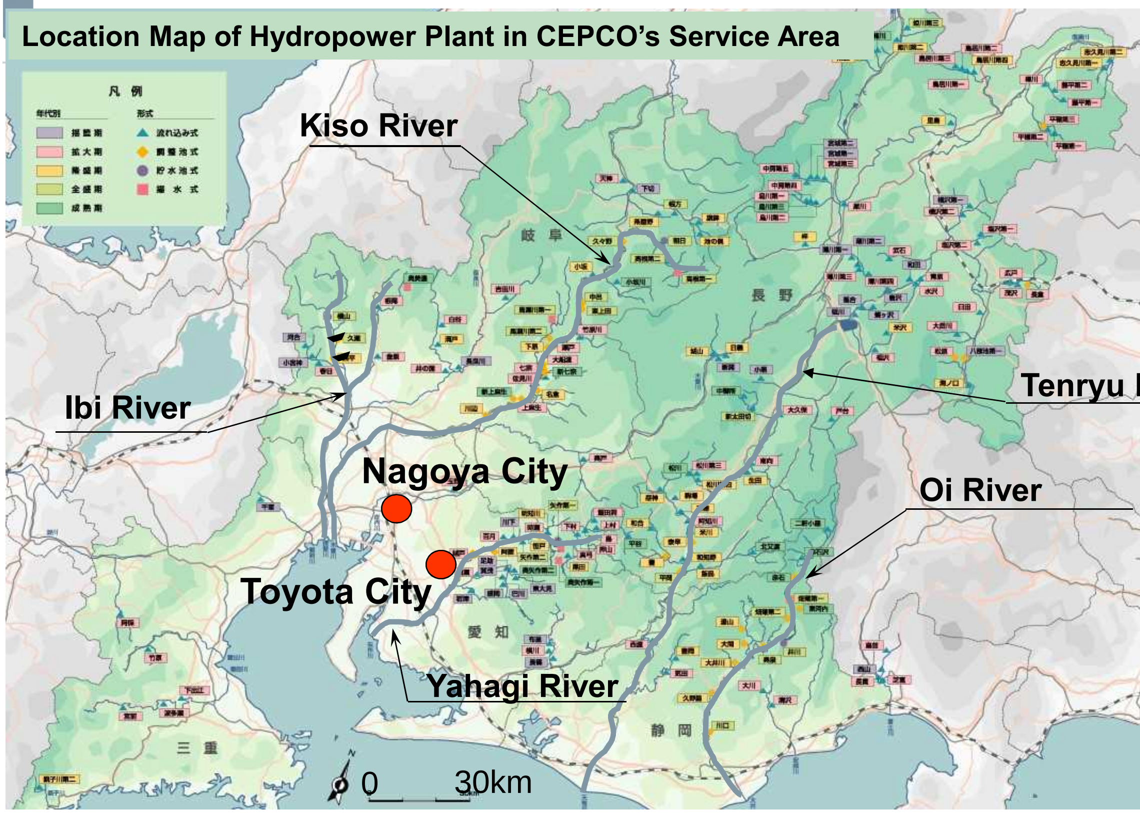

- Flood time
  - Secure of safety for downstream


4-a. Safety dam control at flood period

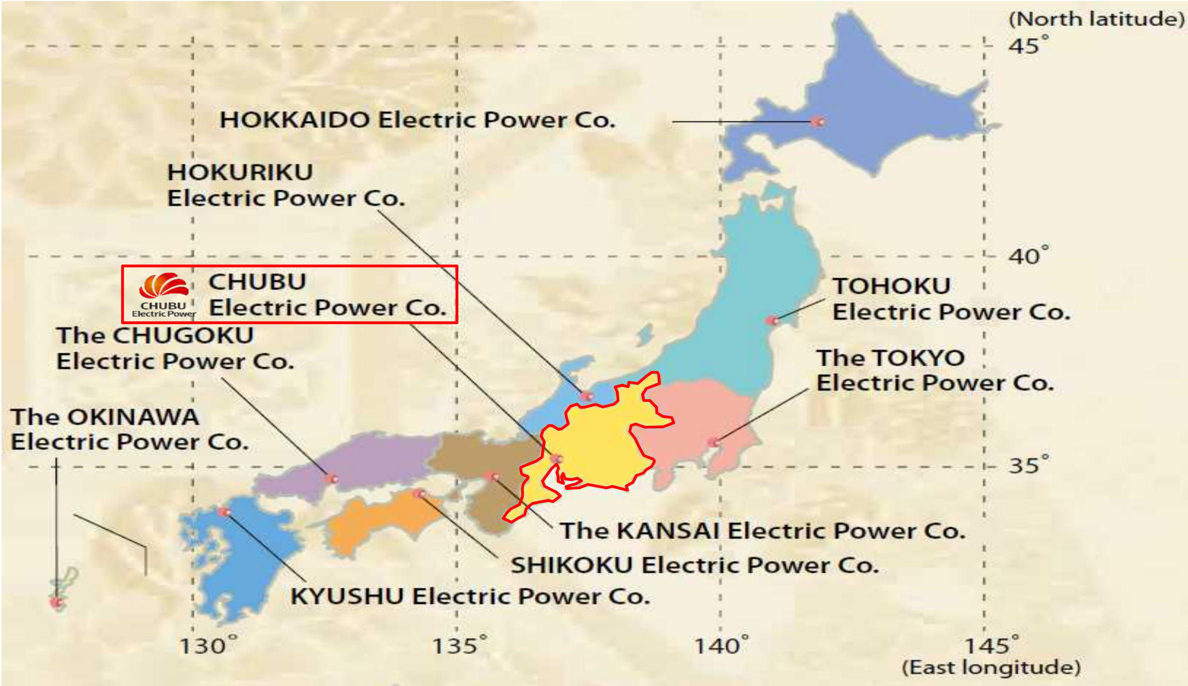
- Safety first operation for downstream
- Forecast the inflow volume analyzing the precipitation and other weather conditions.
- Strictly rule for Spillway operation
  - Limitation of increment and decrement amount of discharge
  - Notification
  - Alert system of sirens and patrol along river

4-b. Simulation system for training

- Before working at the dam control office
- At transferring to the other dam control office
- Periodically doing training and step up the operator status



- There are 10 electric power companies (EPCos) in Japan.
- The electric power companies own and operate generation, transmission and distribution facilities in each region.



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5. Summary

- One river had been developed by one company/ utility traditionally in Japan,
  - **to use the hydro potential at the maximum**, and
  - **to manage the flood control safety**.

Training and education system is also important for safety and optimum operation of the Hydropower Plant.

[for Reference] Oldest Hydropower Plants of CEPCO

(As of October, 2016)

Rank	Power Station	Age	COD	Capacity (kW)
1	Iwazu	**119**	July 1897	130
2	Susuigawa	**116**	Dec 1899	390
3	Kawashita	**116**	Sep 1900	380
4	Ochiai	**115**	Dec 1900	200
5	Miyagi No.1	**112**	Sep 1904	400

Iwazu Hydropower Plant (The oldest plant of CEPCO)

Start of operation : 1897
Output capacity : 140 kW
Discharge : 0.37 m^3/s
Effective head : 51.73 m

At the time of start operation

At present

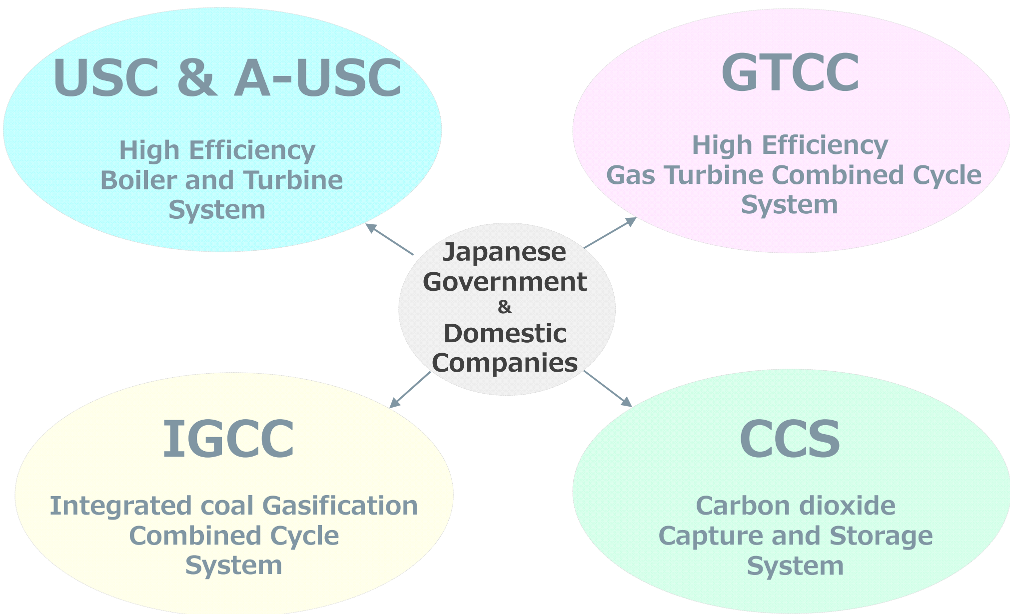
8. Thermal power plant

Contents

1. New Technologies on Thermal
2. USC and A-USC
3. GTCC
4. IGCC
5. CCS
6. Road Map

1. New Technologies on Thermal

New technologies on Thermal are continuously being developed by Japanese Government and the collaboration with the domestic companies from the beginning of the 19th century to the present. Currently, the following 4 themes are being pushed forward as the most important technologies.

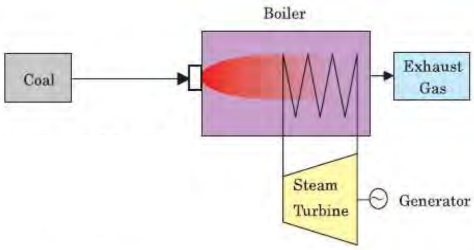


2. USC & A-USC

Technical overview

USC (Ultra Super Critical)
A-USC (Advanced Ultra Super Critical)

	USC	A-USC
Outline of System	It is a high efficiency boiler and steam turbine generation system. That is making high temperature and high pressure steam (600deg.C) in the boiler, and generating electric power by rotating the steam turbine.	As the advanced-USC technology, it achieves higher efficiency than USC by using higher temperature steam (more than 700deg.C).
Year of Commercial Operation	1995 (year)	2020 (year) as target
Plant efficiency	43-45% (Gross, LHV)	48-50% (Gross, LHV)

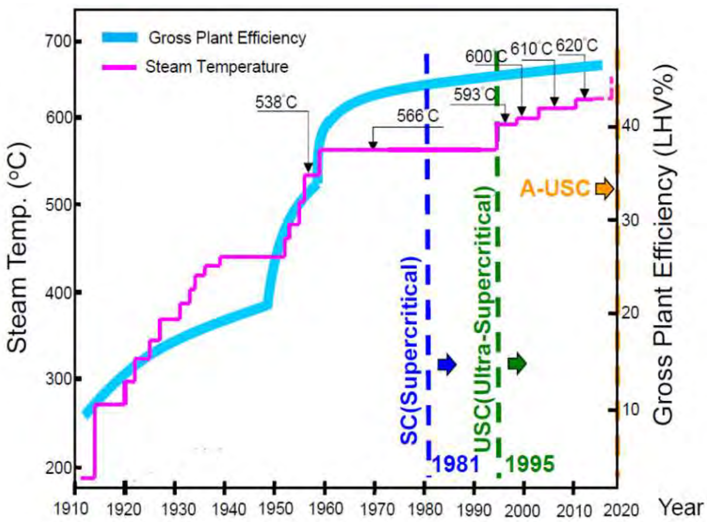


USC System (Typical)

2. USC & A-USC

History of plant efficiency improvement in Japan

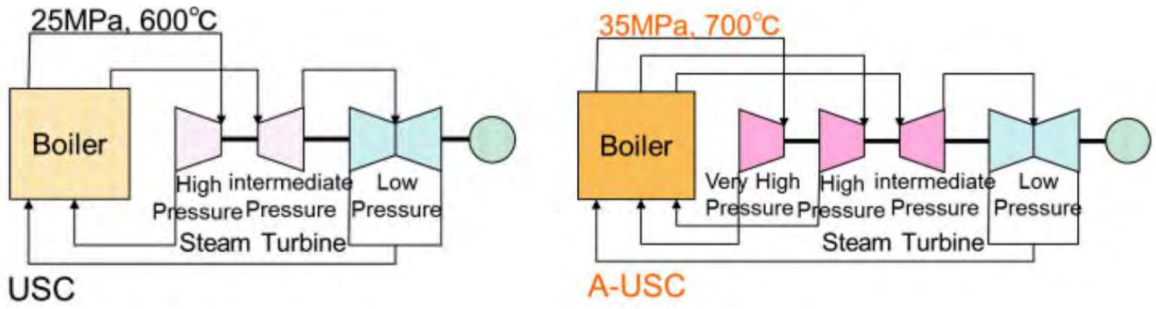
- Higher steam temperature and pressure improve thermal plant efficiency.
- In other words, USC/A-USC technology provides economical power production, fuel energy saving, lower carbon emission and environmental-friendly.



Source : Mitsubishi Hitachi Power Systems

2. USC & A-USC

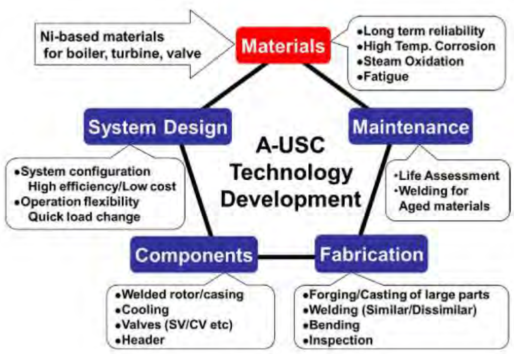
System configuration of USC & A-USC (Typical)



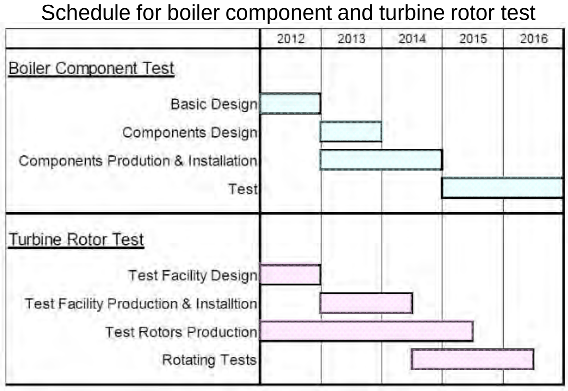
2. USC & A-USC

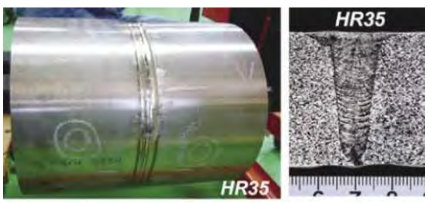
A-USC technology development plan

Development tasks



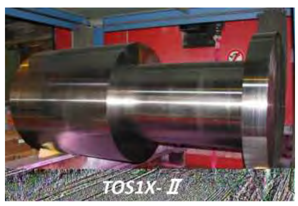
Schedule for boiler component and turbine rotor test





Boiler pipe welding test

Superheater header mock-up



Rotor trial forging

2. USC & A-USC

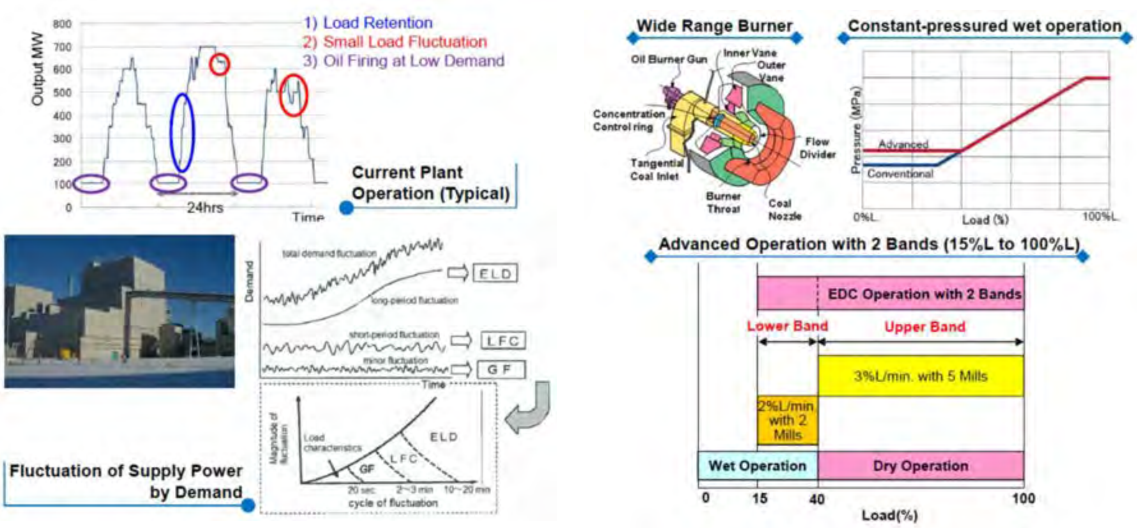
High flexibility operation of PC Boiler

Customers Needs on Current Plant Operation

- Minimization of Load Retention for Mill Start/Stop Operation
- Minimization of Time Lag for Load Change Demand
- EDC/ELD(*) Operation at Minimum Load by Coal Firing
  (*)EDC/ELD：Economic Load Dispatching Control

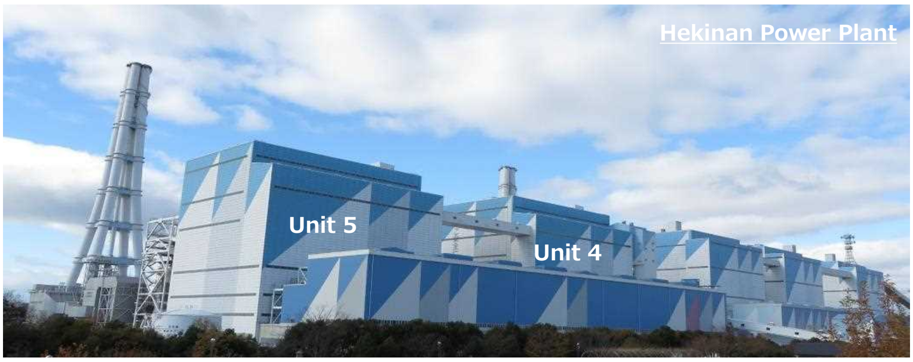
Advance Technology respond to Customers Needs

- Application of Wild Range Burner
- Expansion of Recirculation Operation Range（Wet Mode)
- Constant-pressured Wet Operation
- Optimized Boiler Control System



2. USC & A-USC

Reference plant (in Japan)



	Hekinan Unit 4	Hekinan Unit 5
Capacity	1,000MWW (USC: Ultra Super Critical)	1,000MWW (USC: Ultra Super Critical)
Plant Efficiency	Approx. 44% (Gross, LHV)	Approx. 44% (Gross, LHV)
Fuel	Coal (Bituminous, Sub-bituminous)	Coal (Bituminous, Sub-bituminous)
COD (Operation start)	2001	2002

2. USC & A-USC

Reference plant (in Japan)

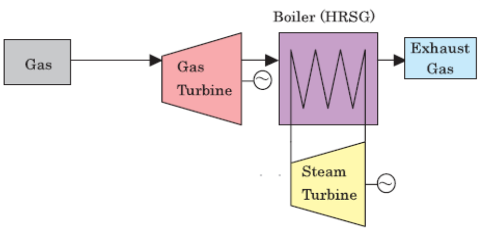
	Hitachinaka Unit 1	Hitachinaka Unit 2
Capacity	1,000MW (USC: Ultra Super Critical)	1,000MW (USC: Ultra Super Critical)
Plant Efficiency	Approx. 45% (Gross, LHV)	Approx. 45% (Gross, LHV)
Fuel	Coal (Bituminous, Sub-bituminous)	Coal (Bituminous, Sub-bituminous)
COD (Operation start)	2003	2013

3. GTCC

Technical overview

GTCC (Gas Turbine Combined Cycle)

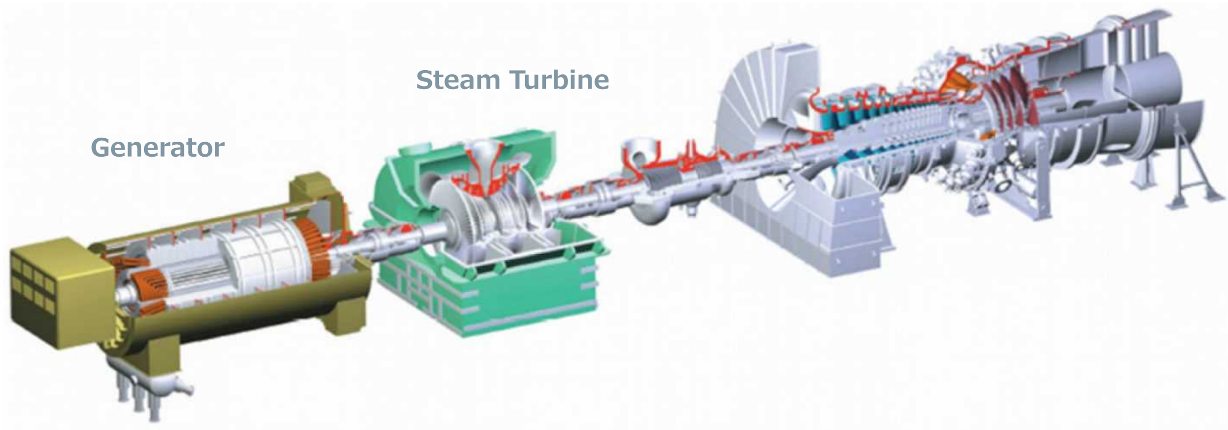
	GTCC
Outline of System	It is the highest efficiency generation system in thermal. That is a combination of gas turbine and steam turbine system.
Year of Commercial Operation	1985 (year) as 1,100deg.C-class GTCC
Plant efficiency	1,100 deg.C-class 48-50% (Gross, LHV) 1,300 deg.C-class 54-57% (Gross, LHV) 1,500 deg.C-class 58-60% (Gross, LHV) 1,600 deg.C-class 60-62% (Gross, LHV) 1,700 deg.C-class 62-64% (Gross, LHV) as target



GTCC System (Typical)

3. GTCC

Sectional Figure



Sectional Figure of GTCC System (Typical)

3. GTCC

Reference plant (in Japan)

	Futtsu Group1 &2	Futtsu Group 3	Futtsu Group 4
Capacity	2,000MW (1,100deg.C-class GTCC x 14units)	1,520MW (1,300deg.C-class GTCC x 4 units)	1521MW (1,500deg.C-class GTCC x 3 units)
Plant Efficiency	Approx. 48% (Gross, LHV)	Approx. 56% (Gross, LHV)	Approx. 59% (Gross, LHV)
Fuel	LNG	LNG	LNG
COD (Operation start)	1985	2001	2008

3. GTCC

Reference plant (in Japan)

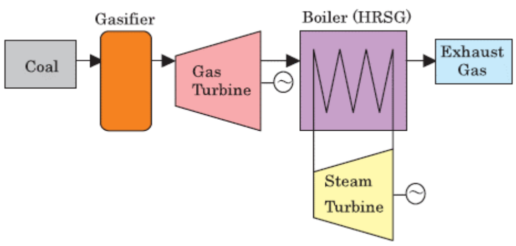
	Kawasaki Group 1	Kawasaki Group 2
Capacity	2,000MW (1,500deg.C-class GTCC x 4 units)	1,440MW (1,600deg.C-class GTCC x 2 units)
Plant Efficiency	Approx. 59% (Gross, LHV)	Approx. 61% (Gross, LHV)
Fuel	LNG	LNG
COD (Operation start)	2007	2016

4. IGCC

Technical overview

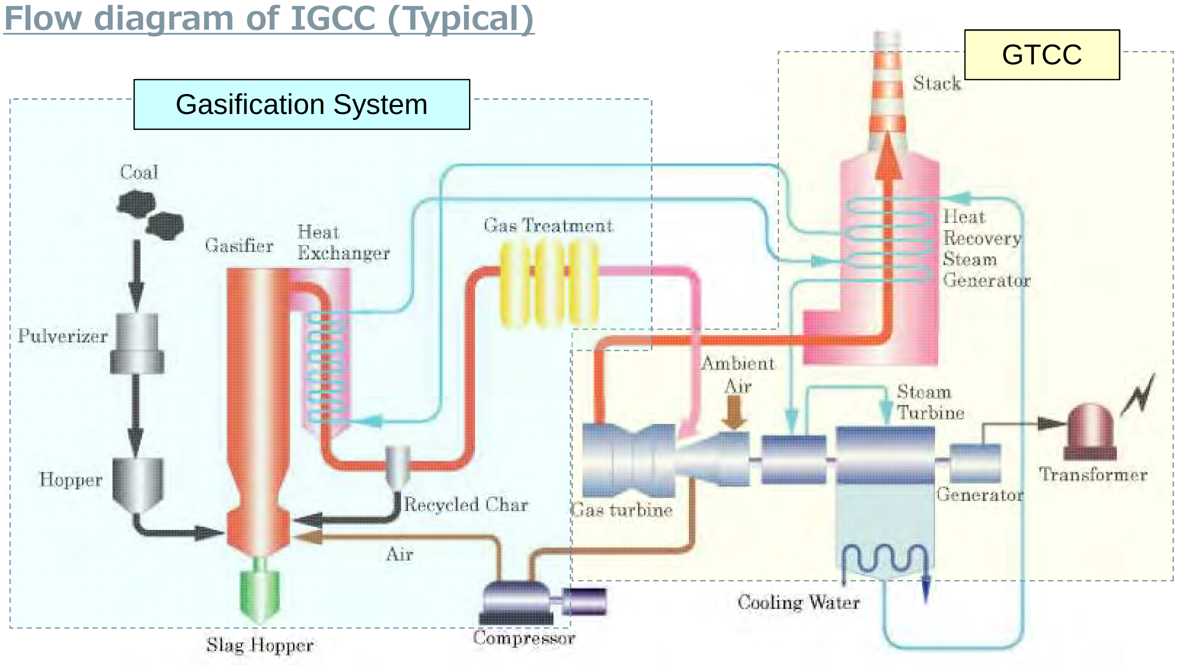
IGCC (Integrated coal Gasification Combined Cycle)

	IGCC
Outline of System	It is one of GTCC system that uses gasified coal as fuel. That consists of coal gasification system and GTCC system.
Year of Commercial Operation	2013 (year) as 1,200deg.C-class IGCC
Plant efficiency	1,200 deg.C-class 46~48% (Gross, LHV) 1,500 deg.C-class 50~52% (Gross, LHV) as target 1,700 deg.C-class 54~56% (Gross, LHV) as target



IGCC System (Typical)

Flow diagram of IGCC (Typical)



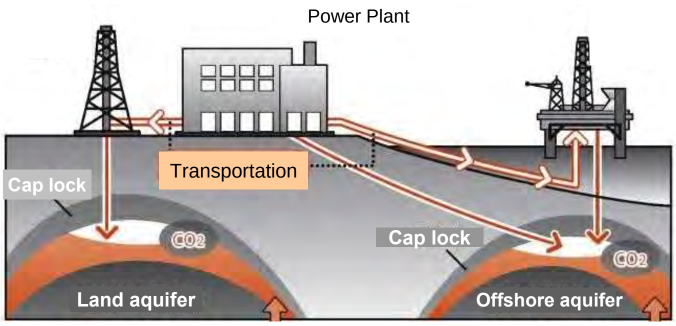
Reference plant (in Japan)

	Nakoso Unit 10	Extension Project
Capacity	250MW (1,200deg.C-class IGCC x 1 unit)	500MW (1,500deg.C-class IGCC x 1 unit)
Plant Efficiency	Approx. 46% (Gross, LHV)	Approx. 50% (Gross, LHV)
Fuel	Coal	Coal
COD (Operation start)	2013	2020 (as target)

Technical overview

CCS (Carbon dioxide Capture and Storage)

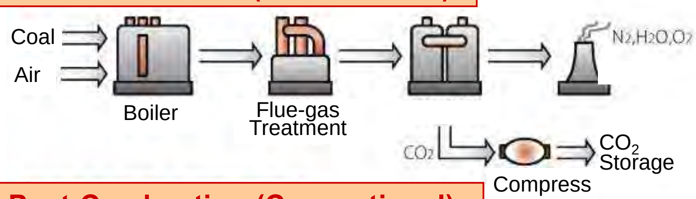
	CCS
Outline of System	It is a carbon-dioxide capture and storage system from thermal power generation. Since that is much environment-friendly, early development is expected from a lot of industrial.
Year of Commercial Operation	2012~



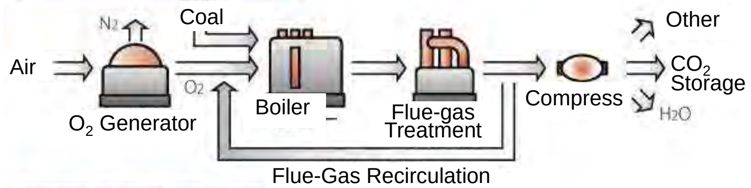
CCS System (Typical)

System Configuration

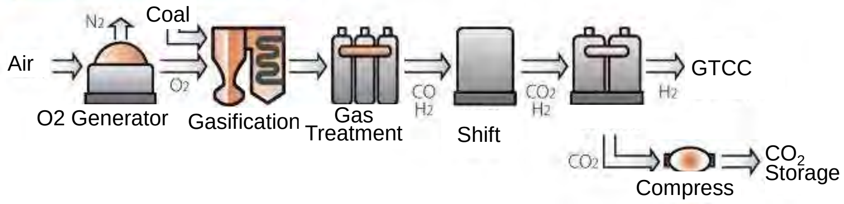
1. Post-Combustion (Conventional)



2. Post-Combustion (Conventional)



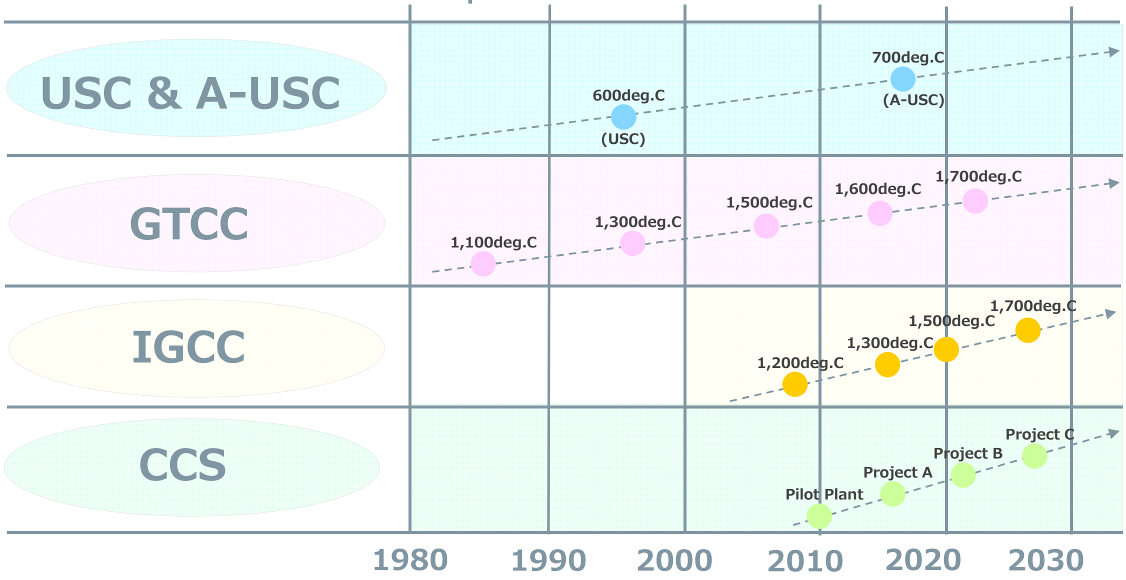
3. Pre-Combustion (IGCC)



6. Road Map of New Technologies

The road map of Japanese new technologies on thermal

To improve plant efficiency and reduce environmental impact, more and more, Japanese government and domestic companies continues to implement further developments with best effort. We would like to share this Japanese technologies with South Africa countries to assist improvement of SAPP.



Data Source

Source of data & figures in this report

-Literature
(日本電気協会新聞部　火力発電カギのカギ)

-Academic journal
(スマートプロセス学会誌　第3巻　先進超々臨火力発電(A-USC)技術開発)

-IHI