Power Grid Connection and its Technical Issues

The fourth in a 2020 series of webinars from the Clean Energy Ministerial Regional and Global Energy Interconnection Initiative

May 26, 2020 1200(GMT)/2000(GMT+8, Beijing Time) Duration: 1 hour

Event Link: https://meeting.tencent.com/s/5WUWiqfd9c1a(Conference ID: 950 855 652)

Speaker: Prof. Ryuichi Yokoyama (Waseda University)

The webinar will address:

- What are the current status and challenges of power grid connection in Japan and the rest of the world?
- Which technical performance is better in High Voltage Direct Current transmission regarding Line Commuted Converter (LCC) or Voltage Source Converter(VSC) ?
- What impacts does the COV-19 have on the development of energy interconnection in future?

Ryuichi Yokoyama is a Professor Emeritus of Waseda University, a Life Fellow of IEEE, a Senior Life Member of IEE of Japan, a member of CIGRE. He is also Chairman of Standardization Commissions of Electric Apparatus in METI Japan. He received the degrees of B.S., M.S., and Ph.D. in electrical engineering from Waseda University, Tokyo, Japan, in 1968, 1970, and 1974 respectively. After working in Mitsubishi Research Institute, from 1978 through 2007, he was a professor in the Faculty of Technology of Tokyo Metropolitan University. Since 2007, he had been a professor of the Graduate School of Environment and Energy Engineering in Waseda University. His fields of interests include planning, operation, control and optimization of large-scale environment and energy systems, and economic analysis and risk management of deregulated power markets.

About the Regional and Global Energy Interconnection (RGEI) Initiative

The RGEI Initiative was established at the 9th Clean Energy Ministerial meeting in Copenhagen/Malmö in May 2018. RGEI's objectives are to:
* Discuss conducive policy and regulatory framework regarding regional and global power system integration
* Build consensus on facilitating energy transition via increased proportion of renewable energy in energy consumption and enhanced grid interconnection
* Encourage CEM member countries to engage in the process of RGEI and seize collaborative opportunities

CEM Members: China, Chile, Finland, Korea, South Africa, United Arab Emirates. RGEI works with other regional and national technical organizations in the field of power system integration including State Grid Corporation of China, the Korea Electric Power Corporation, and others.

Operating Agent: Global Energy Interconnection Development and Cooperation Organization (GEIDCO)

Contact: Zhu Zheng, zheng-zhu@geidco.org, +86-1063411675

RGEI Link: https://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/regional-and-global-energy-interconnection-rgei-initiative

GEIDCO Link: https://www.geidco.org/

International Power Grid Connection and its Technical Issues

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Outline of Presentation

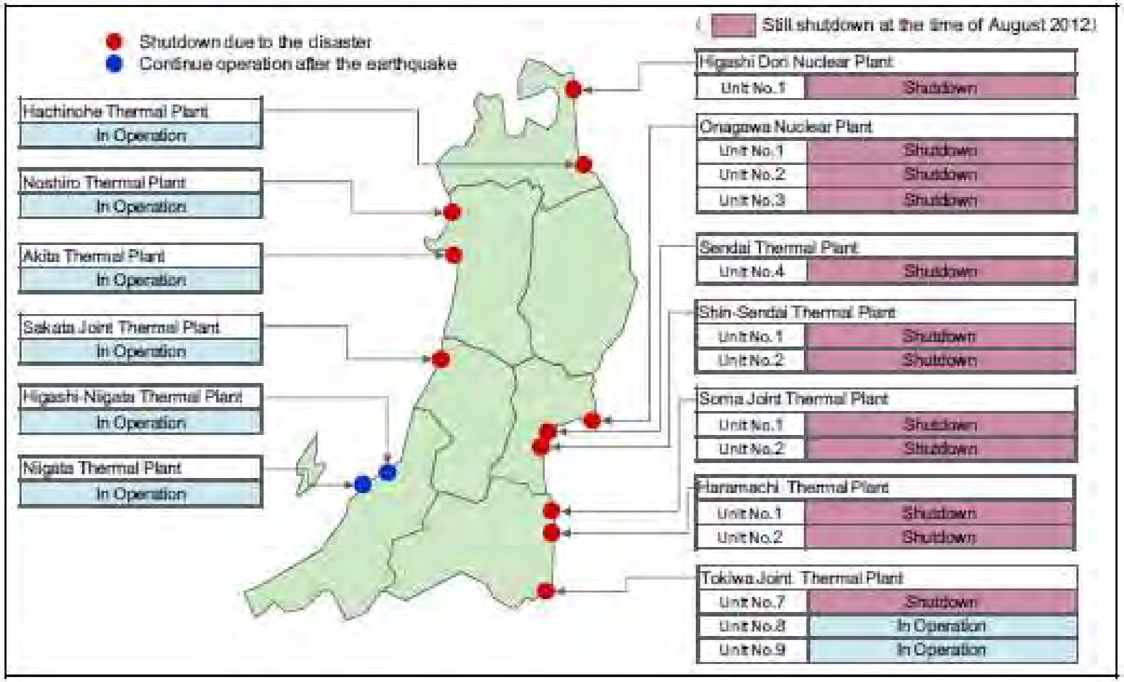
- ***Future Electric Power Grids for Effective Use of Sustainable Energy***
- ***Concept and Background of Super Grid***
- ***Proposals and Initiatives of Cross-Reginal Electricity Transfer in Asian Countries***
- ***Features of Power System and Issues on International Connection in Japan***
- ***Prospects of International Grid Connections in Asian Countries***

Future Electric Power Grids for Effective Use of Sustainable Energy

Disaster by East Japan Earthquake and Tsunami

Shutdown of Nuclear Plans and Damage of Energy Infrastructures

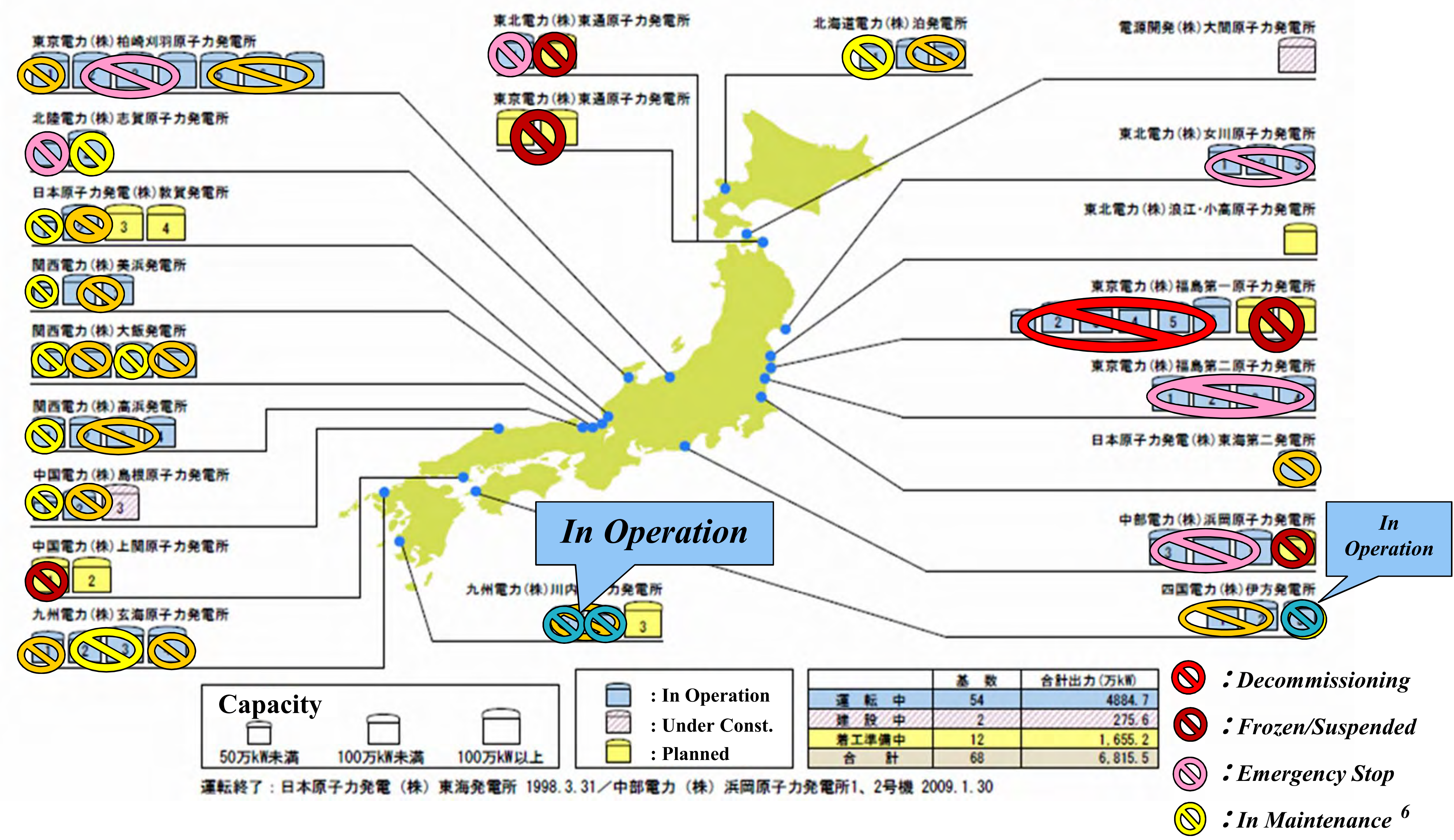
Destruction of transmission lines and buildings



Sendai Minato LNG Gasification Plants

11 sites of nuclear plants fell into shutdown and Sendai Minato LNG gasification plants were damaged, however municipal gas was supplied continuously after the East Japan Great Earthquake since the high pressure gas pipelines from Niigata were survived.

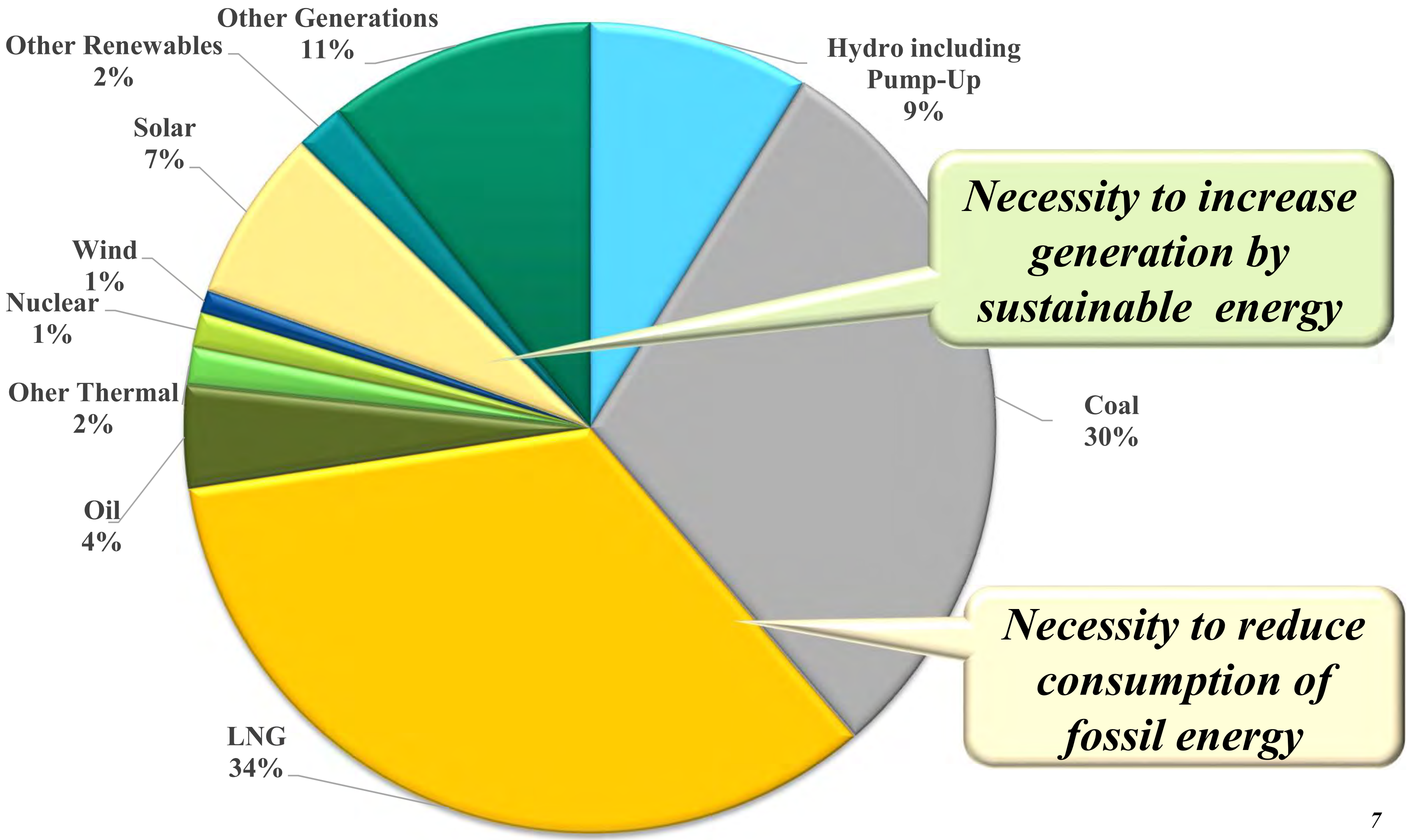
Current Situation of Nuclear Plants After Disaster in Japan



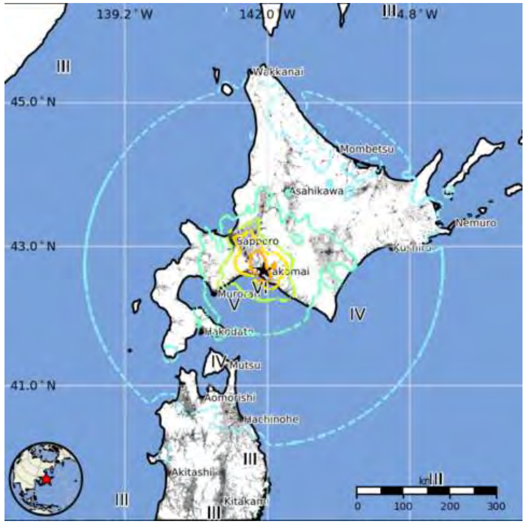
	基　数	合計出力(万kW)
運　転　中	54	4884.7
建　設　中	2	275.6
着工準備中	12	1,655.2
合　　計	68	6,815.5

Transition of Generation Mix and Estimate in 2020

Generation Mix in 2020（Estimate by OCCTO,2016,KWh-Base）



What happened in Japan : Earthquake in Hokkaido



Source: https://www.washingtonpost.com/world/asia_pacific/

- ***August 2018***
- ***Cause and Damage:***
  The magnitude 6.7 earthquake struck before daybreak of 6 September and knocked out power and train service across Hokkaido, home to 5.4 million people.
- ***Nearly 3 million households lost power, according to the Hokkaido Electric Power Company.***
- ***It took two days to restore electricity to most households and over one month is remote areas.***

What happened in Japan : Blackout in Hokkaido

August 2018
Damage from deadly Hokkaido quake estimated at over 367.5 billion yen

(Japanese original by Motomi Kusakabe, Hokkaido News Department)

- ***Wide area power shortages caused operation shutdowns for manufacturers, wholesalers, retailers, and in other sectors, accounting for approximately 131.8 billion yen of the estimated total damage cost.***
- ***Around 13.6 billion yen worth of perishable goods had to be discarded due to the quake.***
- ***The temblor also caused direct damage of about 12 billion yen to factory and other industrial equipment.***
- ***Around 1.15 million people's worth of reservations for accommodations in the prefecture had been canceled as of late September, leading to losses of about 35.6 billion yen in the tourism industry, including for transportation costs and food expenses.***
- ***The Sept. 6 quake also caused extensive damage to the agriculture, forestry and fishery sectors and to public works facilities.***

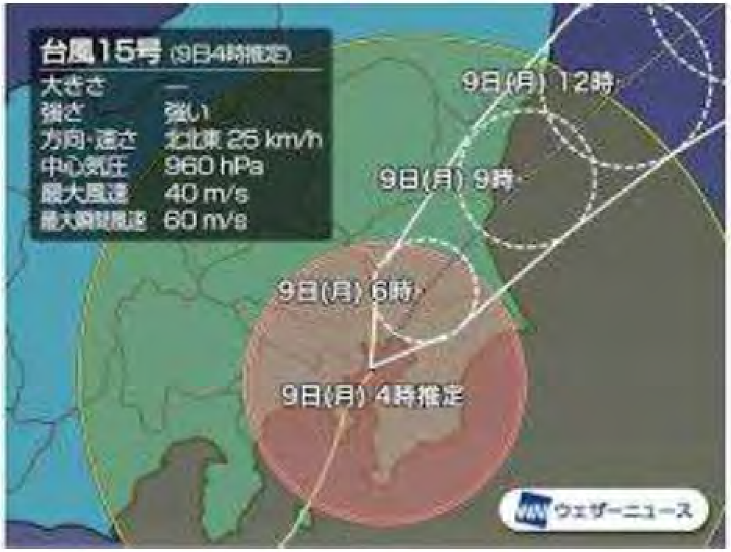
What happened in Japan : Use of PV Generation

Approximately 85%(364/428) of Solar PV user in the houses use the autonomous driving function even without storage battery, saying that they could "use electricity effectively during a power outage“.

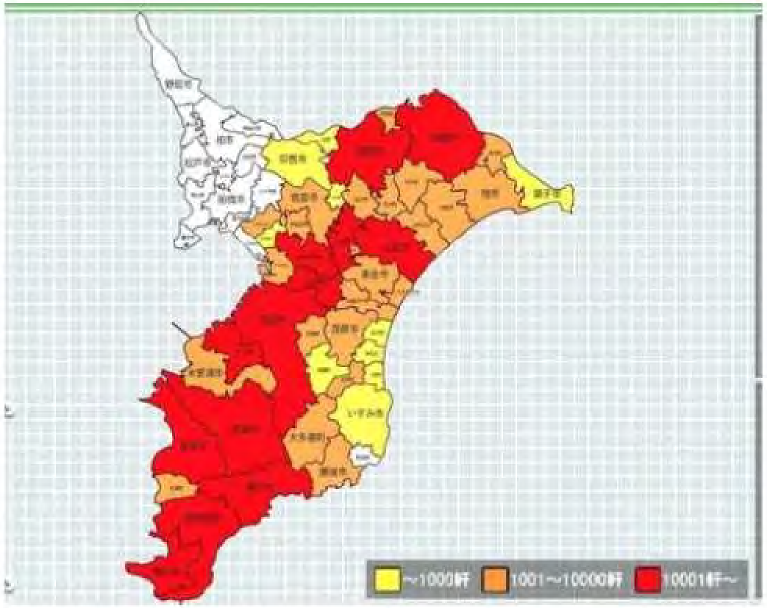
People who used the autonomous driving function could "keep the food in the refrigerator without rot", "cook rice with a rice cooker", "charge a mobile phone", and charge nearby people. "I was able to get the earthquake information quickly on a portable TV."

On the other hand, the reason who did not use self-sustained operation in residential photovoltaic power generation systems, “I did not know how to drive” (33 cases), “I did not know that there is an independent operation function” (13 cases)). In addition, "Independent operation outlet not installed (PCS installed outdoors)" "I could not find the location of the outlet" "Independent operation function did not work" "An error was displayed and I thought that it would switch automatically" " The power was restored before use. "

What happened in Japan : Huge Typhoon in Chiba



Typhoon course of September 9th 2019



Power outage occurs in about 930,000 houses in Chiba Prefecture

Transmission tower collapsed in Chiba Prefecture

About 2,000 Electric poles collapsed in Chiba Prefecture

State of the blackout in Chiba Prefecture

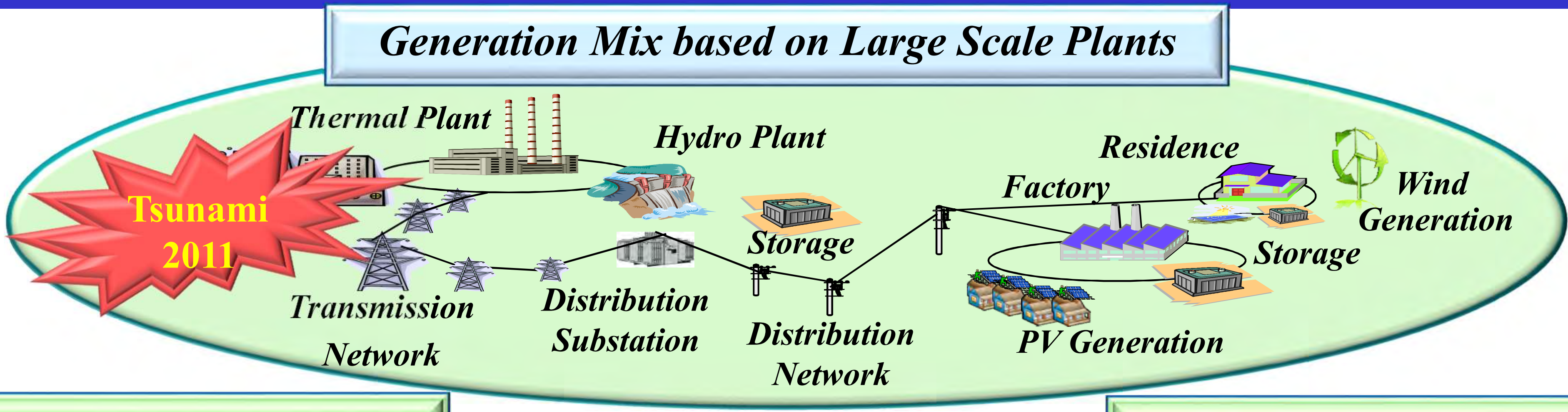
What happened in Japan : Blackout in Chiba

On Sept. 9, 2019, 5 hours after black out, upon checking submergence and electrical leak, starting cogeneration system

Mutsuzawa Town implemented sustainable and resilient energy system to use electric in the Community

Area: 2.86ha
Parking: 140 cars
Opened: Sep. 1, 2019

Paradigm Shift toward Best Energy Mix from Nuclear-Centered Generation Mix

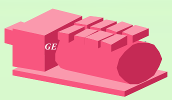


Energy Saving

Local Generation

Best Energy Mix based on Distributed Generation and Network

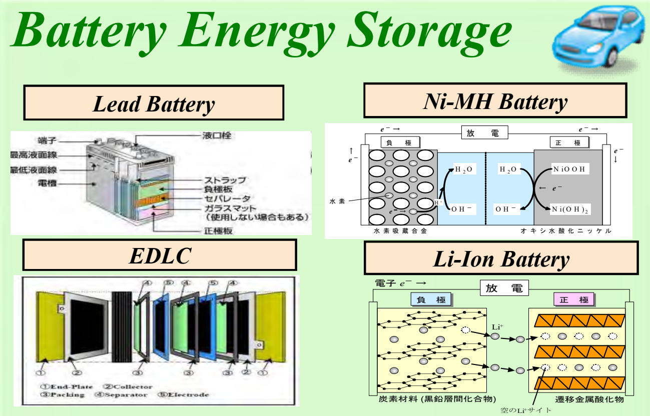
Generation with Fossil Energy



- *LNG Thermal Plant (1GW)*
- *Gas Combined Cycle (0.3GW)*
- *Gas Engine (10KW – 1MW)*
- *IGCC (Clean Coal Generation)*
- *Fuel Cell*

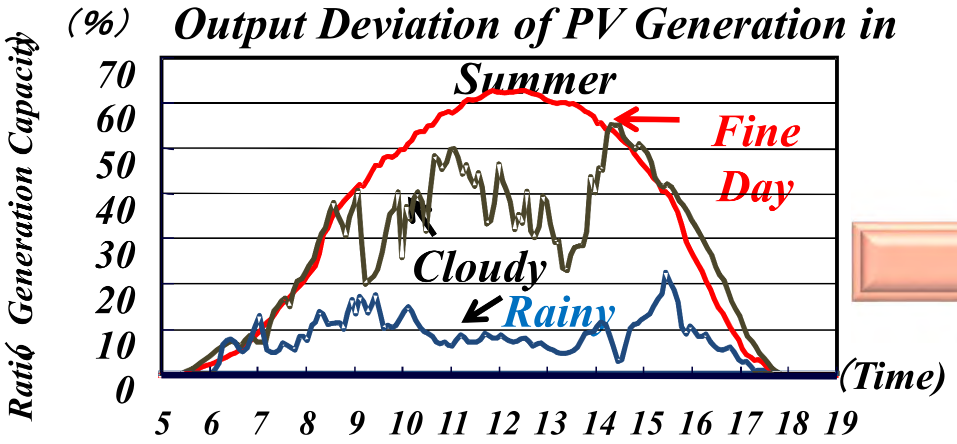
Generation with Sustainable Energy

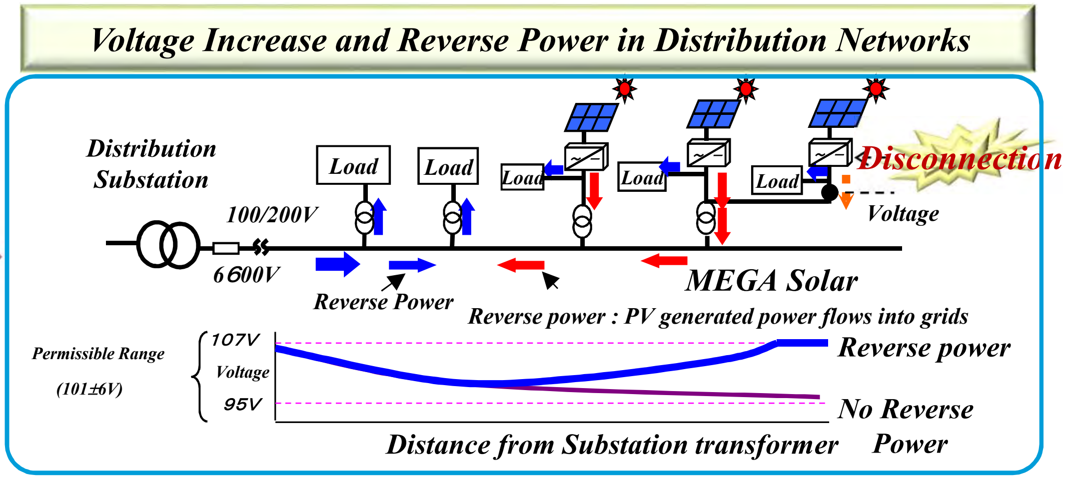
Battery Energy Storage

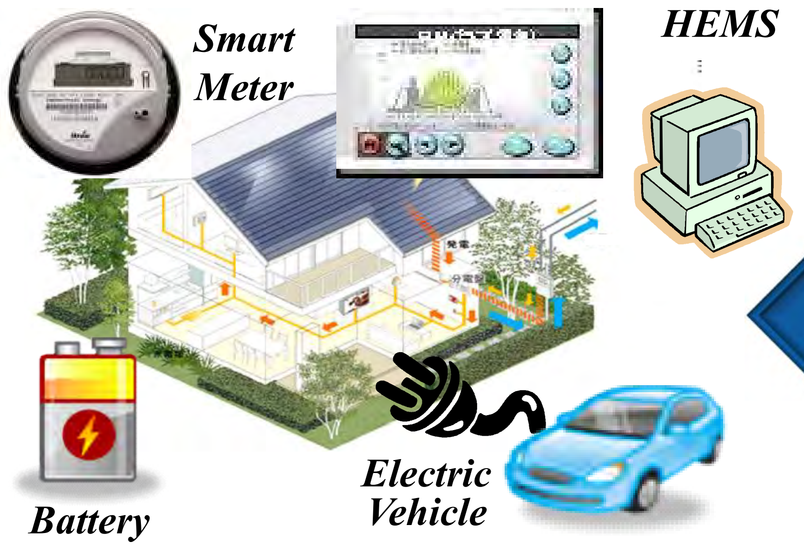


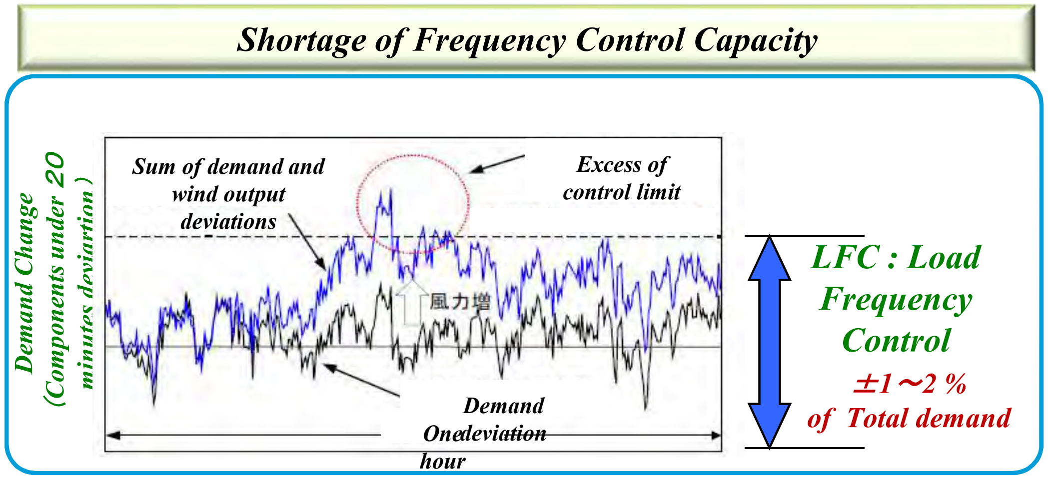
Issues in Power System Operation by Large Scale Instillation of Sustainable Energy

- By large scale installation of sustainable energy such as PV generation, new problems in power grids ; Excess energy, Voltage increase and Shortage of frequency control capacity occur.
- Necessity of power stabilization control to keep their own functionality of power networks

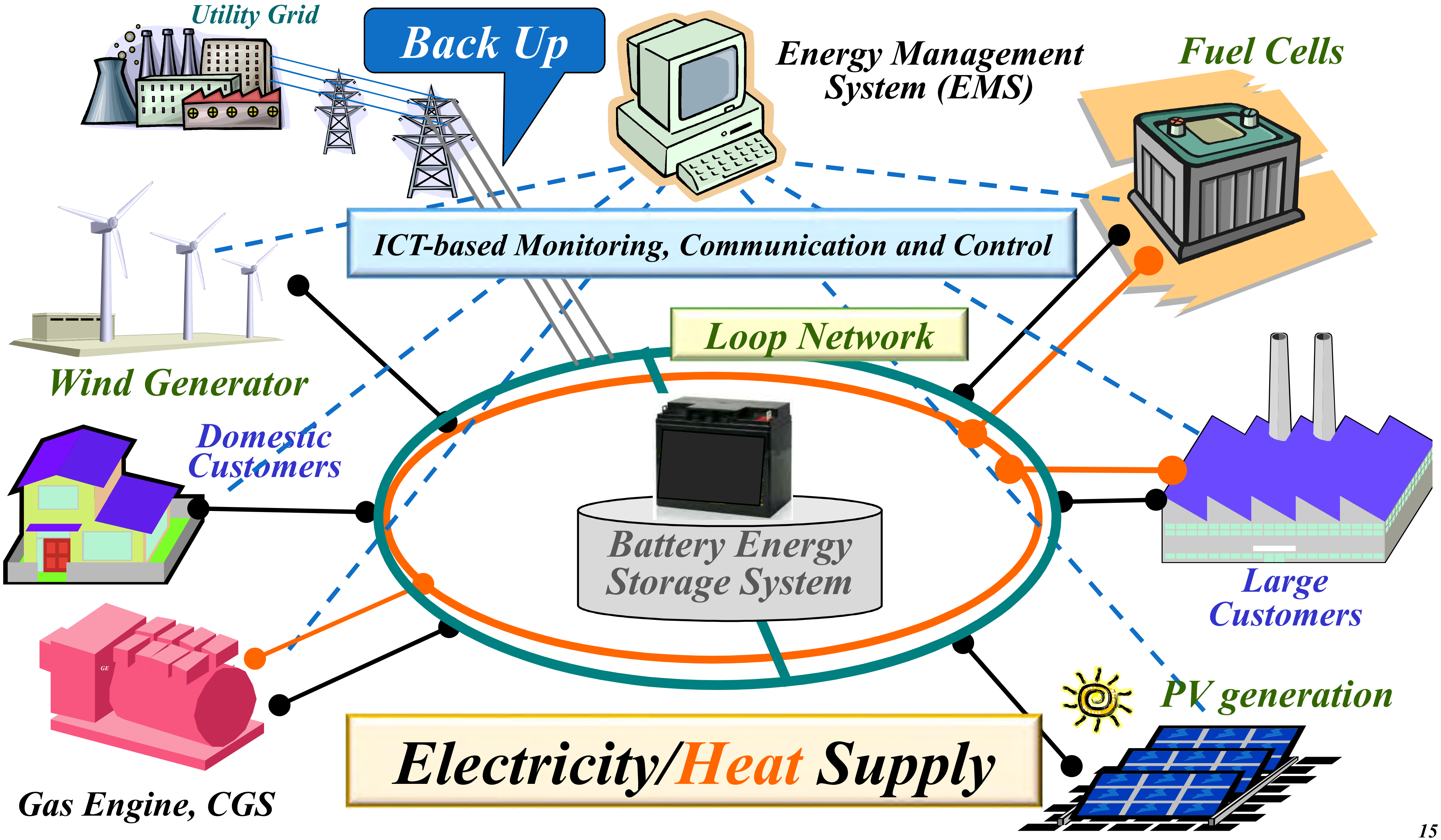




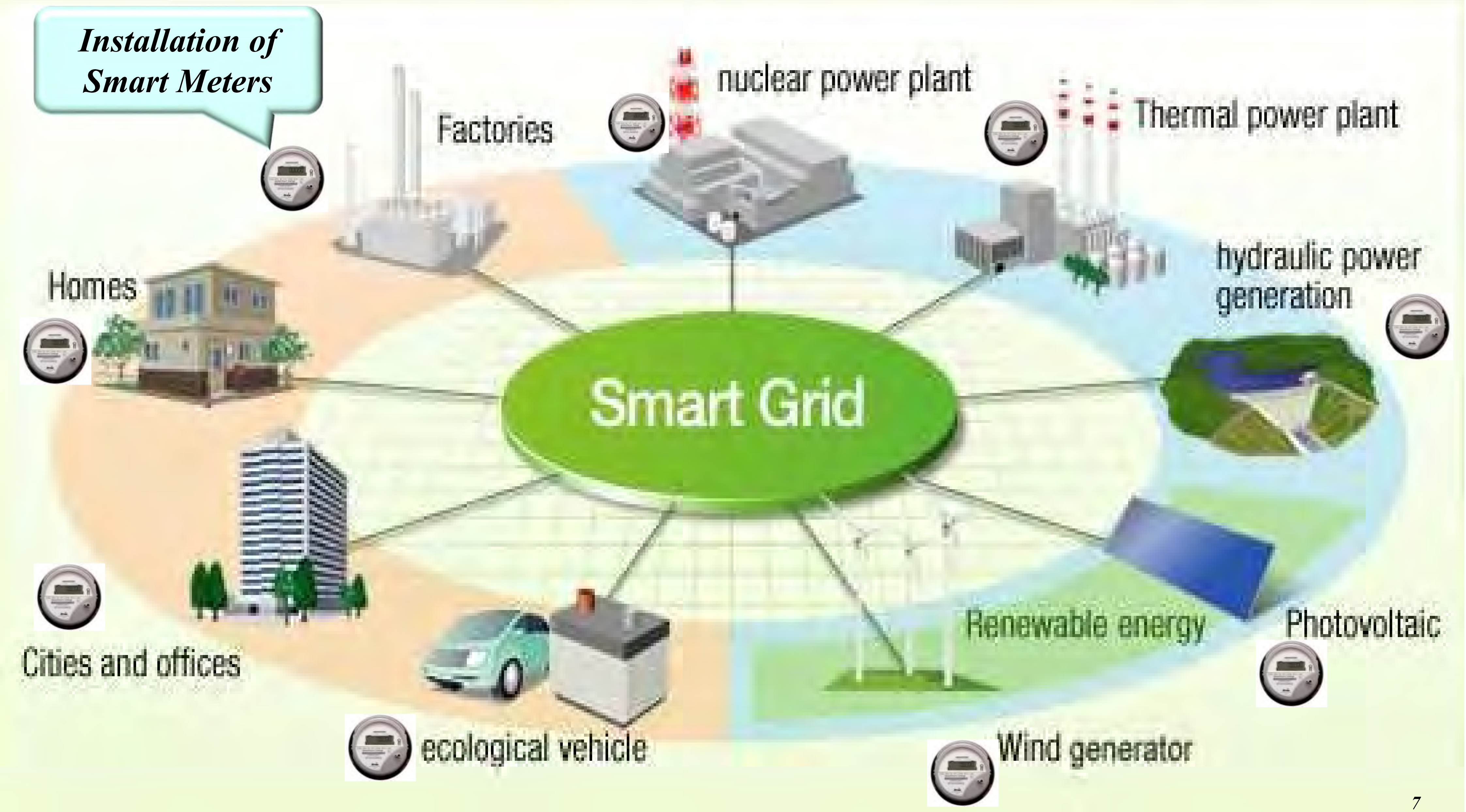




Autonomous MicroGrid for Effective Use of Sustainable Energy



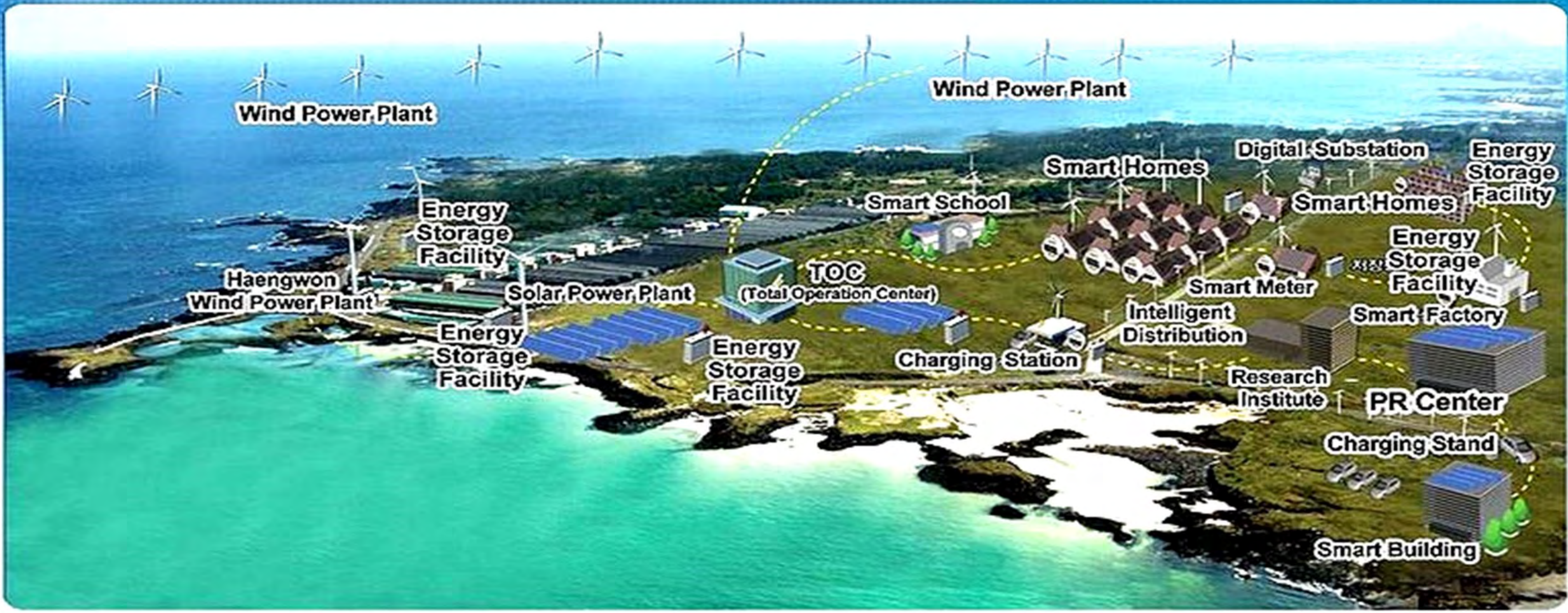
Changes of Power System Structure by Introducing Smart Technology



Smart Grid Development in Countries

Smart Grid Development in Countries

Jeju Island Smart Grid Test Bed, Korea



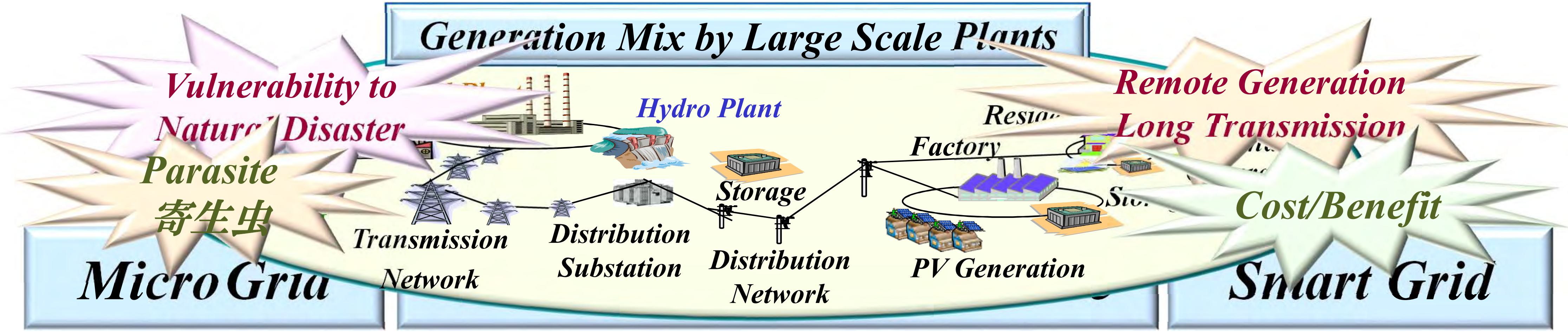
Features:
- Integrated test bed
- Close collaboration between public and private sectors
- Verification of different power market models
- Participants: Korea Electric Power Corporation (KEPCO) plus automakers, telecommunications companies and home appliance manufacturers
  - Includes major companies such as LG, SKT, KT and Samsung
- Open to foreign companies

Ref.: Jeju Smart Grid Test Bed by KEPCO2011

Toward Future Power Delivery Networks

Stable Power Supply | Reasonable Price | Low Carbon Society

Generation Mix by Large Scale Plants



Resiliency
Disaster-resistant Network

Comfortability
Smart & Eco Life

Resource Accommodation
Power Transfer Crossing the Border

Local Government-Driven Autonomous Network

Electricity, Heat, Waste, Life Style Transportation

Inter-Regional Connection (Area/Region/Country)

Clustered Microgrid

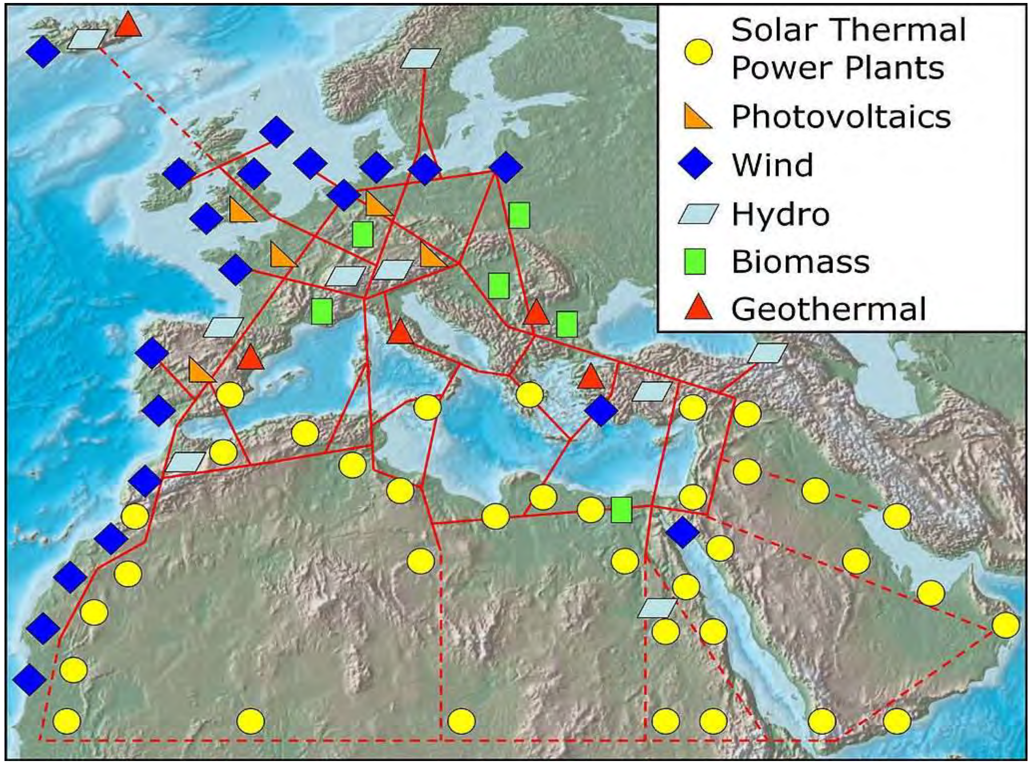
Smart Community
Eco Town, Compact City

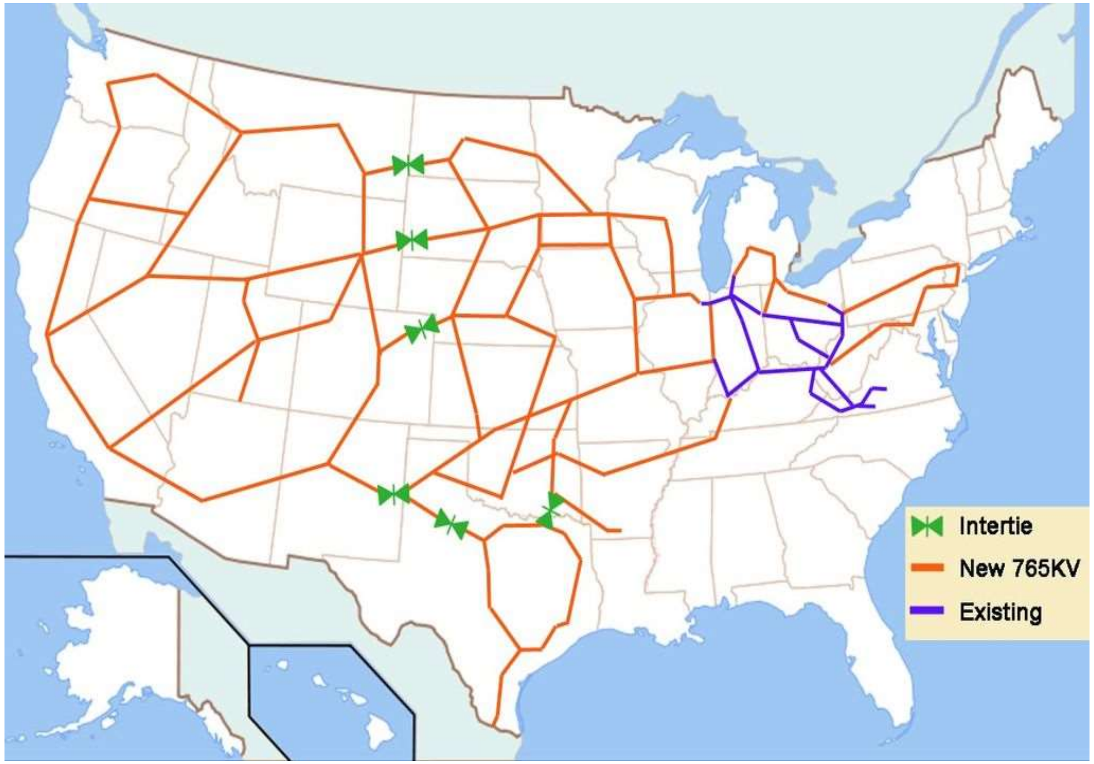
Super Grid

Concept and Background of Super Grid

Concept of Super Grid and Mega Grid

A super grid is a wide area transmission network that makes it possible to trade high volumes of electricity across great distances. It is sometimes also referred to as a "mega grid".





Background of Super Grid

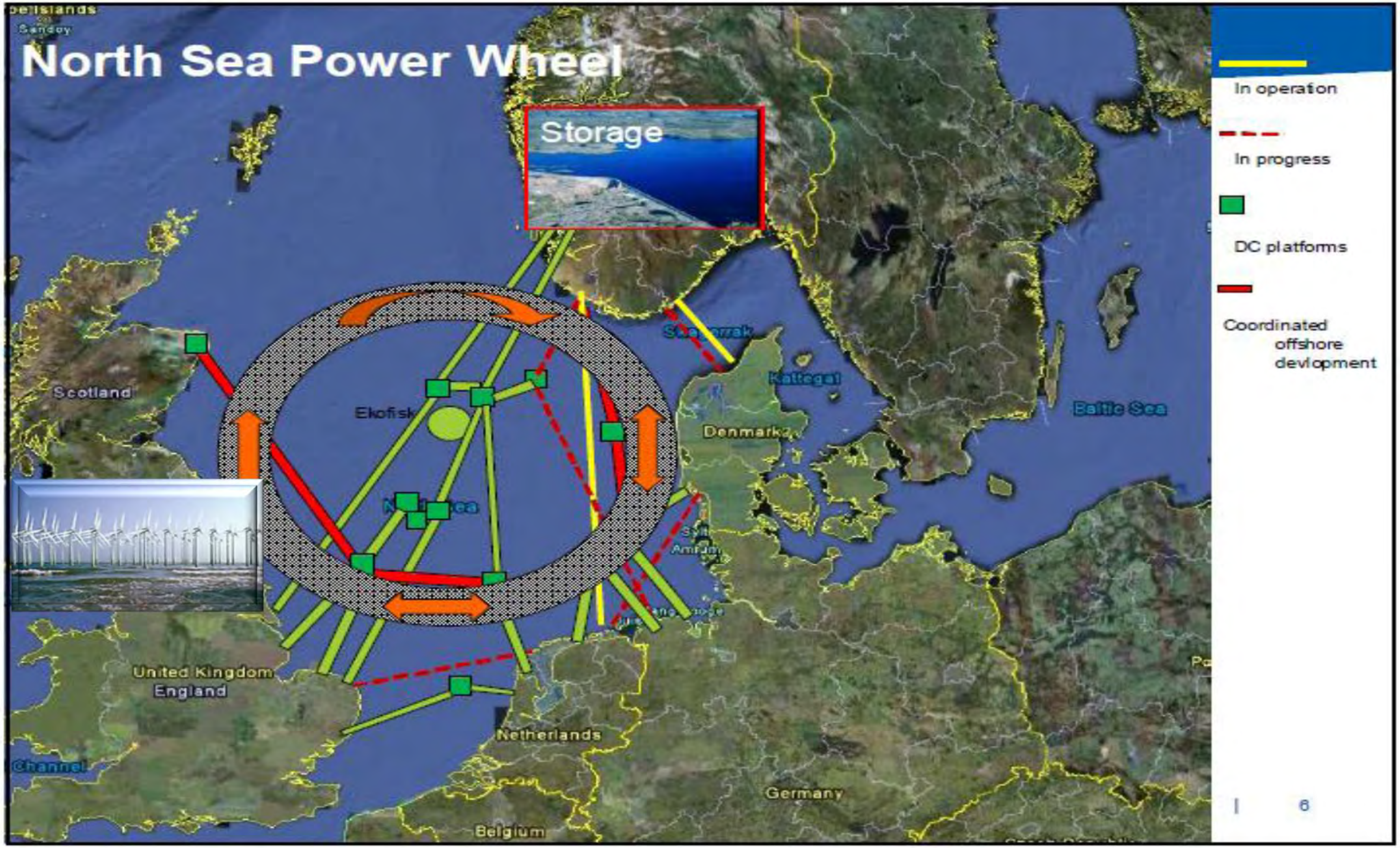
- ***The concept of a "Super grid" dates back to the 1960s and was used to describe the emerging unification of the Great Britain grid.***
- ***In the code that governs the British Grid, the Grid Code, the Super Grid is currently defined - and has been since this code was first written, in 1990 - as referring to those parts of the British electricity transmission system that are connected at voltages in excess of 200 kV (200,000 volts).***

- ***What has changed during the past 40 years is the scale of energy and distances that are imagined possible in a super grid.***
- ***Europe began unifying its grids since the 1950s and its largest Unified Grid is the Synchronous Grid of Continental Europe serving 24 countries.***
- ***Serious work is being conducted on unification of this synchronous European grid (previously known as the UCTE grid), with the neighboring synchronous transmission grid of some countries.***
- ***If completed, the resulting massive grid would span 13 time zones stretching from the Atlantic to the Pacific.***

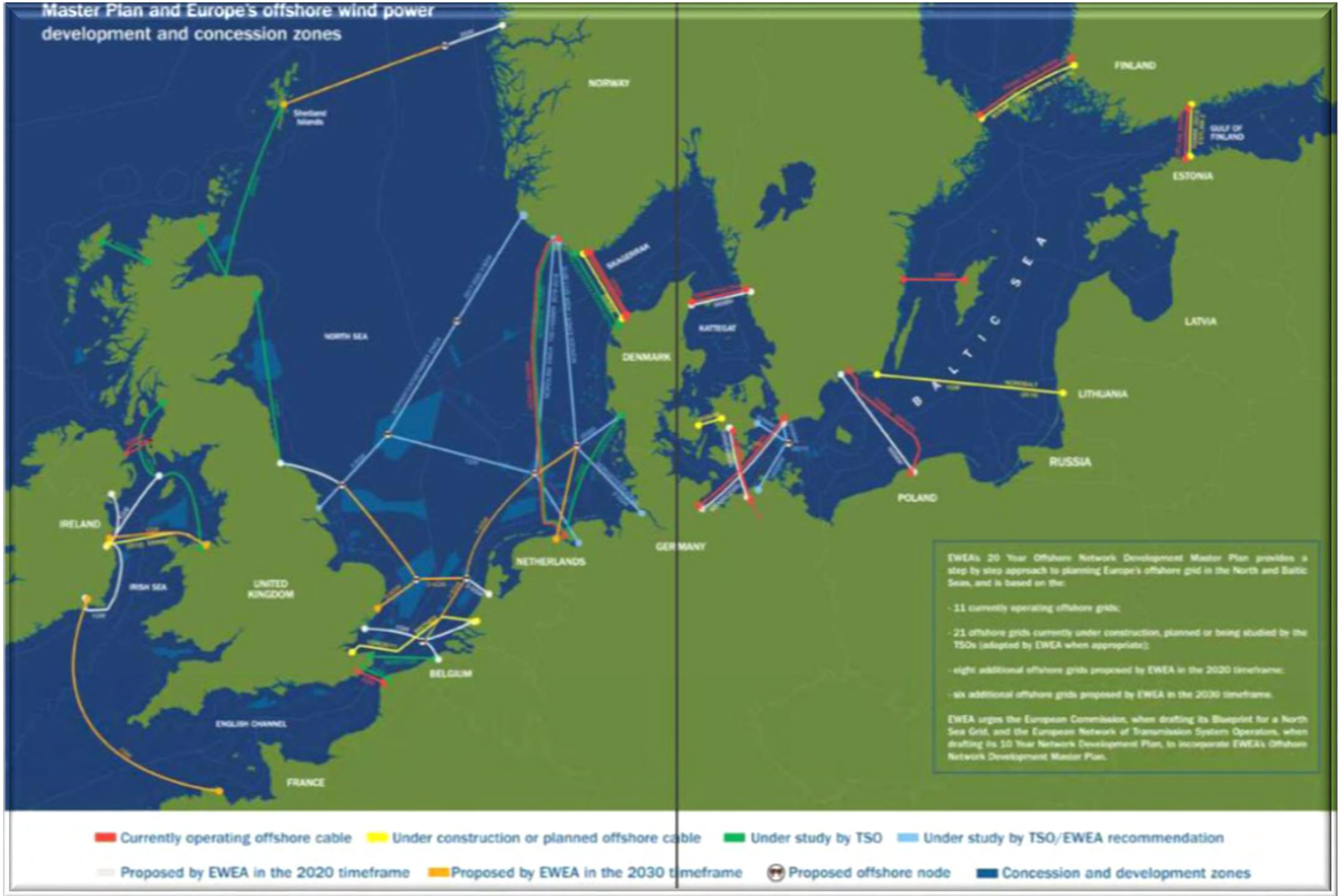
Super Grid Initiatives in Europe

- Electric Power Super Grid aims at transferring electricity generated in an area to other areas through submarine cables of several thousands Km.
- Even Off-Shore wind farms can be connected to many countries.
- Excess electric power generated by off-shore wind farms in UK is transferred to Norway and is used to pumped up water in hydro plants.
- In case of shortage of electricity in UK, electric power generated in the hydro plans in Norway is sent back to UK.
- International electricity transfer (Accommodation) among countries

The North Sea Countries' Offshore Grid Initiative by EWEA



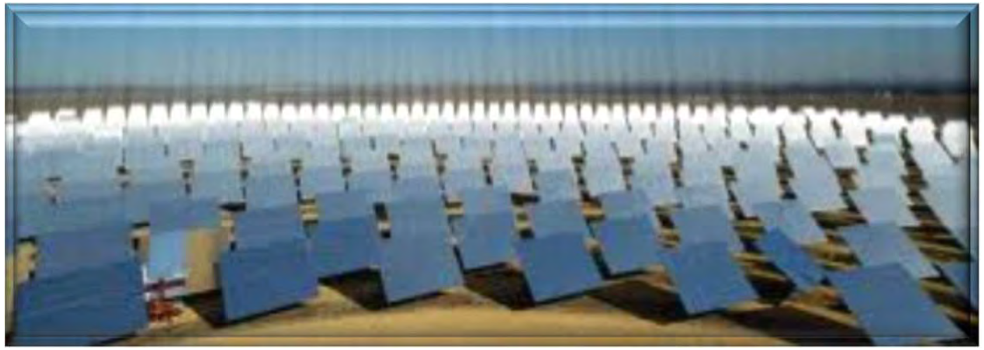
Conception of EWEA Super Grid



DESERTEC Industrial Initiative (DII)

- *DESERTEC initiative was proposed by Club of Rome to transfer electricity generated by PV and solar thermal plants in North Africa to European countries by HVDC.*
- *Range of the plan is far longer than North Sea Super Grid project and will be completed after 2050.*
- *DESERTEC Industrial Initiative (DII) is established in 2009 by 12 players including solar thermal and HVDC companies led by Germany to realize the project.*
- *15% of electricity in Europe is planed to be supplied by interconnection lines spreading over the Sahara Desert and the Mediterranean Sea areas by DII.*
- *Major finance, heavy electric and engineering corporations such as, Munich Insurance, Siemens, E.ON, Asea Brown Boveri, German Bank participated in the DII.*
- *400 Billion Euro is to invest for CSP(Concentrating Solar Power) in South Europe and North Africa.*
- *Technology used in DII is existing one, however the project is the largest in scale compared with plants in USA and Spain.*

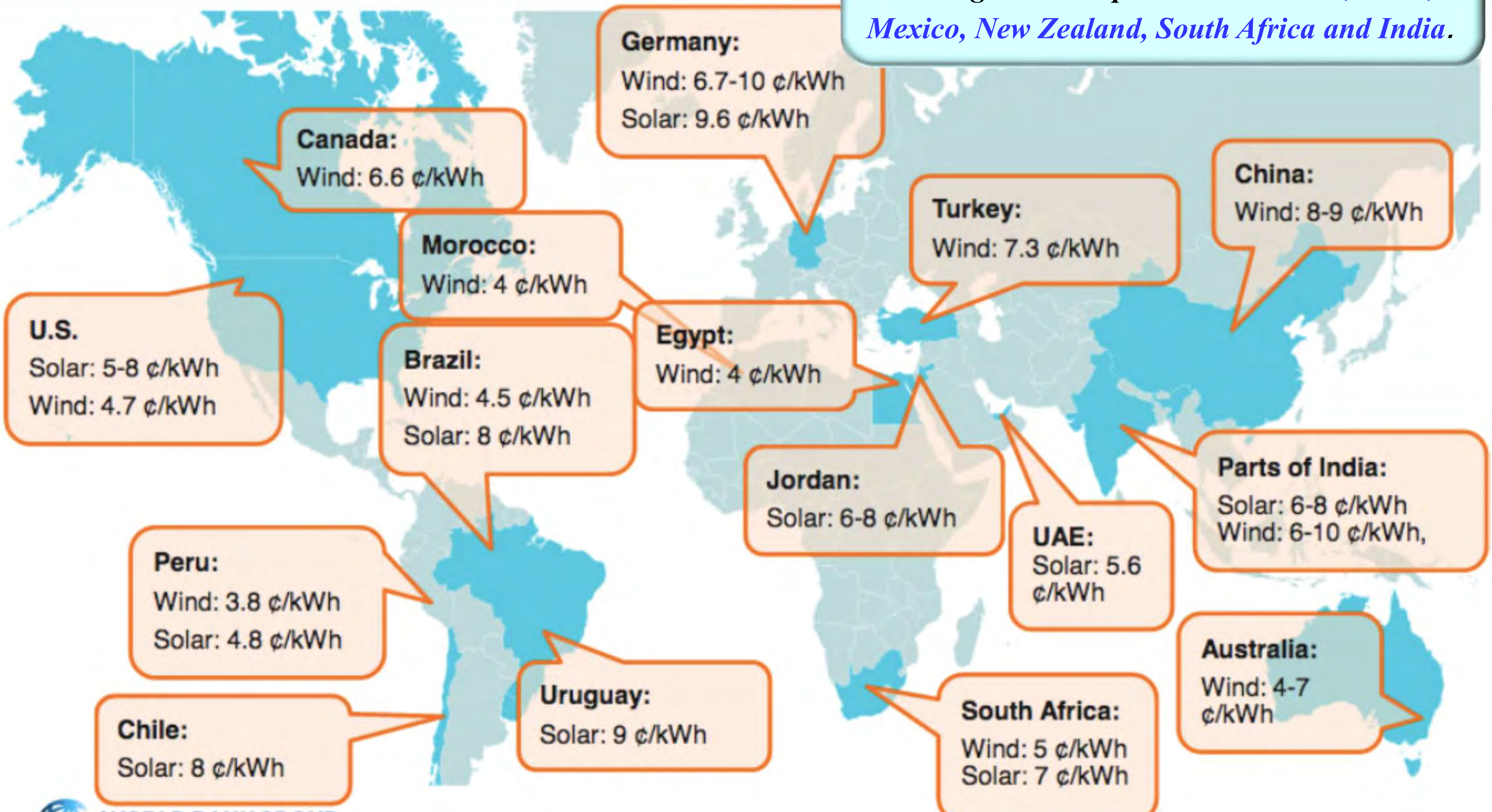
European Super Grid
DESERTEC Industrial Initiative



Strong Competitiveness of Sustainable Energy

- ***In many countries, the electricity price by PV generation on the roof is cheaper than the electric price of utilities.***

The price of commercial wind and PV generation is cheaper than the price of coal thermal generation plants in Australia, Chile, Mexico, New Zealand, South Africa and India.

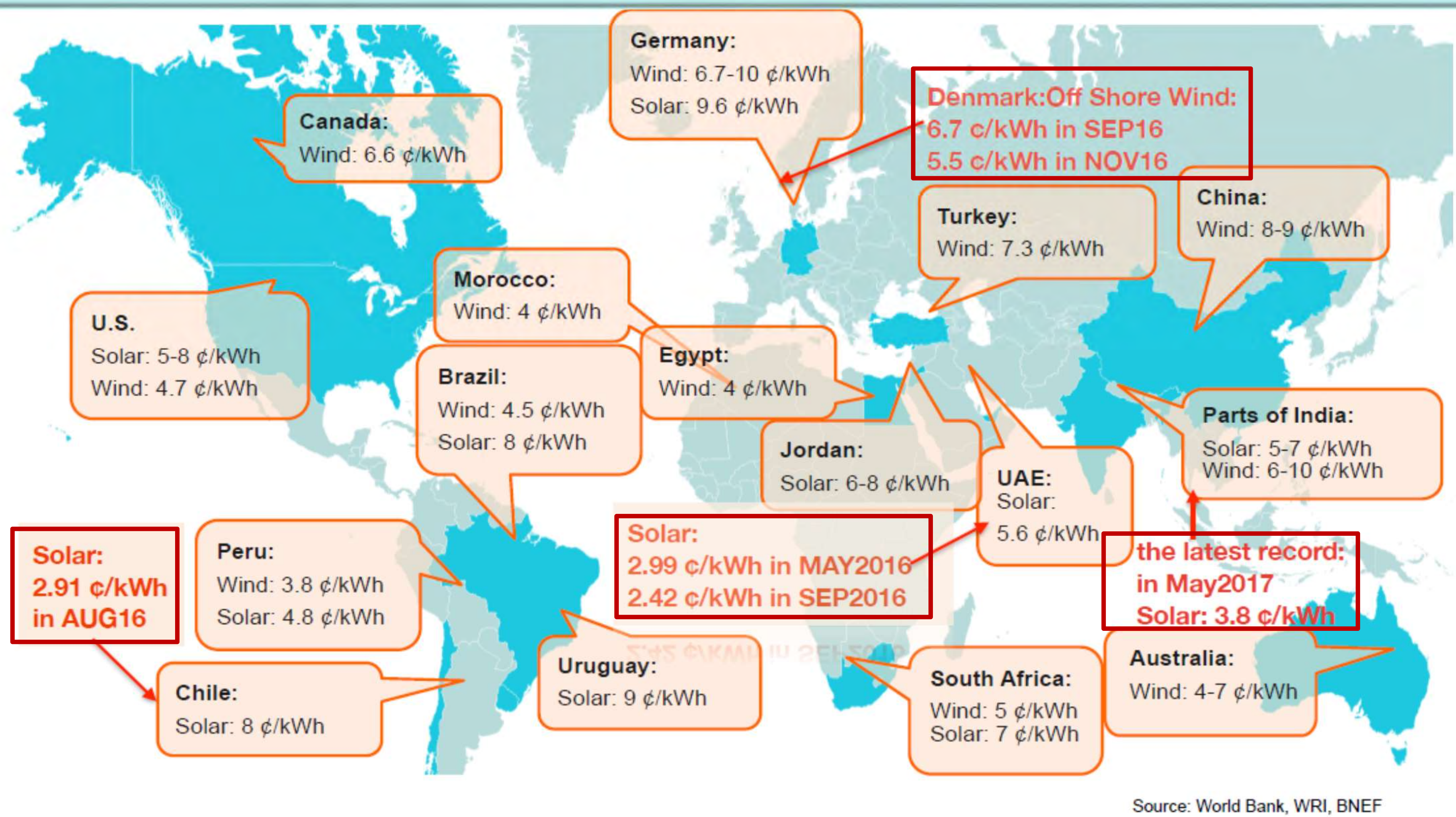


WORLD BANK GROUP
Energy & Extractives

Source: WRI The New Climate Economy, BNEF, WB

Reduction of Production Costs of Sustainable Energy

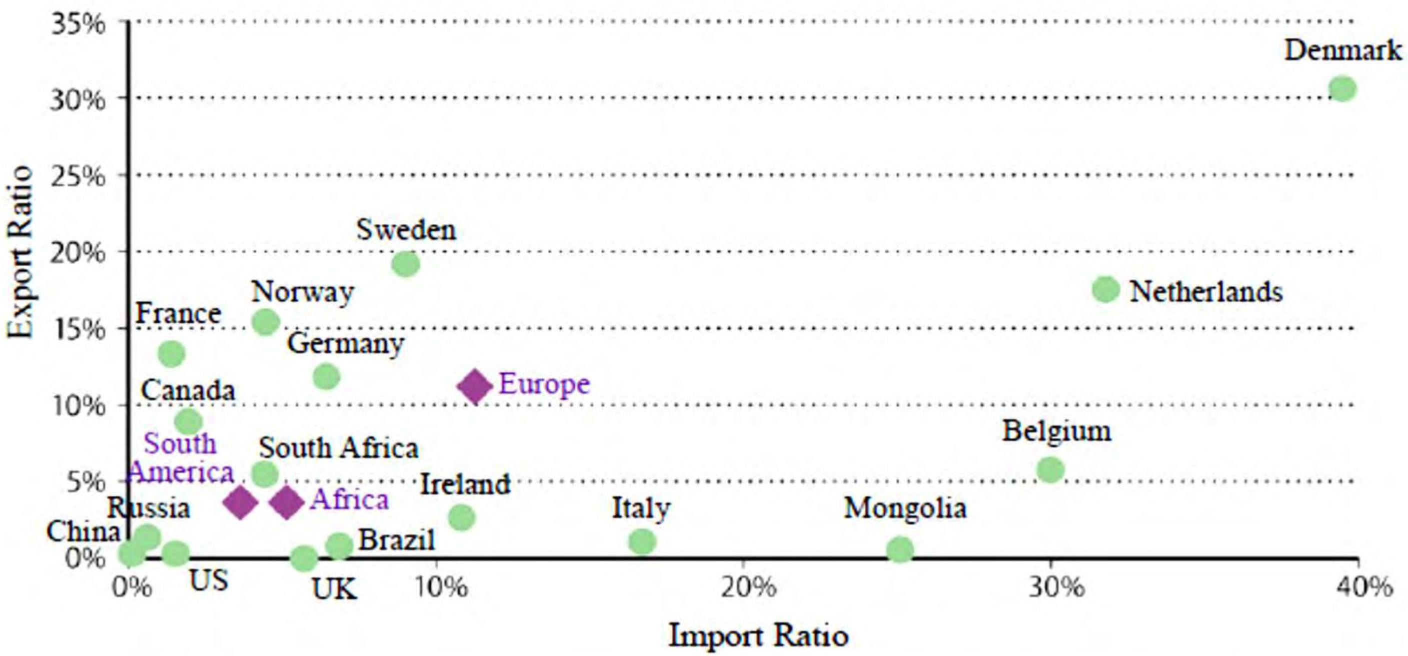
- *In 2017～2018, the minimum price of PV generation is 2.4Cent/kWh in UAE and the minimum price of off-shore wind generation is 5.5 Cent /kWh in Denmark.*
- *In India, the unit price of PV generation is 3.8 Cent /kWh and is cheaper than that of coal thermal generation..*



Source: Originary from the presentation made by Gevorg Sargsyan, Global Lead for Clean Energy, World Bank , at REvision 2016, REI Conference

Electricity Traded between Countries

- ***The import and export ratios are defined as the proportion of imported and exported electricity to generation, respectively, both on an annual basis.***
- ***In Europe as a whole, import and export ratios are 11.3% and 11.2%, respectively, a higher level of interconnection on the globe.***
- ***Outside the region, the United States, China, and Russia all import and export very little, around 1% of generation.***
- ***Japan and South Korea do not appear on the chart, as with no interconnection.***



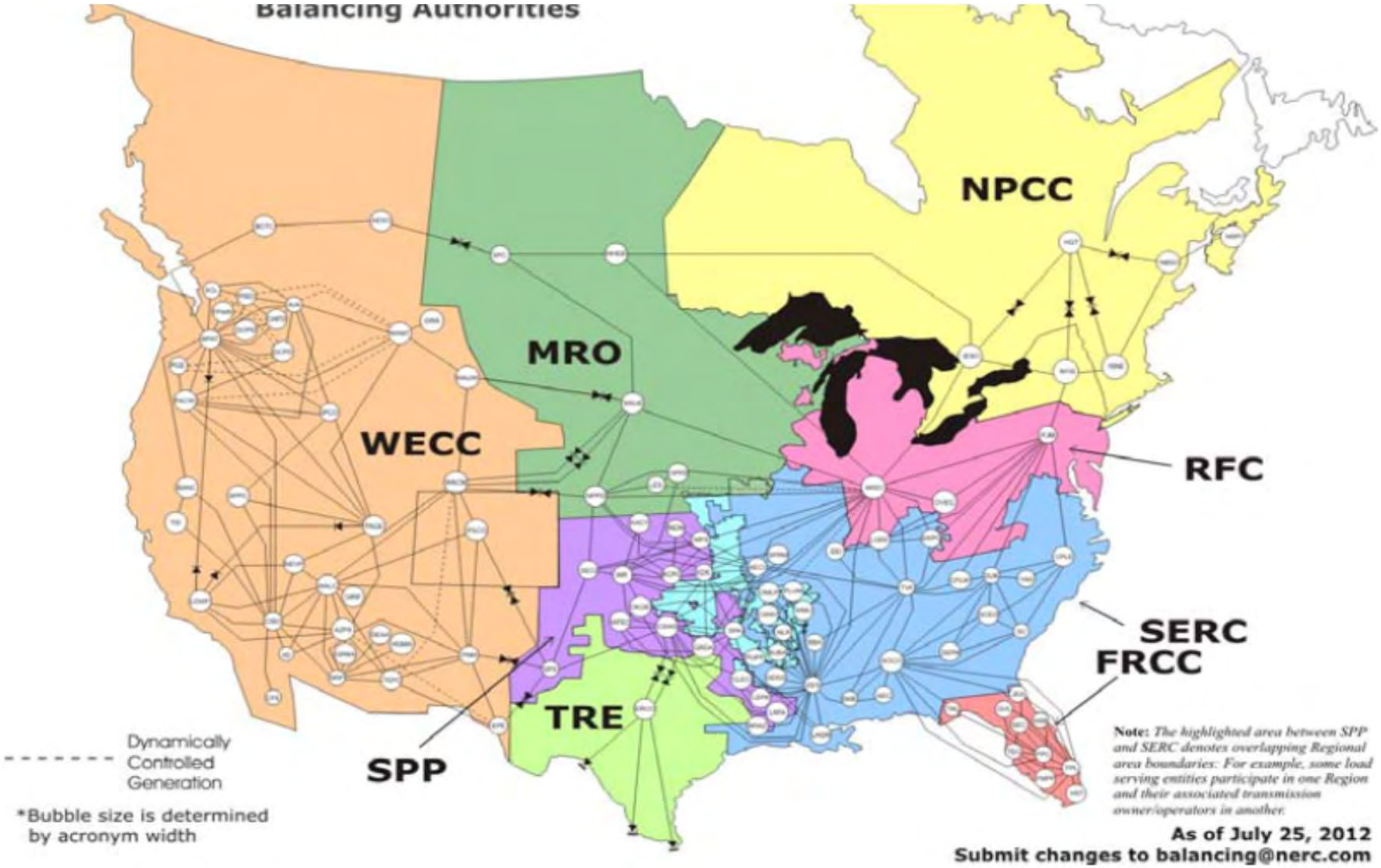
Electricity import and export ratios of major countries and regions (FY2014)

Source: Created by Renewable Energy Institute based on IEA, Electricity Information 2016. Here, "Europe" and "South America" refer to "OECD Europe" and "Non-OECD America," respectively.

Proposals and Initiatives of Cross-Reginal Electricity Transfer in Asian Countries

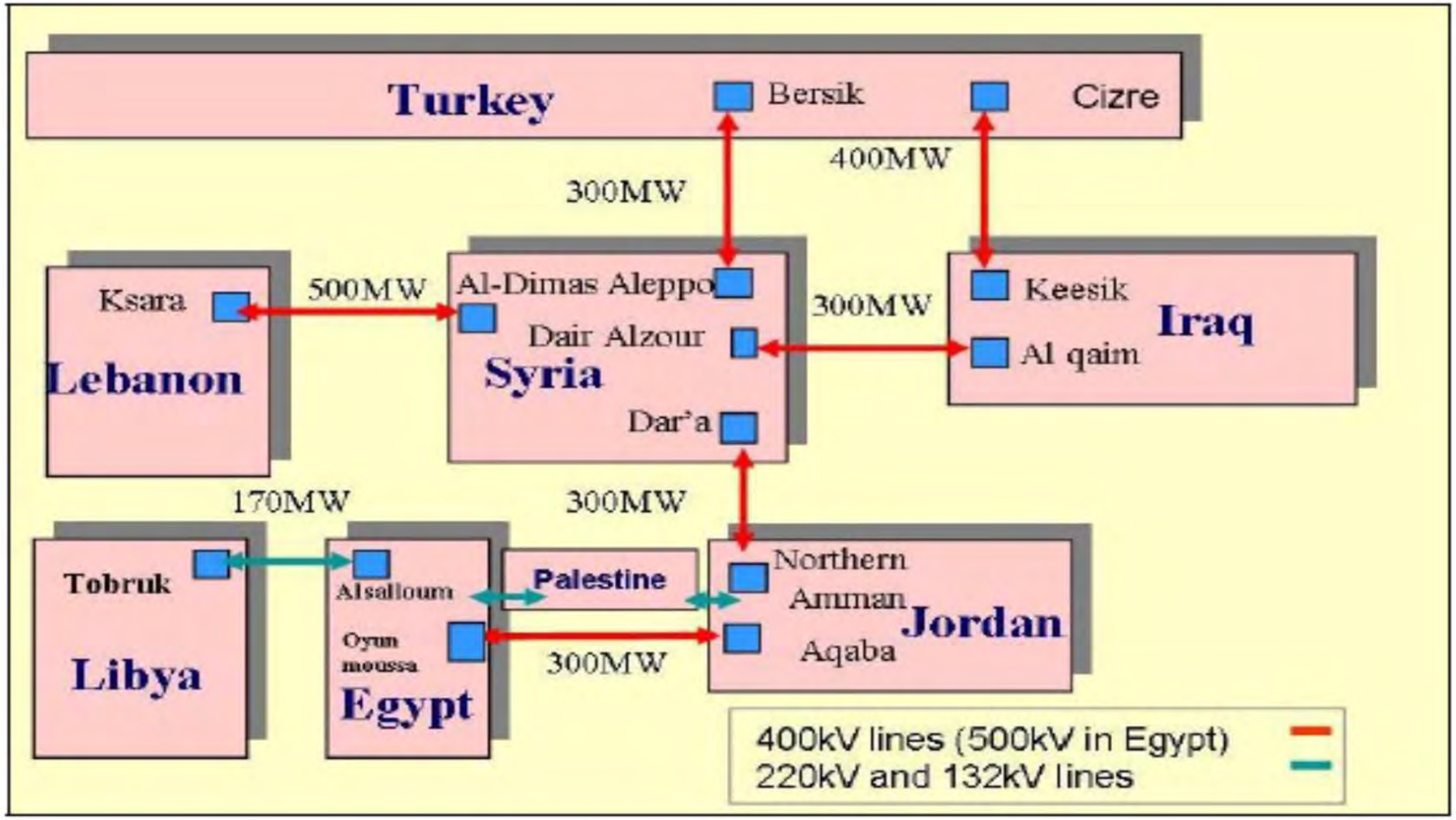
Current Situation and Objectives of Reginal Interconnections in USA

- ***Since 2012, reinforcements of transmission lines have been conducted by 5,5094km in US, 1,3604km in Canada, 622km in Mexico, and 69,320km in NERC total area***
- ***66,582km for AC transmission lines and 2,738km for DC transmission lines, DC lines is constructed mainly in Canada.***



International Grid Connection Project by Eastern Arabic Eight Counties

- *The Eight Country Interconnection Project in Eastern Arabic area, named as EIJLLPST5 was planned to promote in 1989, and mutual power grid interconnections were conducted firstly by five countries (Egypt, Iraq, Jordan Sharia and Turkey) and Lebanon joined as the sixth country.*
- *After that, Libya and Palestine joined the project and now eight countries have connected each other.*



Source: Arab Fund Home page > Projects & Operations> Projects > Arab Regional Projects >Electricity

International Grid Connections in Africa

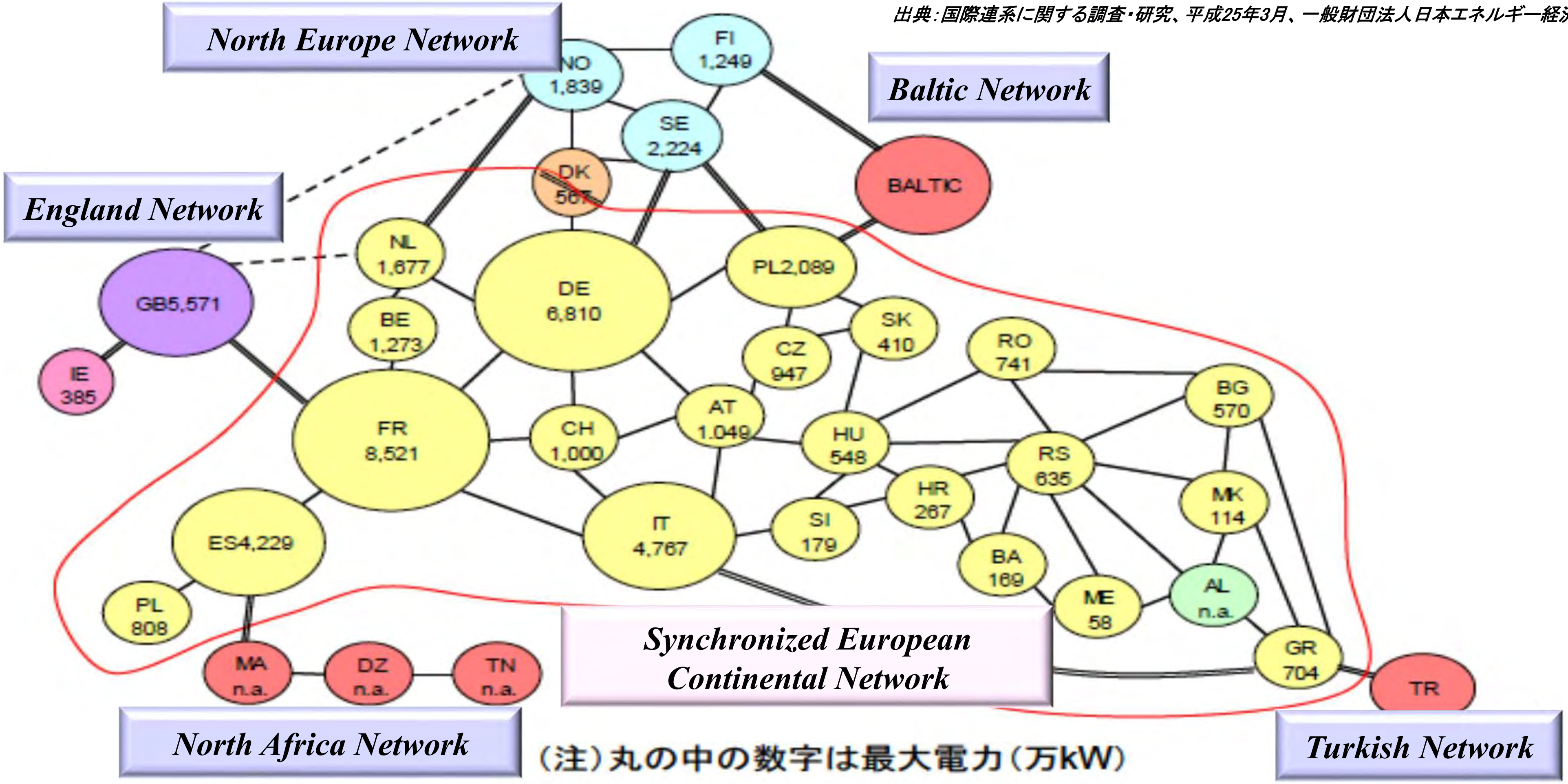
- *In 1950, the Republic of the Congo and Zambia were connected by 220kV/210MW transmission line and in 1960, Zambia and Zimbabwe were connected by 330kV（Two circuits）/1,400MW and also in 1975, Mozambique and South Africa were connected by 500kV/5,000MW DC transmission line, therefore international connections were promoted snice 1950s.*
- *Southern African Democratic Community (SADC）、Economic Community of West African States（ECOWAS）were established and electricity is possessed jointly in this area.*
- *Southern African Power Pool（SAPP）was established by concluding MOU between countries in 1995.*
- *In SAPP, countries in Southern Africa area, such as, South Africa, Mozambique, Zimbabwe, Zambia, Namibia, The Republic of the Congo, , Botswana, Swaziland, Tanzania, The Kingdom of Lesotho, The Republic of Malawi are connected and purchase of electricity by the regulated price is available in the power pool.*
- *Kenia and Tanzania plan to connect to SAPP through Zambia grid and South Africa and Ghana are major exporting countries of electricity in Africa*

（出所）SAPP

Interconnections of Power Grids in Europe

- *Power grids of European countries are connected strongly by international tie lines.*
- *Synchronized AC networks in Europe are divided into European Continental network, North Europe network, England network and Baltic network, and networks are connected each other by HVDC.*
- *Spain network is connected to North Africa and Greece network is connected to Turkish network.*

出典：国際連系に関する調査・研究、平成25年3月、一般財団法人日本エネルギー経済研究所



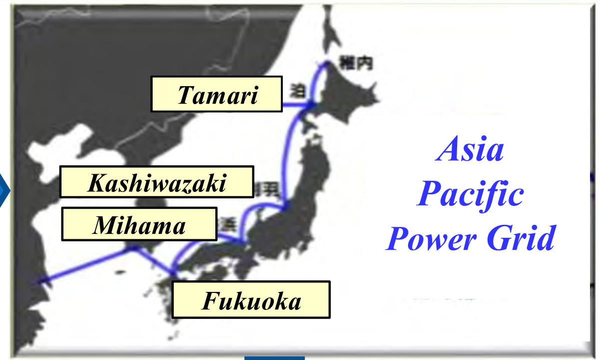
（注）丸の中の数字は最大電力（万kW）

International Grid Connection Projects in Asia

Japan-Russia Power Bridge Project (2000)

ASEAN Power Grid Connection (2007)

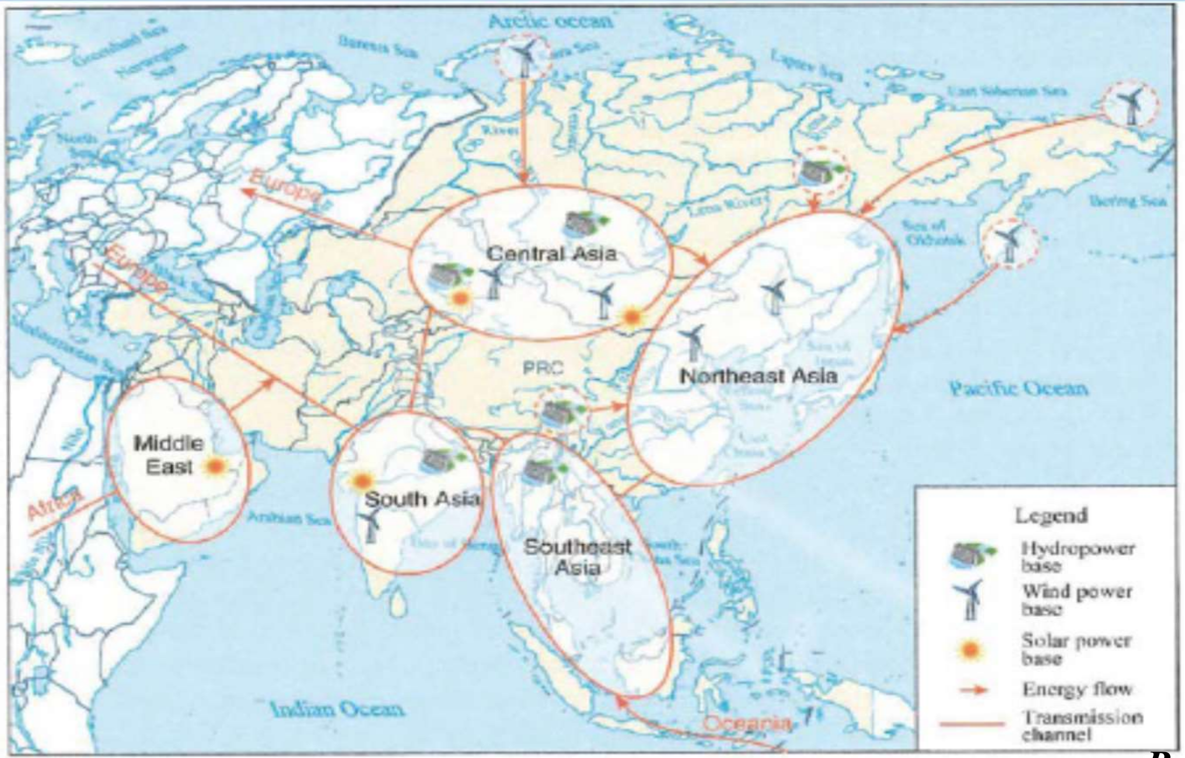
Asia Pacific Power Grid by JPC (2011)



Asian Super Grid by REF (2011)

Supegrid, Smart Energy Belt (2014)

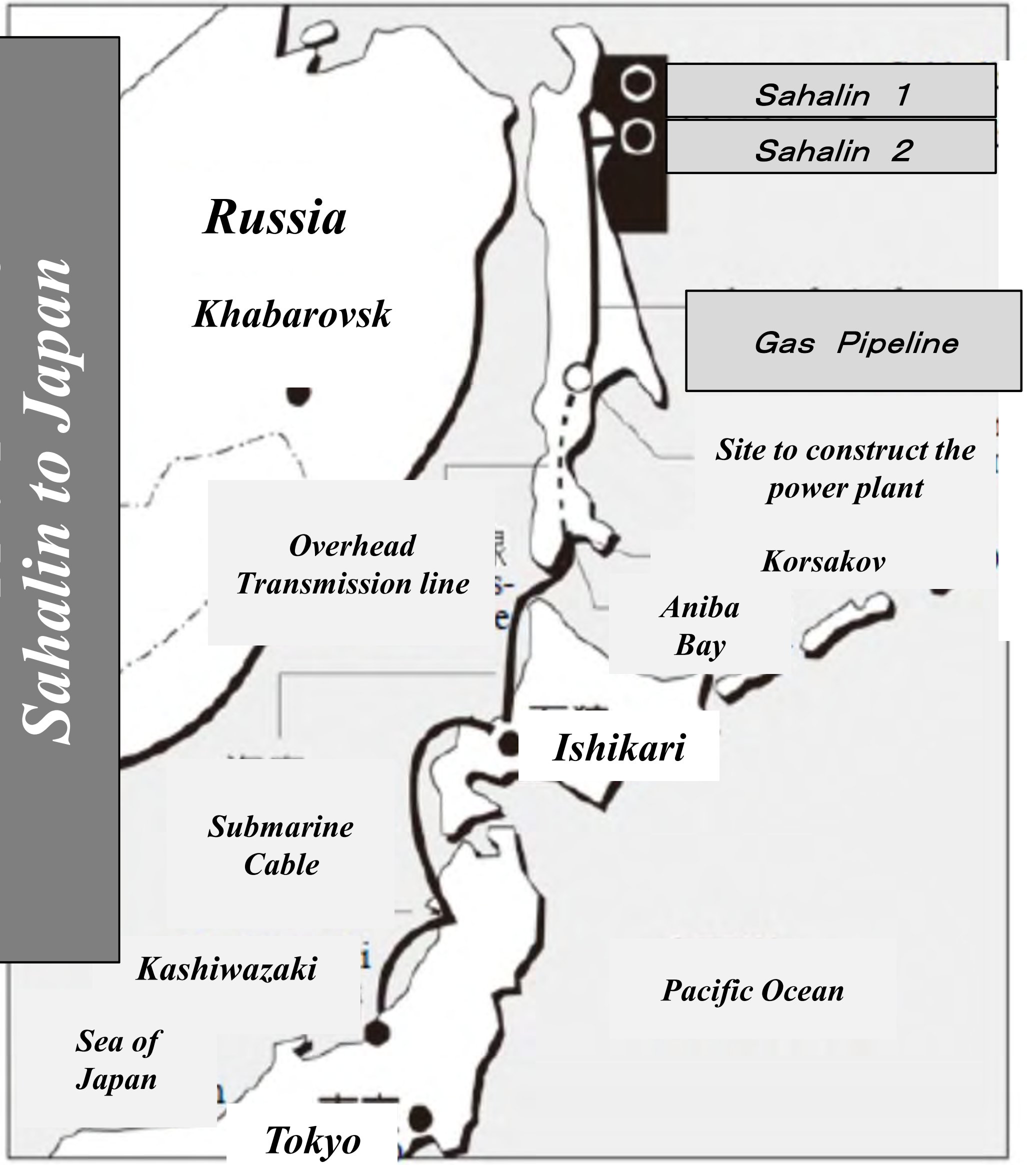
Global Energy Interconnection Vision proposed by SGCC (2015)



By Ryuichi Yokoyama, Waseda University, Japan

Transmission Line and Cable route of the Japan-Russia Power Bridge Project

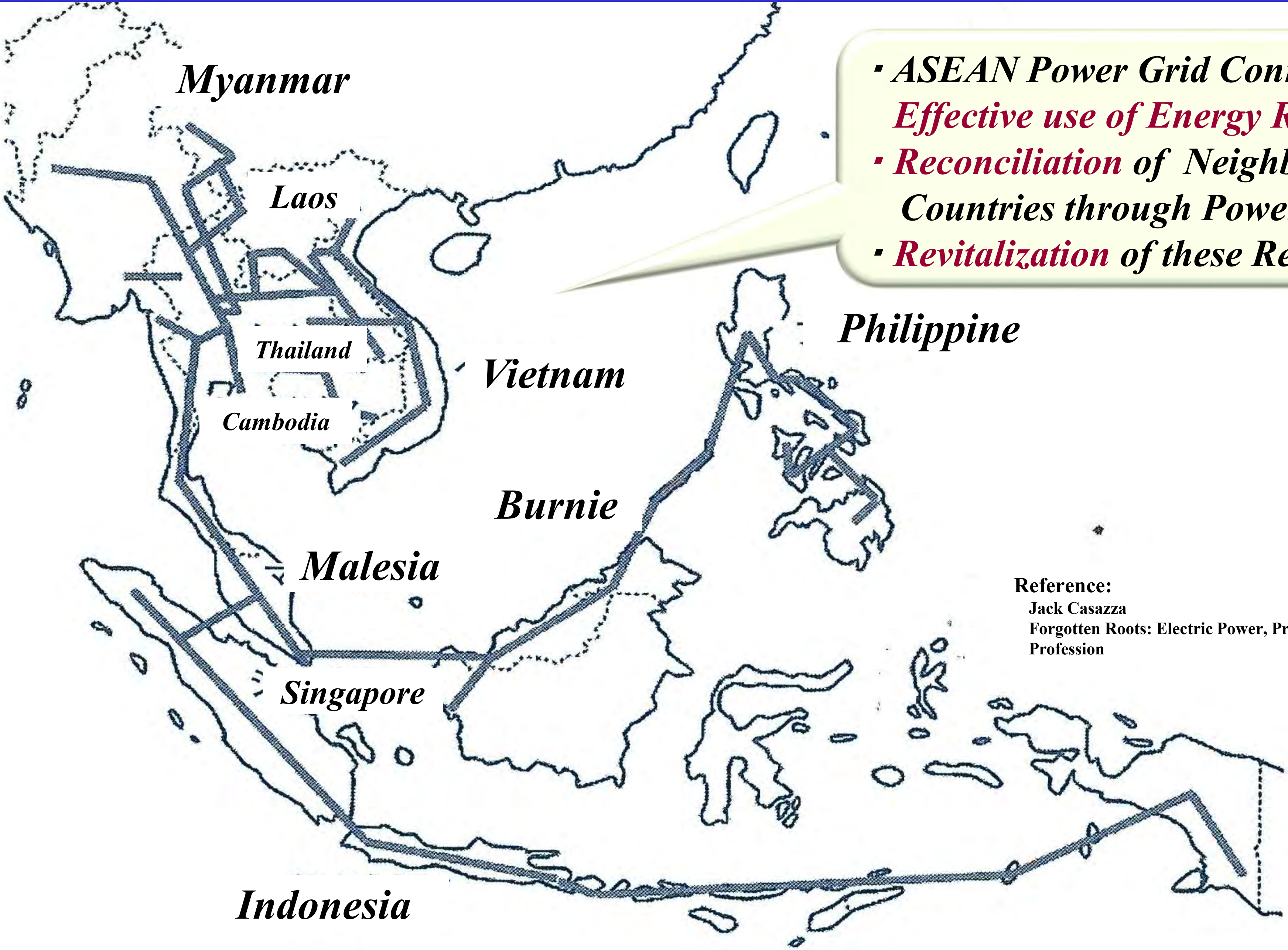
Plan to supply power from Sahalin to Japan



- *Companies that would serve in main roles* ***promoting interconnection projects*** *also are carrying out studies for the realization of the projects.*
- *A study report on* ***a Japan-Russia Power Bridge Project*** *that would link a thermal power plant on Russian Far East Sakhalin Island to Niigata via Hokkaido, using undersea transmission lines was already released in the first half of the 2000s.*
- *This is* ***a feasibility study*** *conducted by Marubeni, Sumitomo Electric Industries, and Russia's Unified Energy System.*
- *This study report proposed the schedule to start 2 GW transmission in 2010 and 4 GW transmission in 2012.*
- *This project has not been implemented as of 2017, but schemes to* ***export electricity from the Russian Far East to Japan*** *have continuously been studied by multiple enterprises.*

ASEAN Power Grid (APG) Initiative

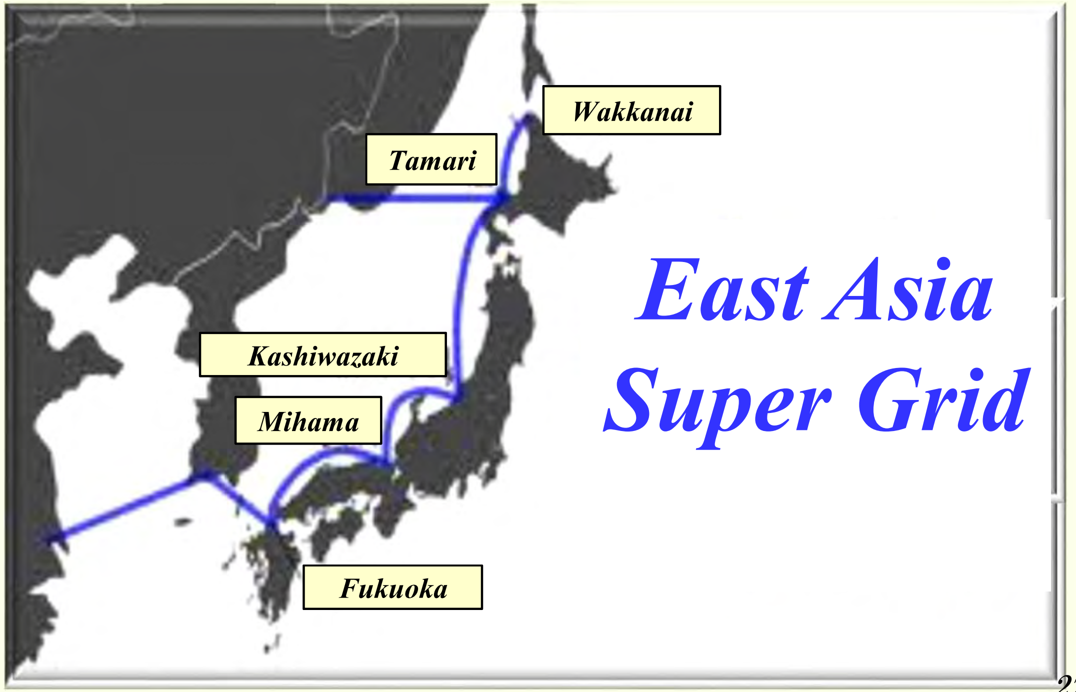
- ASEAN Power Grid Connection for Effective use of Energy Resources
- Reconciliation of Neighboring Countries through Power Transfer
- Revitalization of these Regions



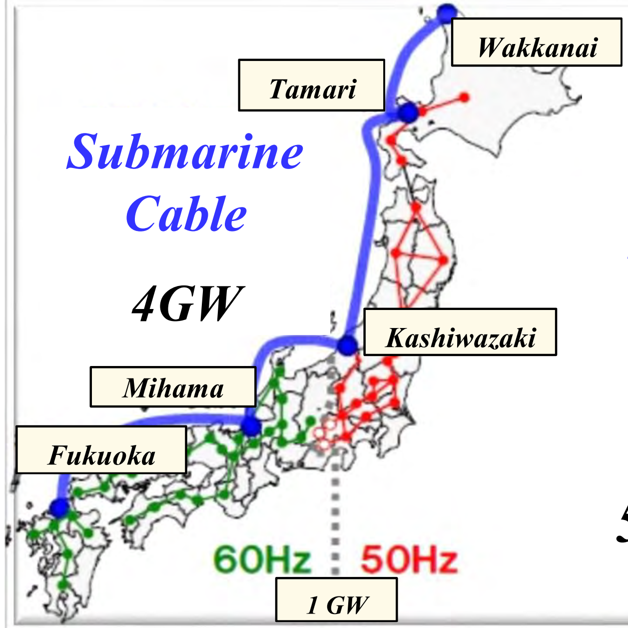
Reference:
Jack Casazza
Forgotten Roots: Electric Power, Profits, Democracy and a Profession

Proposal of East Asia Super Grid

- East Asia Super Grid is proposed to restore the shortage of Electricity caused by East Japan Earthquake and accompanied Tsunami in 2011.
- Japan Policy Council composed of economists and researchers (Chairman is Hiroya Masuda, Visiting professor of Tokyo University) proposed a new scheme for isolated power grids in Japan to connect to foreign countries and exchange power mutually by crossing the border.
- As the first stage, construction of Submarine Cable between Korea and Japan was proposed.
- Landing point is assumed to be the most southern end, Fukuoka, and other cables are to construct in Japan Sea side along the Japan Archipelago
- Trunk cables are connected to Western and Eastern utility grid by AC/DC converter.

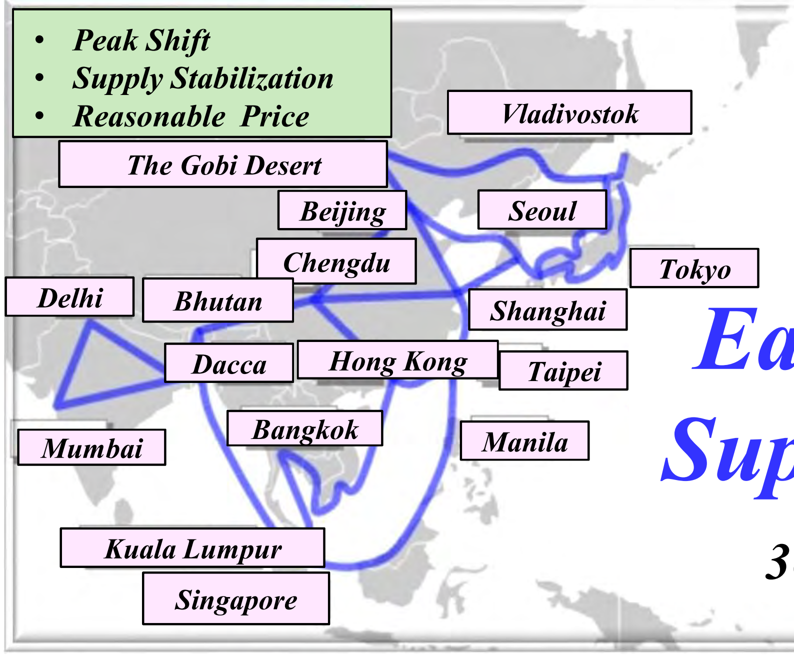


Proposed Super Grid Plans in Japan



Japan Super Grid

2,000Km
2,000 Billion Yen
50 Billion Yen/year

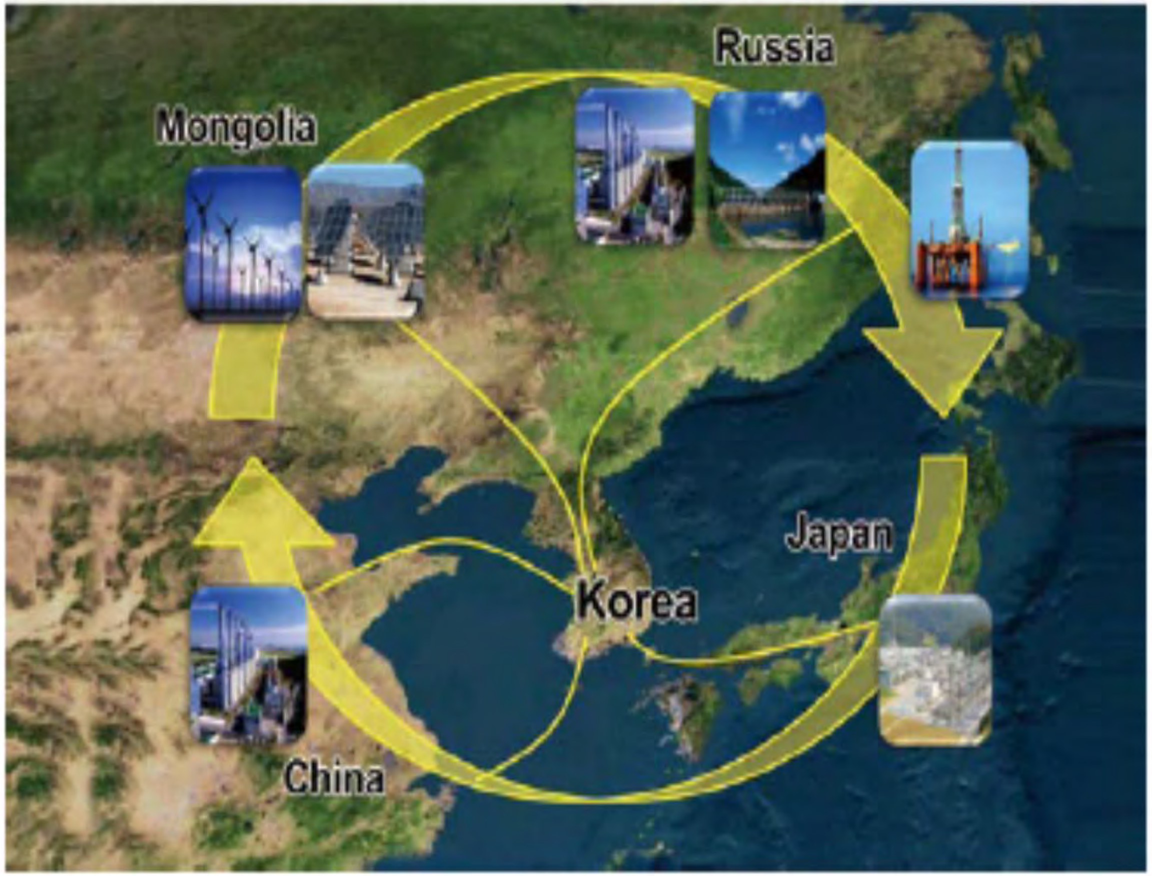


East Asia Super Grid

36,000Km

- *Japan Super Grid is proposed by Masayoshi Son (Renewable Energy Institute , SoftBank Group) and Tetsunari Iida (Environment and Energy Policy Institute)*
- *Connecting Asian power grids including Japan by Ultra-High Voltage DC transmission lines to exchange electricity each other.* （Reference : REI ）
- *Wide Area Cross Reginal Interconnection from the north end Hokkaido to the south end Fukuoka*
- *Construction of these DC trunk lines leads to solution of the two frequency problem between Western and Eastern regions and enables us to transfer electricity generated by solar and wind energy in Wakkanai to Metropolitan area and other areas*

Northeast Asia Interconnection Vision by Korea Electric Power Corporation



- ***For example, the Korea Electric Power Corporation announced the Northeast Asia Super Grid plan in 2014 in cooperation with the Russian research institution Skoltech and other organizations.***
- ***The company set out the concept of a Smart Energy Belt that connects Japan, China, South Korea, Russia, and Mongolia with a highly efficient electricity supply-demand system combining power storage technologies and smart grid.***

- ***In addition, at an international conference held in Tokyo in 2016, the Korea Electric Power Corporation proposed a Northeast Asia Interconnection Vision as a vision of an international power grid connecting Northeast Asian countries.***

International power grid in Asia in the GEI vision

In 2015, the State Grid Corporation of China (SGCC), the world's largest power transmission company, announced its Global Energy Interconnection (GEI) vision. This is a vast vision calling for connecting the world through ultra high-voltage transmission systems.

In March 2016, the international nonprofit foundation Global Energy Interconnection Development and Cooperation Organization (GEIDCO) was established with the goal of realizing this GEI concept. Consisting of research institutions and relevant enterprises in various countries, GEIDCO aims to develop a global power grid to utilize renewable energy.

Asian Super Grid
International Energy Internet (Interconnection)

Wind Farm in Mongolia

The Gobi Desert

Solar Thermal Farm

Renewable Energy Institute has proposed an Asia Super Grid based on renewable energy. The goal is to utilize renewable energy across Asia by connecting China, South Korea, Russia, and Japan via an international power grid using solar and wind power generated in Mongolia as the main power supply.

AC Transmission Lines

Converter Station

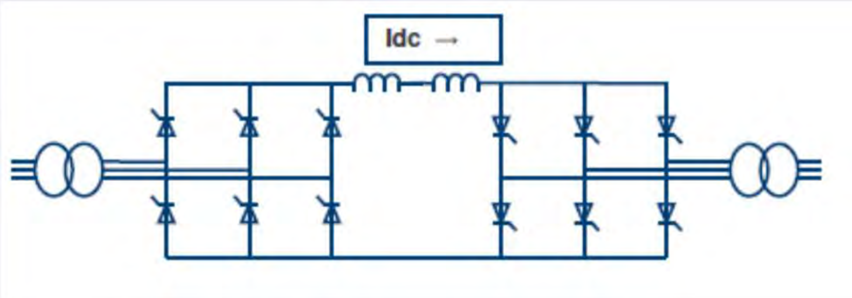
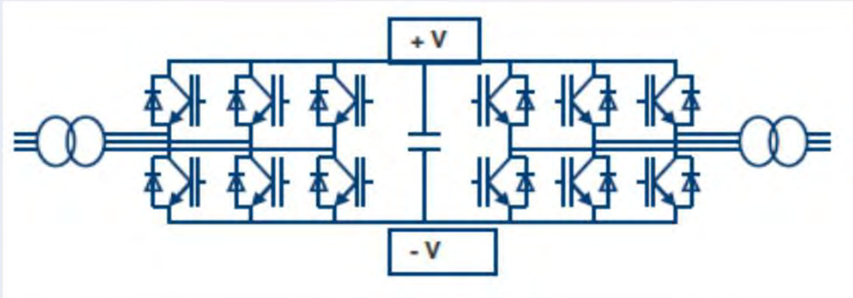
HVDC Cable

Current Status of Submarine Cables

Type	MI-PPLP Mass Impregnated- Polypropylene Laminated Paper	XLPE Cross-linked polyethylene
Features	- A paper-lapped insulation but the impregnation compound is highly viscous - Presently 500kV～600kV - 800kV, Hydro Quebec of Canada - Operational achievements over 40 years	- The entire cable core is impregnated with a low-viscosity insulation fluid (mineral oil or synthetic) - Presently 420kV - In the future 500kV - Operational achievements over 15 years
Structure	 DC500kV PPLP-MI Cables	 500kV 1x1,400 mm^2 XLPE cable
Manufactures	- Sumitomo Denko - Prysmian	- Sumitomo Denko - Furukawa Denko - Prysmian - ABB - LS Cables etc.

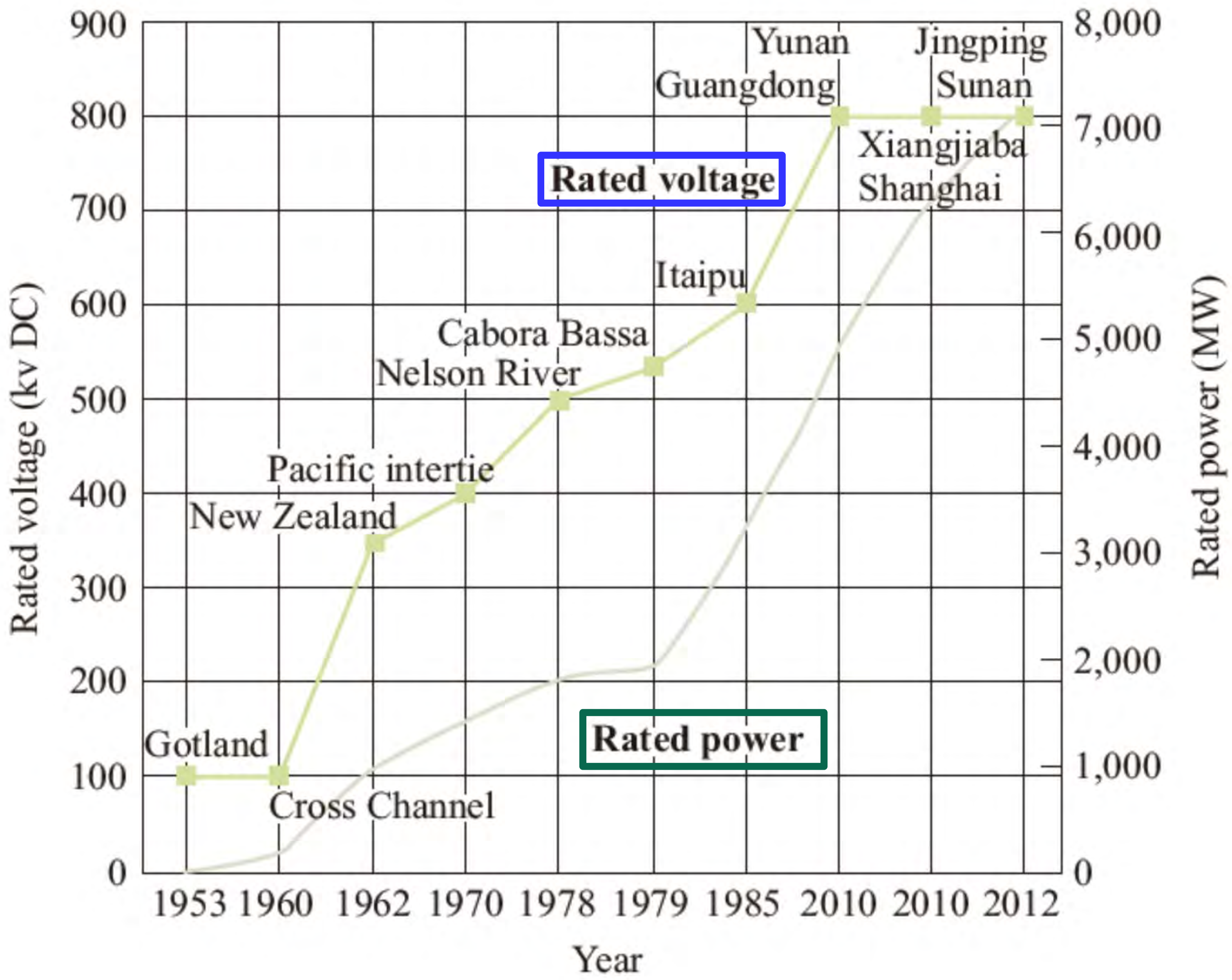
Reference :The Leading Company for Extra High Voltage Underground and Submarine Cable, Sumitomo Denko

Comparison of Performances of LCC & VSC

Type	Line Commutate Converter (LCC)	Voltage Sourced Converter (VSC)
Features	− Current Sourced Converter − Thyristor based Technology	− Self Commutated Converter − Transistor (IGBT, GTO etc.) based Technology
Structure	 	
Performances	- High power capability PE device current capability - Good overload capability - Requires stronger AC systems - "Black" start capability, requires additional equipment - Generates harmonic distortion - AC & DC harmonic filters required - Coarser reactive power control - Large site area, dominated by harmonic filters	- Lower power capability PE device current capability - Weak overload capability - Operates into weaker AC systems - "Black" start capability - Insignificant level of harmonic generation, hence no filters required - Finer reactive power control - Compact site area, 50 ～ 60% of LCC site area

Reference :LCC & VSC – Comparison, Dr Radnya A Mukhedkar Group Leader, Senior Principal Engineer System Design, ALSTOM

Trends of HVDC Voltage and Capacity



Reference :The Test Results of AC and DC HTS Cables in Russia http://ieeexplore.ieee.org/document/7420611/

Major Large-Scale DC Transmission Projects

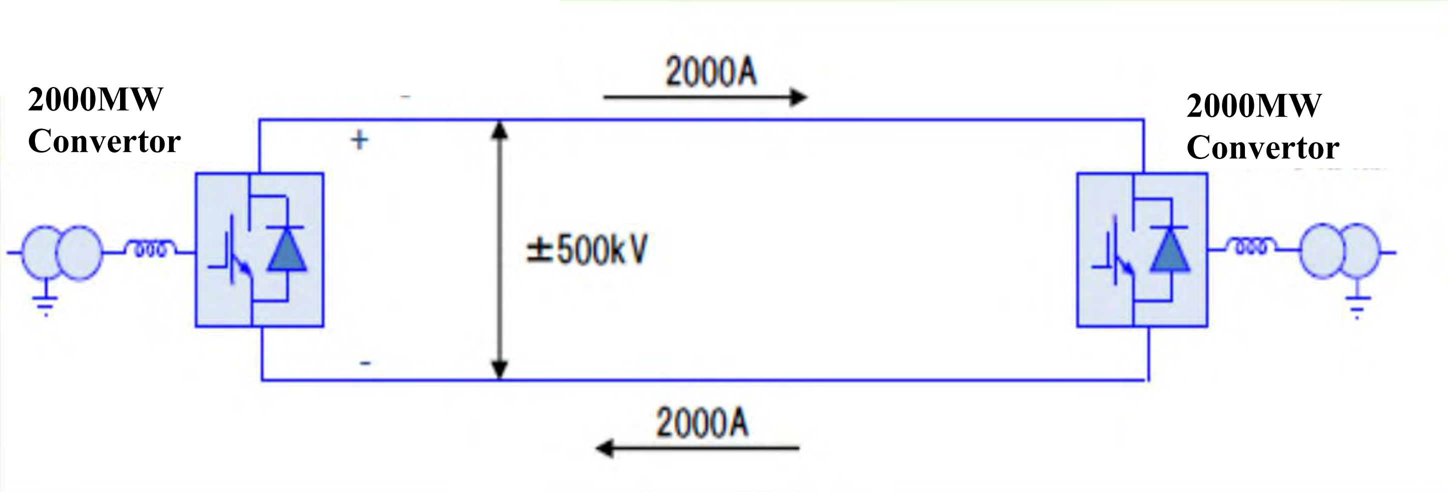
NO.	Project		Distance (km)	Strait, etc. (km)	Trans-mission method	Grid voltage (kV)	DC voltage (kV)	Transmission capacity (MW)	Came into operation in	Transformer cost	Transmission line cost	Total cost	¥10,000/MW km (reference)*
1	**SAPEI**	Italy	435	420	line-Commutated	400	±500	1,000	2011	$180m	€400m	€750m	20
2	**BritNed**	UK - Netherlands	259	250	line-Commutated	400 380	±450	1,000	2011	€220m	$350m	€600m	26
3	**Nemo Link**	UK - Belgium	141	130	self-Commutated	400 380	±400	1,000	2019	—	—	€500m	40
4	**Estlink 2**	Estonia - Finland	171	145	line-Commutated	330 400	450	650	2014	€100m	$180m	€320m	32
5	**NorNed**	Netherlands - Norway	583	580	line-Commutated	380 300	±450	700	2008	$270m	€51m	€600m	17
6	**Fenno-Skan 2**	Sweden - Finland	196	194	line-Commutated	400	±500	800	2011	$170m	€150m	€315m	23
7	**Skagerak 4**	Denmark - Norway	243	140	self-Commutated	400 300	±500	700	2014	$180m	€87m	—	17
8	**Nord.Link**	Germany - Norway	623	516	self-Commutated	380 420	±525	1,400	2019	$900m	€500m	€1.5—2.0b	20~26

*Converted at ¥114.0/€ and ¥103.8/$ (forex rates on October 19)

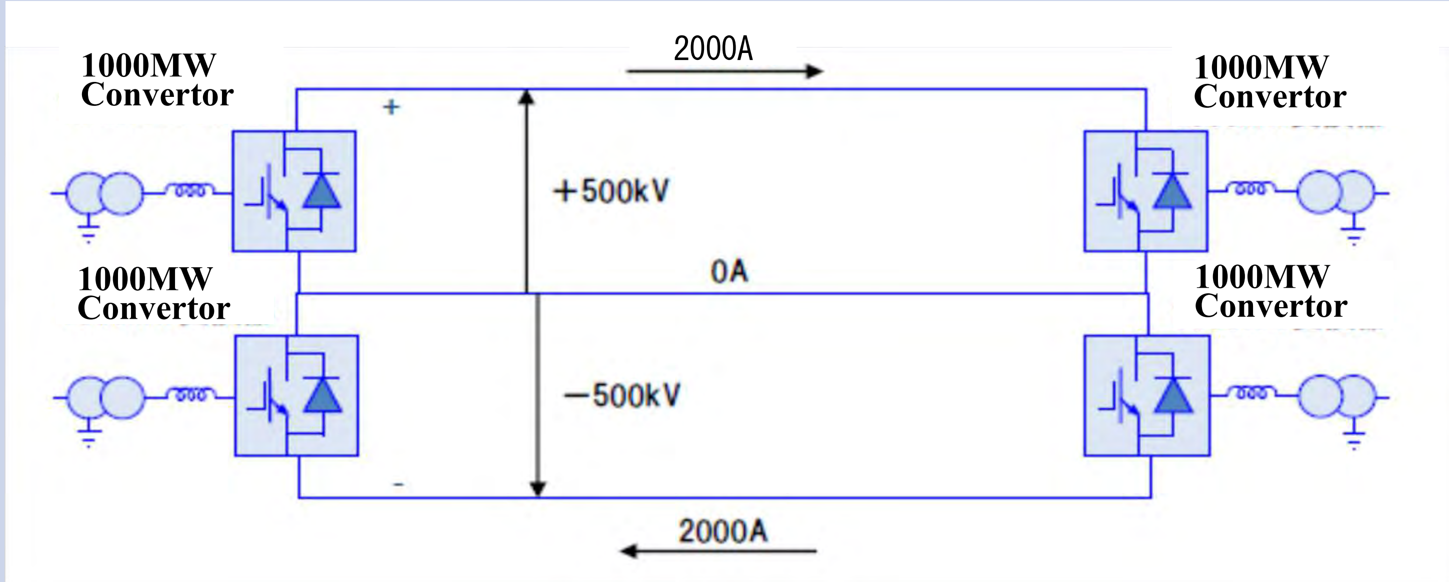
Source: "On Preparation of Long-term Cross-regional Network Development Policy," Material No. 1 for the 18th Meeting of the Cross-regional Network Development Committee, OCCTO (October 25, 2016, Committee Secretariat)

Configuration of Converters and Cables to Transfer 2GW Power by 500kV DC Cable

Symmetric Monopole

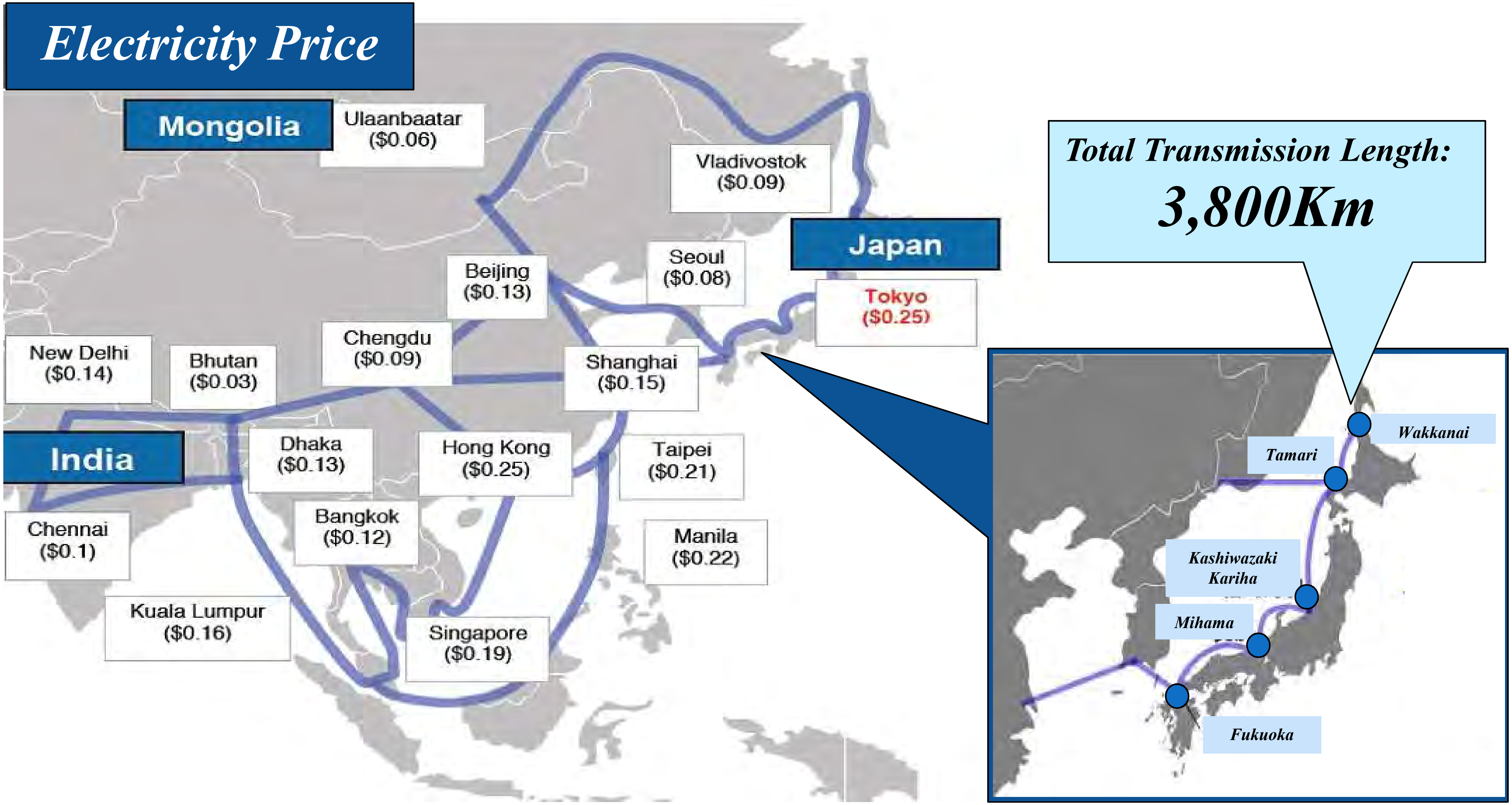


Bi-Pole with Metallic Return



Features of Power System and Issues on International Connection in Japan

Benefit of Asian Super Grid
Difference of Electricity Prices in Countries

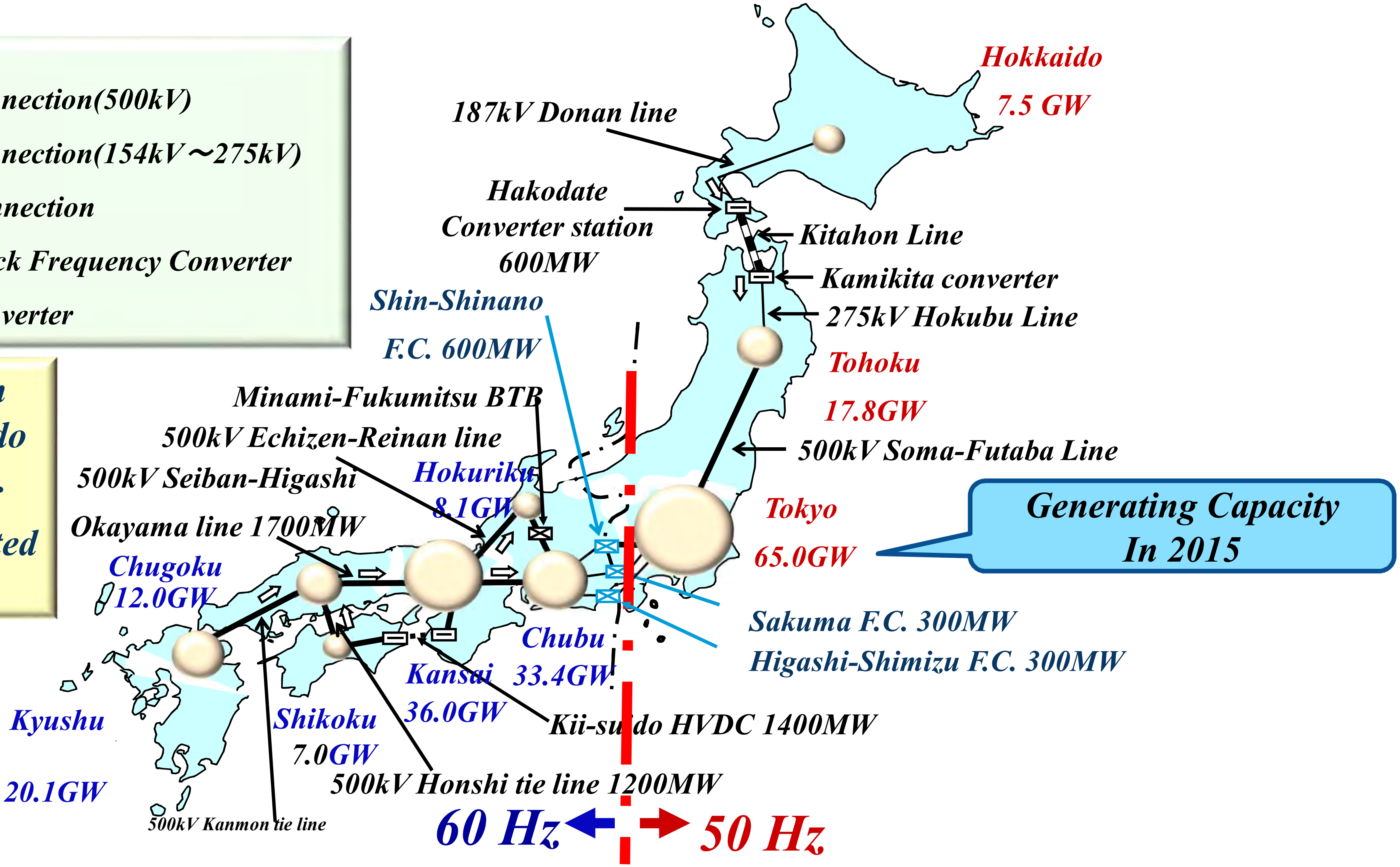


Supply Areas divided by Two Frequencies (50Hz and 60Hz)

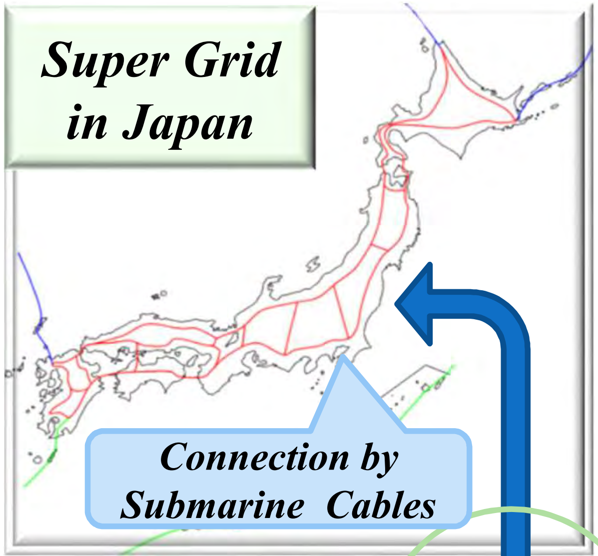
- AC interconnection(500kV)
- AC interconnection(154kV～275kV)
- DC interconnection
- Back-to-Back Frequency Converter
- AC-DC Converter

-Distance between Kyushu- Hokkaido is about 2000 km.

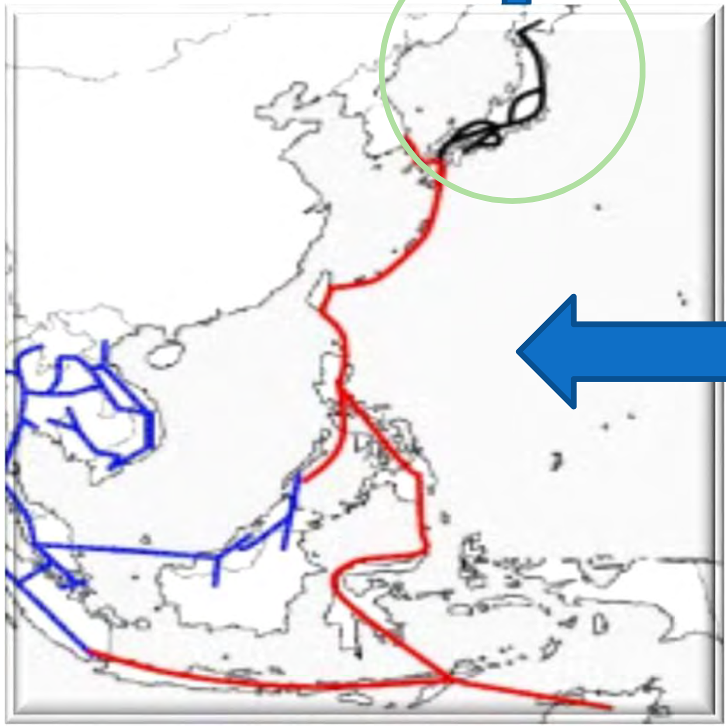
-Utilities are located sequentially.

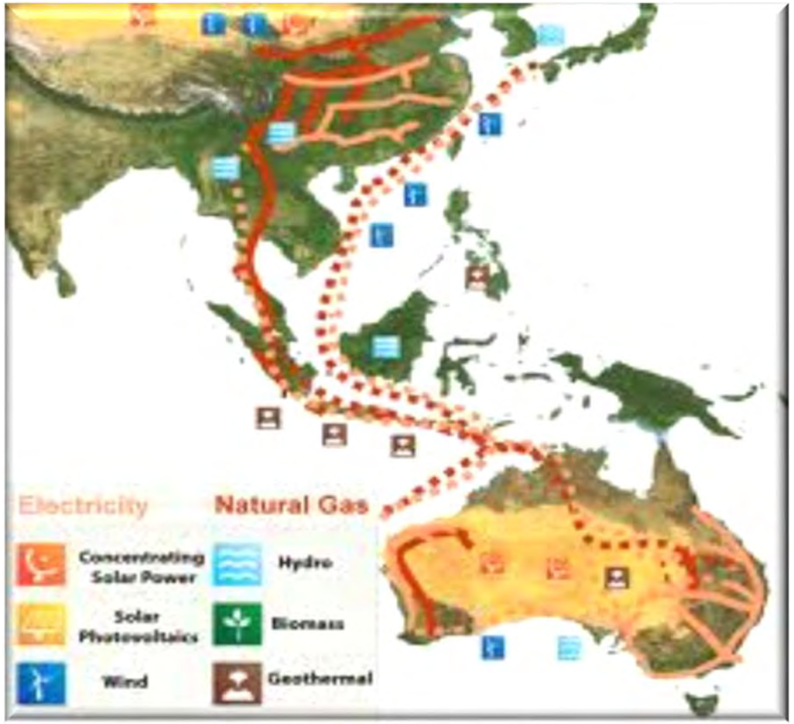


Deployment of Super Grid into Asian Countries

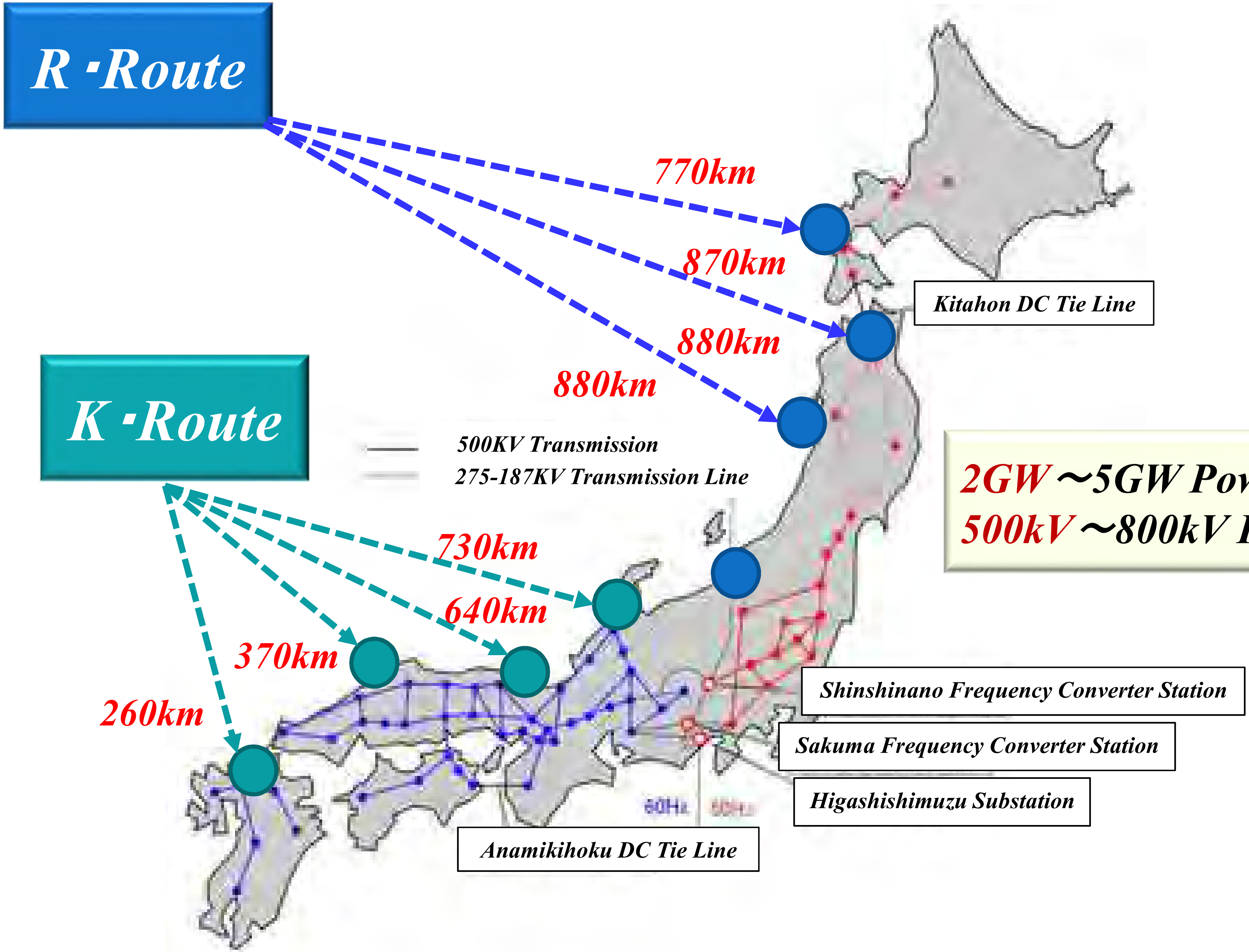


- *Necessity of **feasibility studies** for international interconnection toward the targeted year, 2020 or 2030*
- *In the future, expansion to **multi-national Super Grid** including the North East Asian countries (ASEAN) and Australia*
- ***Creation of a platform** for effective use of renewable energy such as solar and wind*
- *As electric power companies in Japan have been protected by monopoly and regulation, even domestic transfer between areas was not sufficient because of **poor tie line capacity**.*





Feasibility of International Grid Connection in Japan

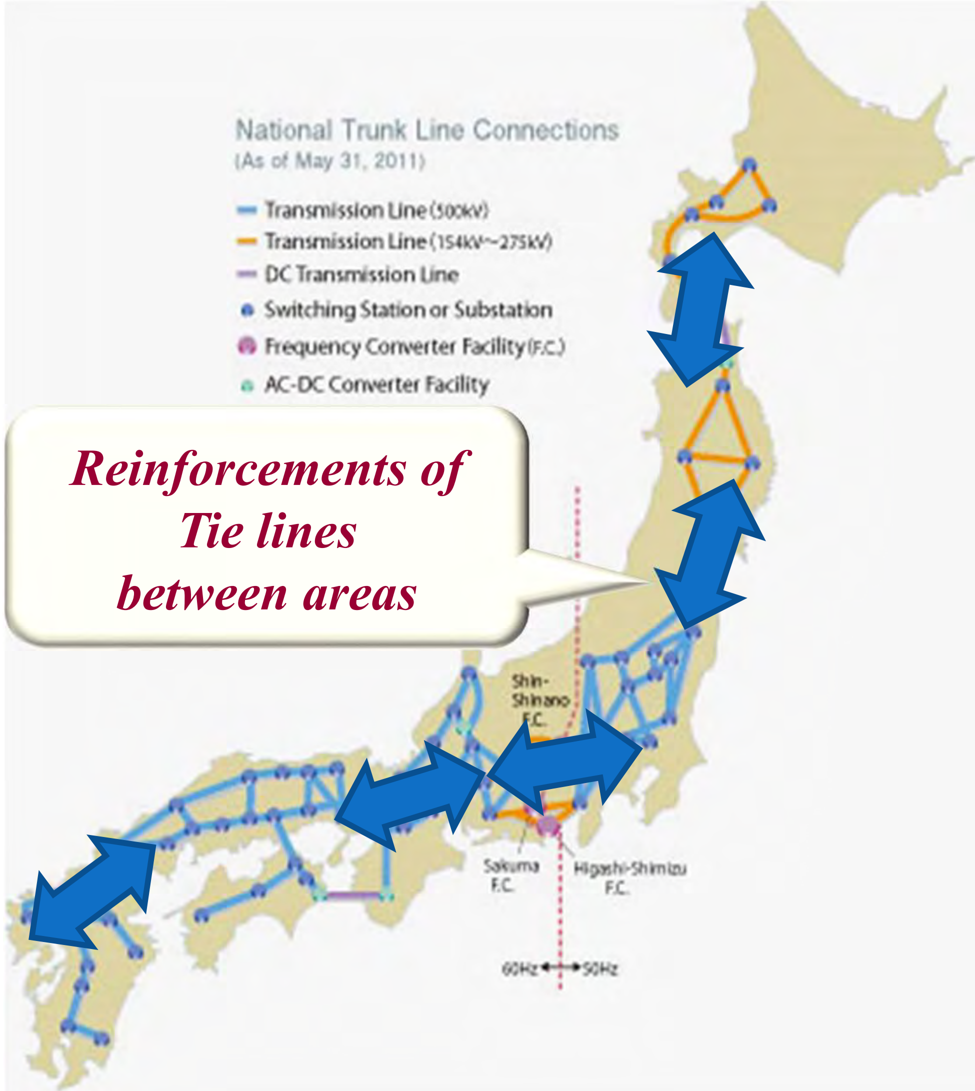


2GW～5GW Power Transfer
500kV～800kV HVDC

Reinforcement of Tie lines for Cross-Reginal Cross regional Operation Toward Super Grid in Japan

Increase of Cross-regional electricity transfer

- To avoid **blackout** occurred by natural disasters by transferring electric power between areas
- To mitigate **output fluctuation** of large scale renewable energy installation by enhancement of nationwide demand and supply balancing capability
- **Establishment of OCCTO**: Organization for Cross–regional Coordination of Transmission Operators, Japan



Reference: OCCTO, Summary of electricity supply plan in2015, June 2015

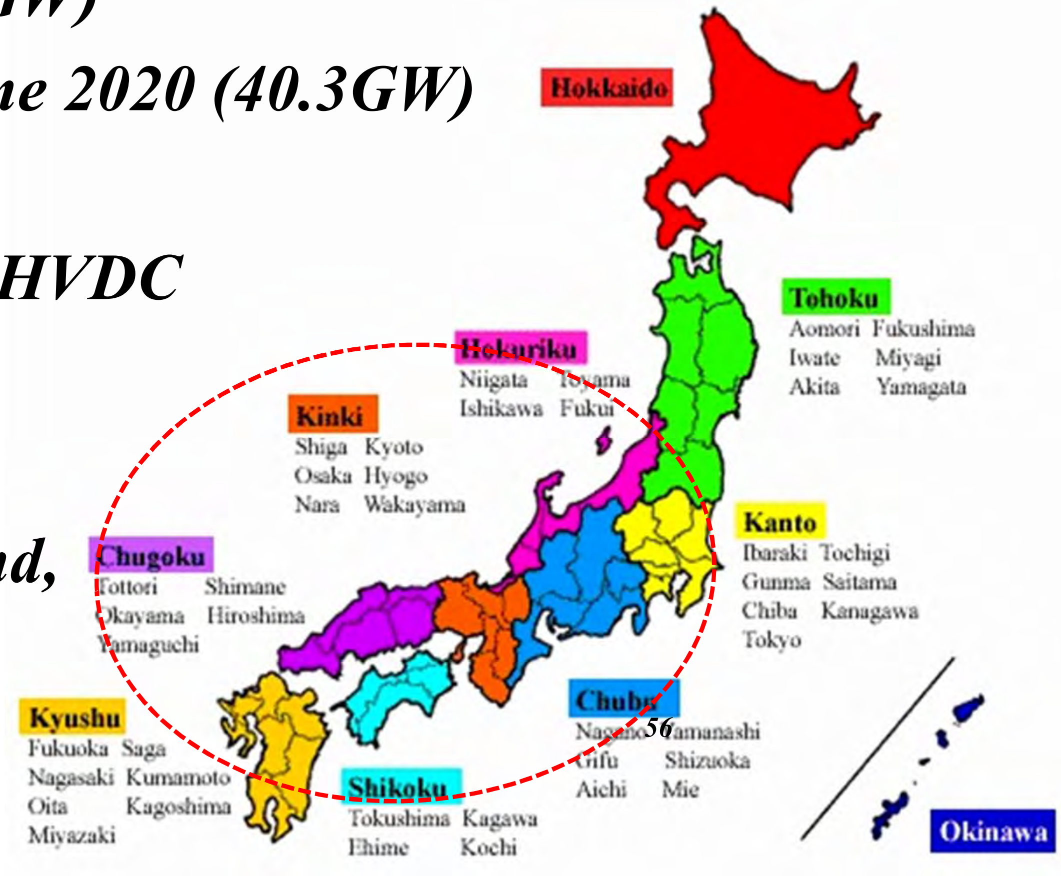
Feasibility Studies of International Grid Connections of Korea and Japan

(1) Power Flow Calculation
(2) Stability Analysis
(3) Short Circuit Analysis

Energy and Environment Technology Research Institute

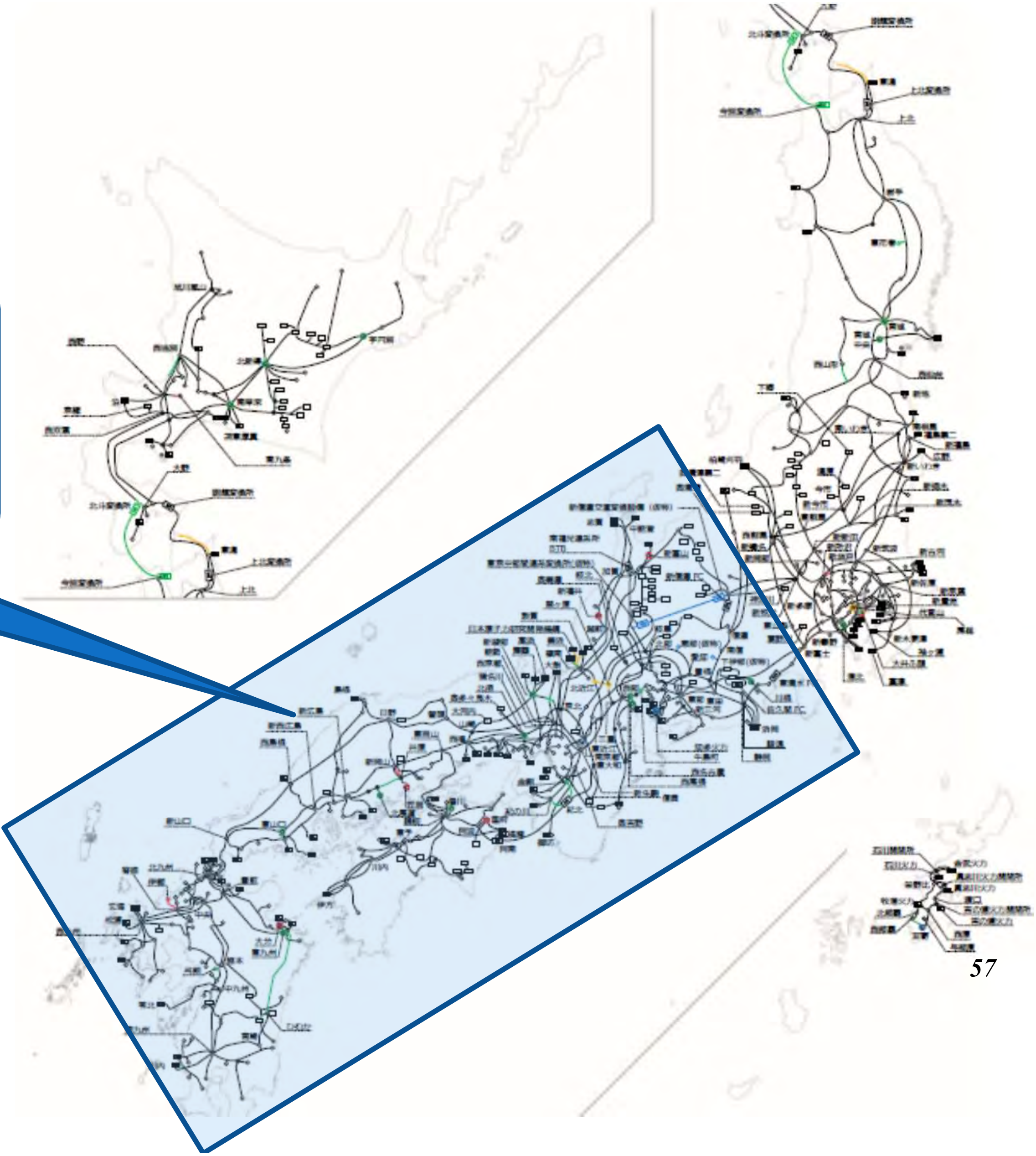
Boundary Conditions of Power System Analysis

- ***a.*** ***Simplified backbone power system model of 60Hz area in west Japan***
- ***b.*** ***Peak / Off-peak demand mode***
  - ***- Peak demand: August 2020 (89.5 GW)***
  - ***- Off-peak demand: August Nighttime 2020 (40.3GW) (45% of Peak demand)***
- ***c.*** ***Supply-demand balances with 2GW HVDC were adjusted by generations in Kansai for peak demand, and in Kansai and Chubu for off-demand, respectively.***

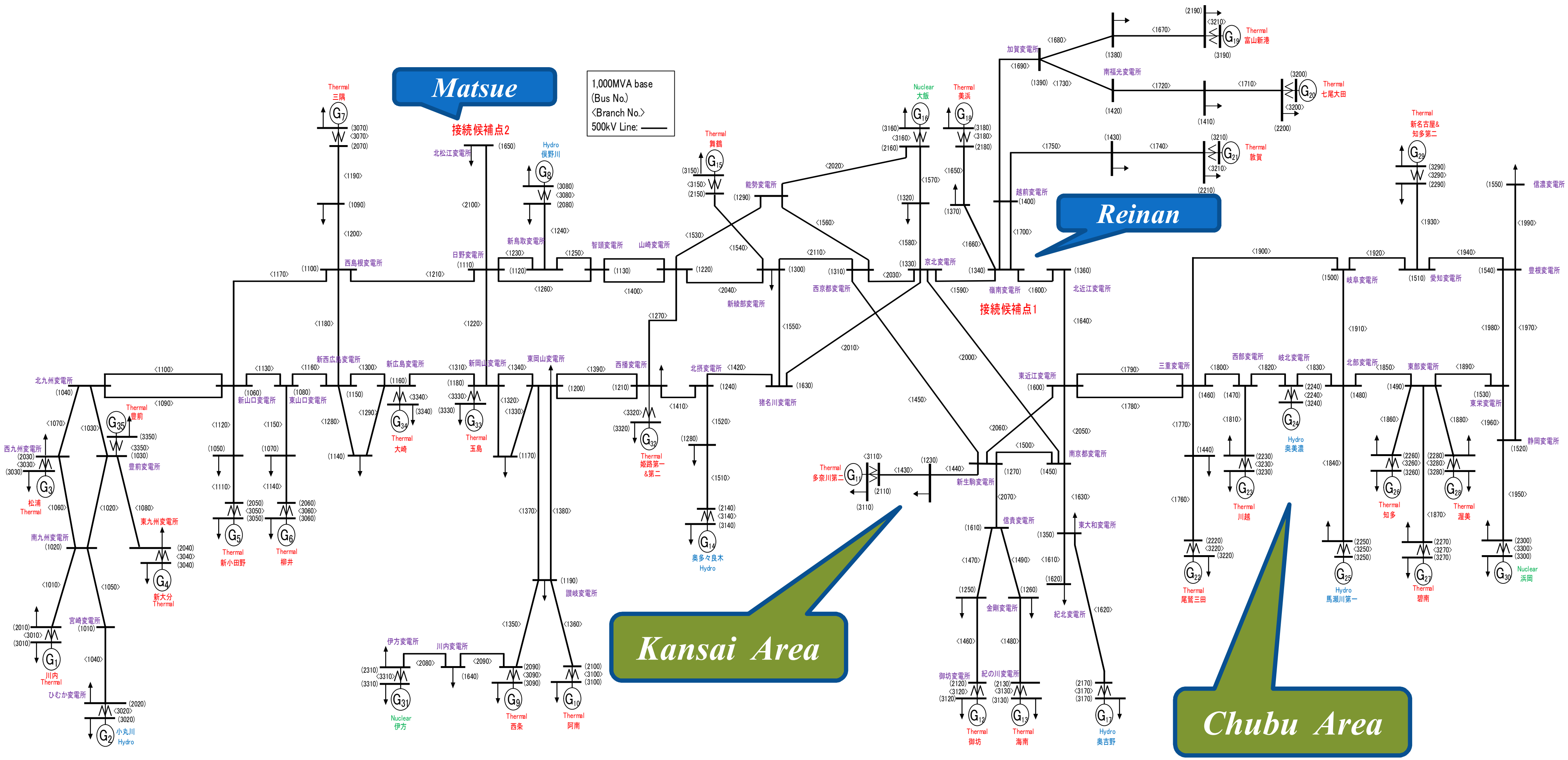


Configuration of West-Interconnection Power System in Japan

West Power System consists of 6 EPCO (60Hz Area)

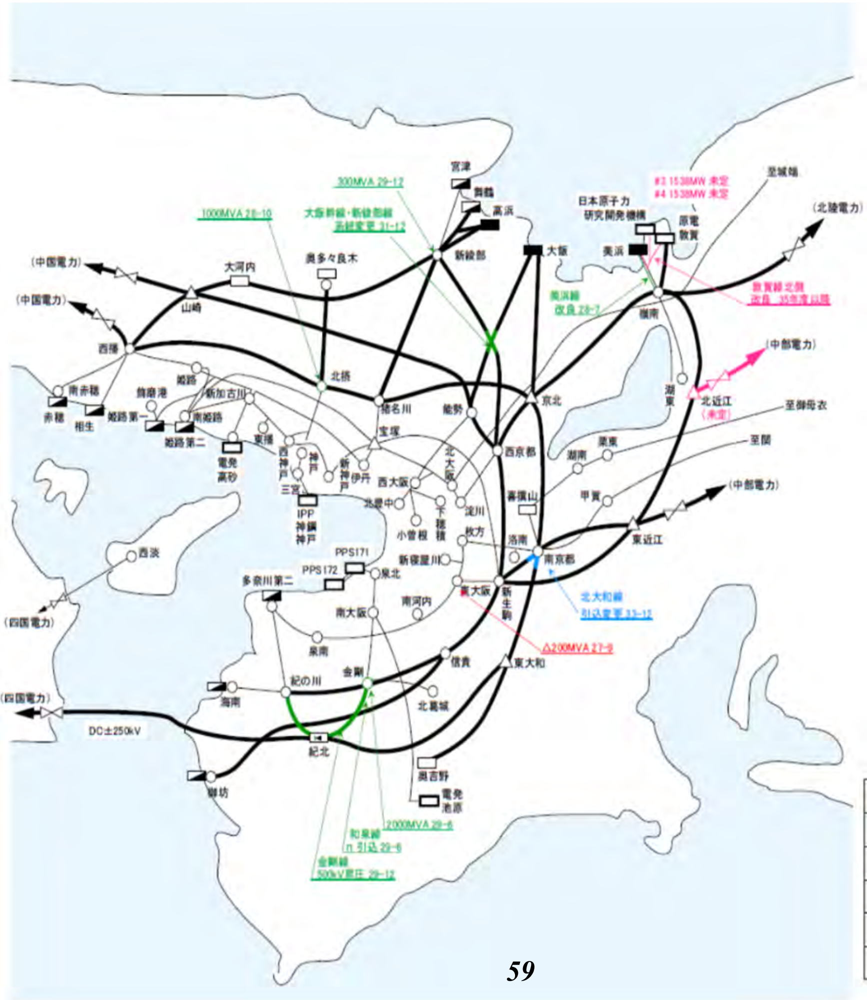


Revised Test Power System of Western EPCOs (60Hz Area)

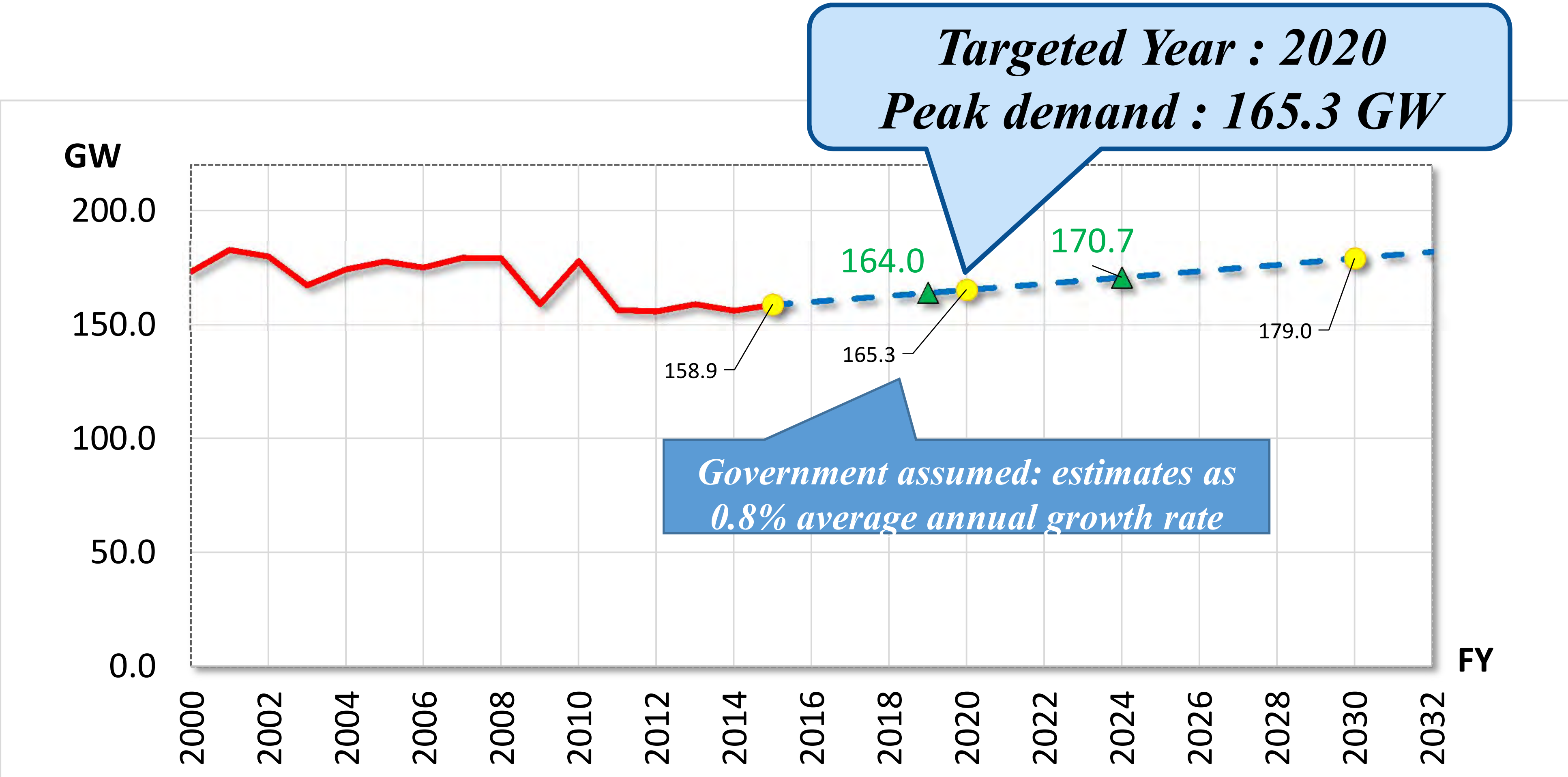


Test Power System and Power Flow Calculation

- *The test power system was revised based on Standard Power System West-30 published by IEE Japan (IEEJ Technical report No.754).*
- *As topology of the test system for Kansai area differs largely from the current network, revision has been conducted focusing on transmission lines in Kansai area.*
- *Newly constructed transmission lines are add to the IEEJ standard power system and line impedances are estimated by measuring the line distance and the specification of lines*
- *As a base case for power flow calculations, demands and active powers at buses are specified by taking account of the average power of top three days and power flow of tie lines.*
- *Confirmed the power flow calculation converged properly for the base case.*



Estimates of Total Peak Demand at Target Year

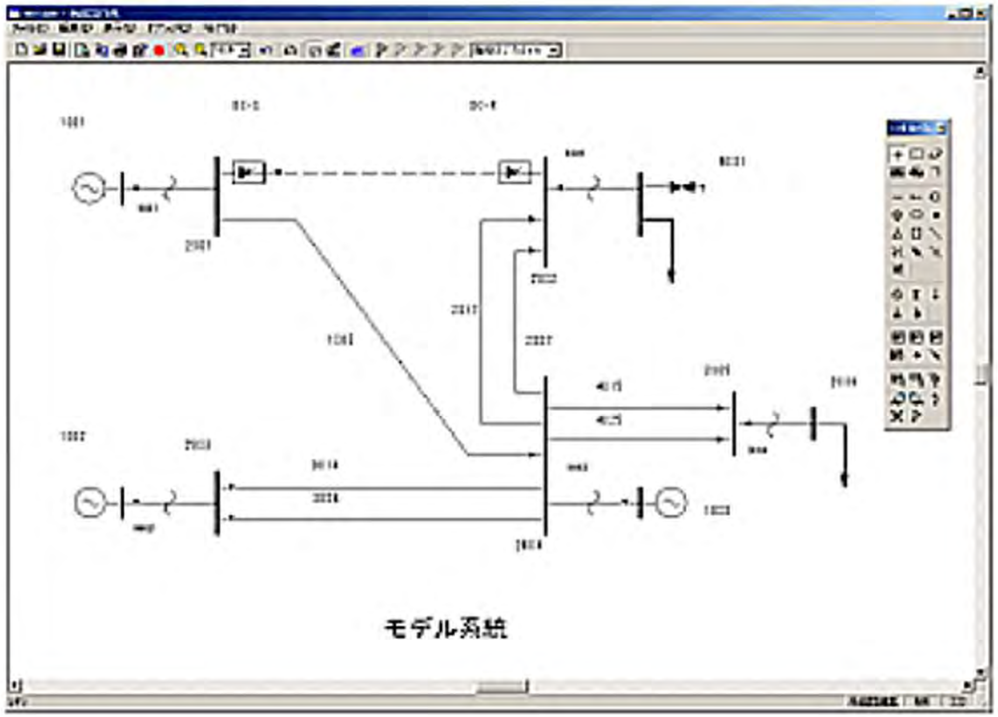


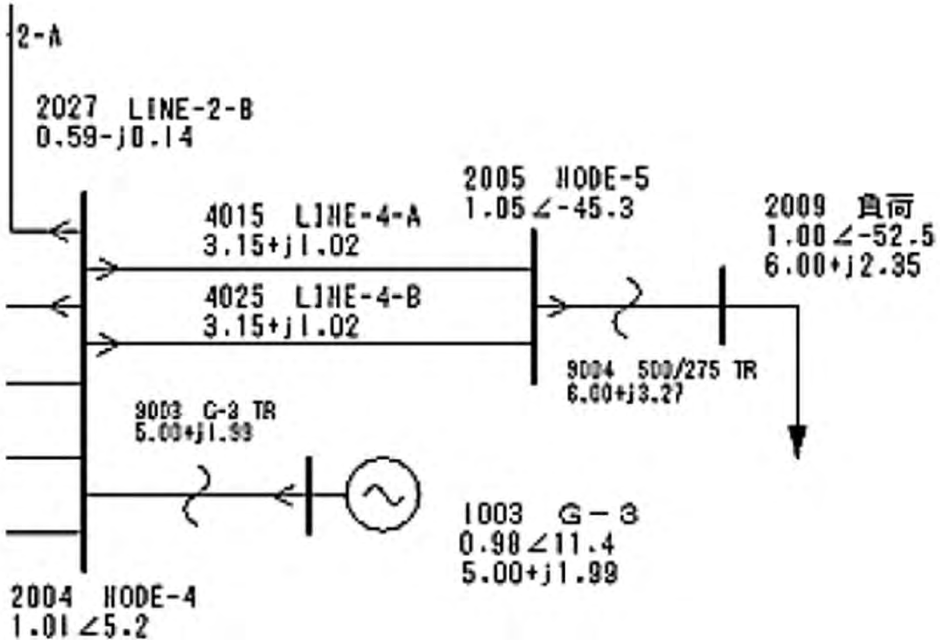
Estimates of total peak demand(9 EPCO total) from 2015 to 2030

CPAT with POPONAS as Calculation Tools

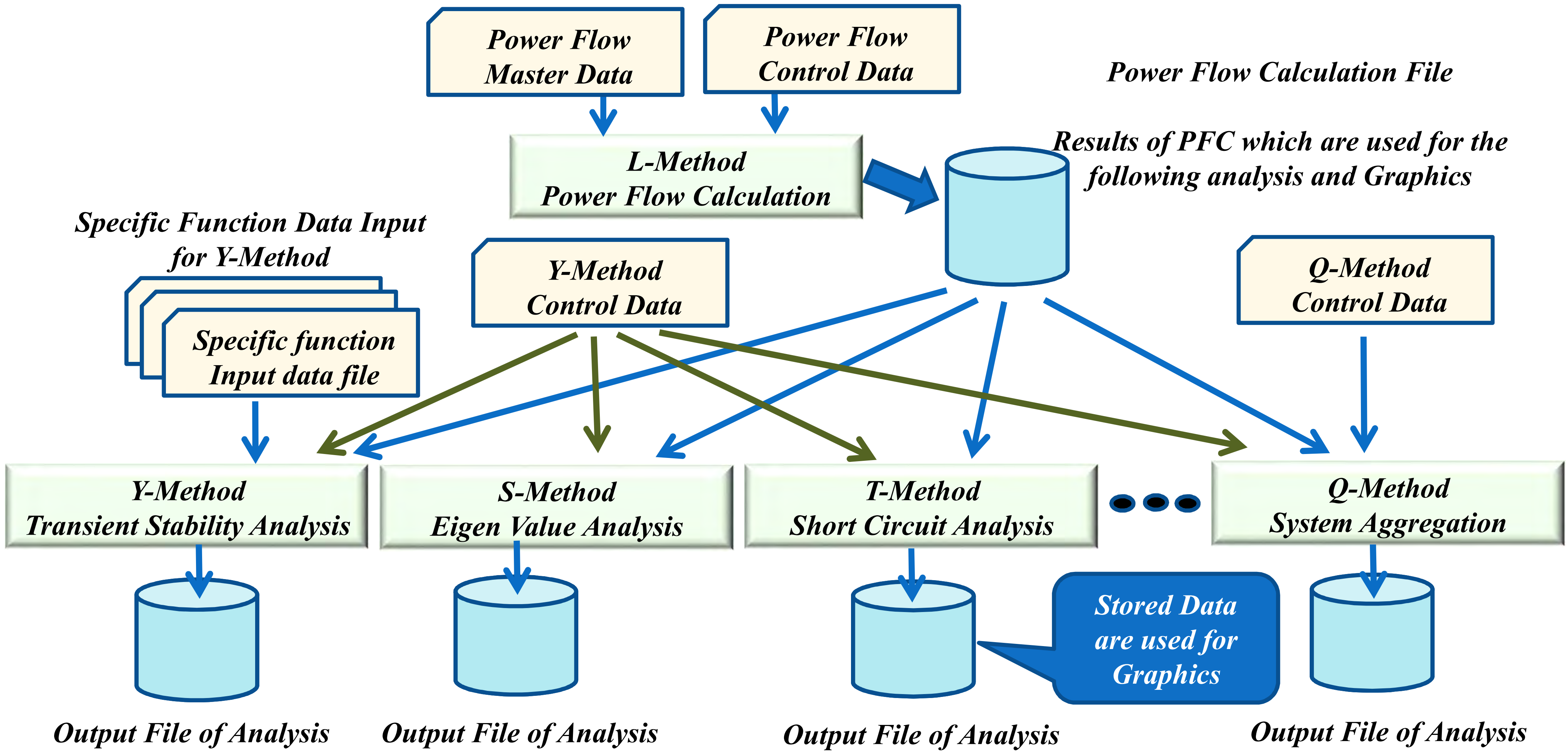
CPAT with POPONAS

CPAT: CRIEPI's Power system Analysis Tools
CRIEPI: Central Research Institute of Electric Power Industry
POPONAS: Windows execution environment for CPAT





Configuration of CPAT Program

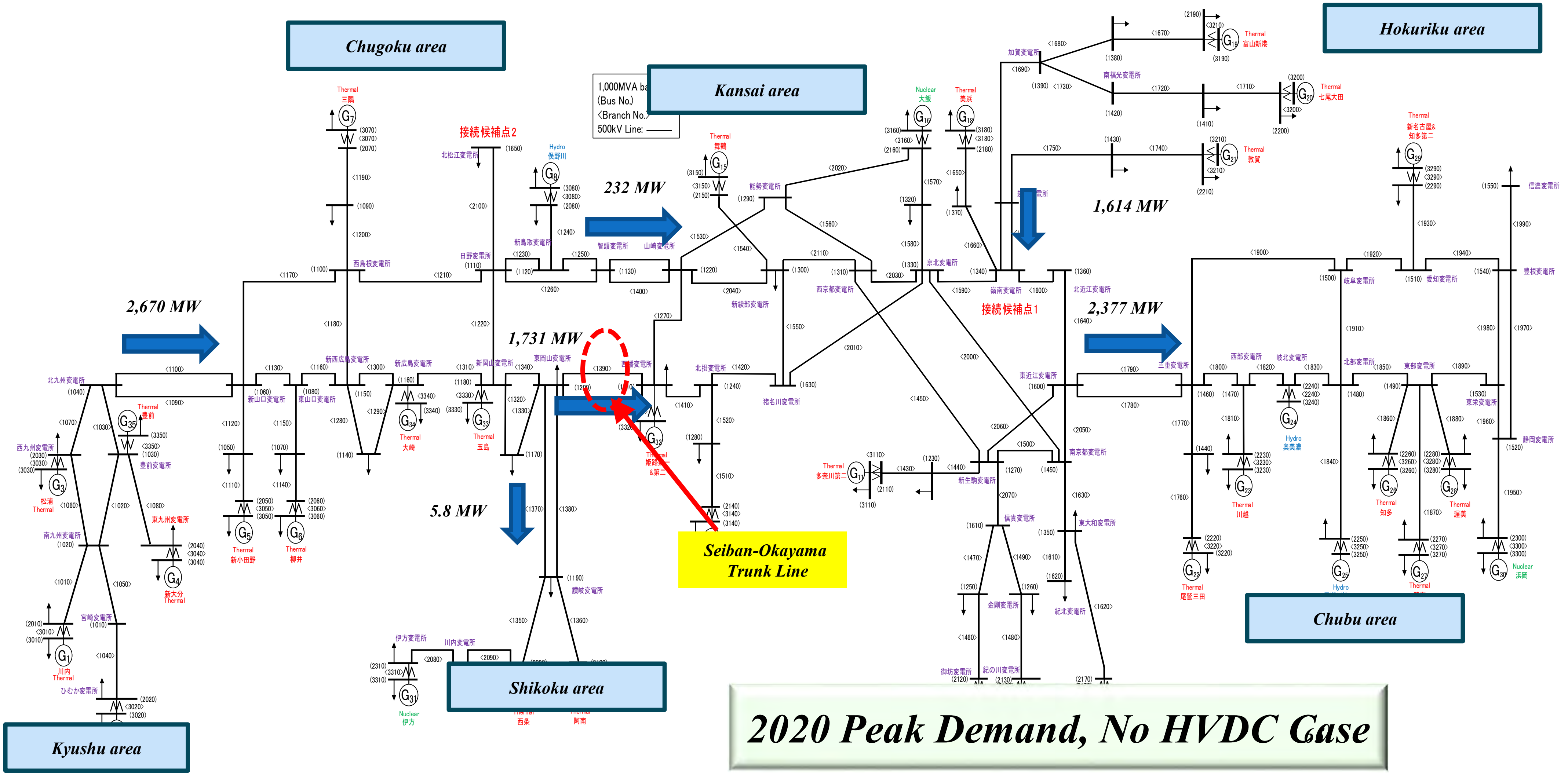


Calculation Contents and Criteria

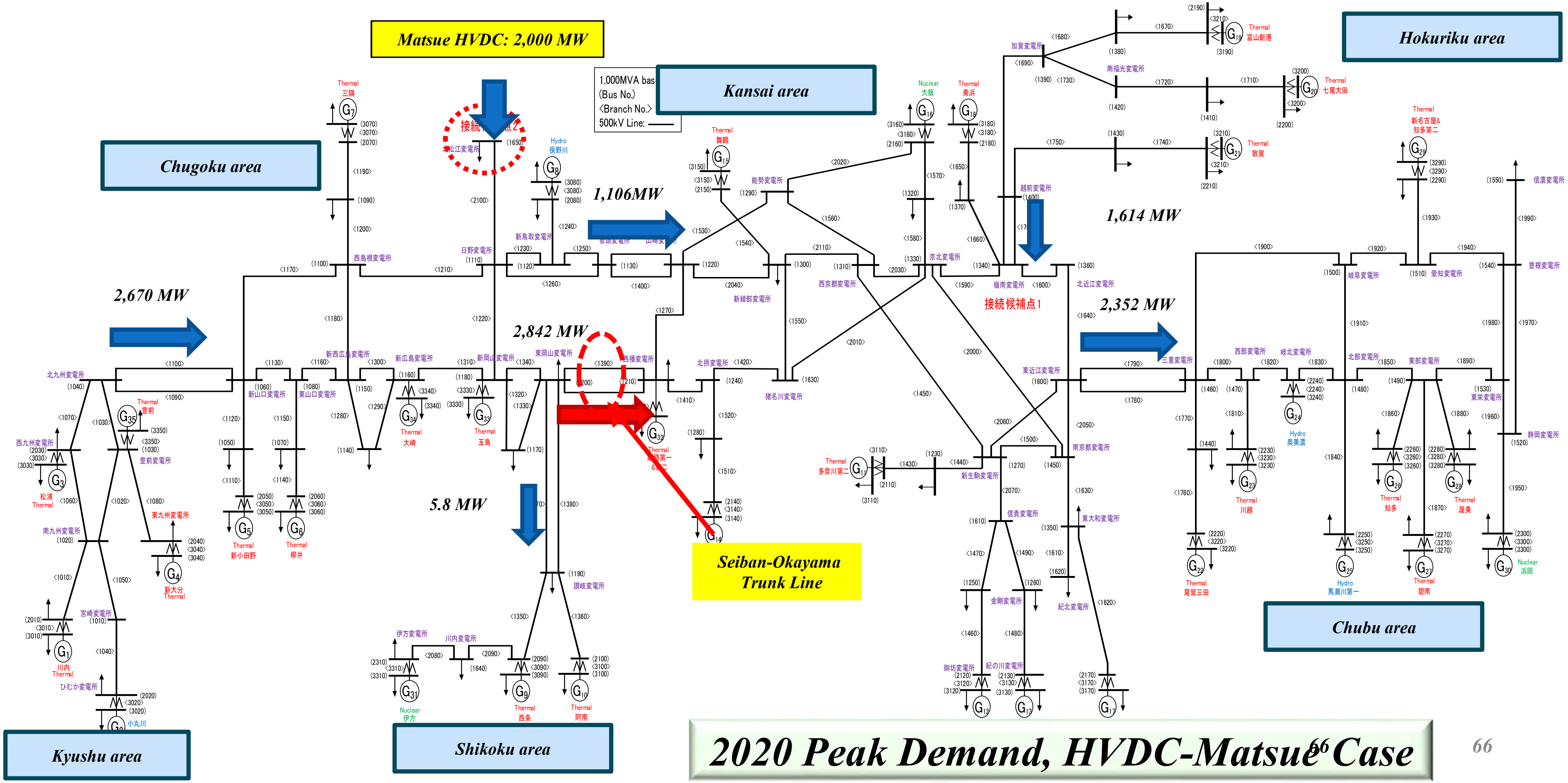
Power Flow	*Transient Stability*	*Short Circuit Current*
• *Peak and Off Peak Demand* • *Check for Overloading*	• *Sudden HVDC Stop* • *AC System N-1 Contingencies* • *Check for Power-angle / Voltage Stability*	• *Short Circuit Capacity* • *SCR Value at HVDC Terminal Bus*

Power Flow Calculation for Year 2020

Power Flow in Tie lines between Areas (Year 2020, Peak Demand, No HVDC)

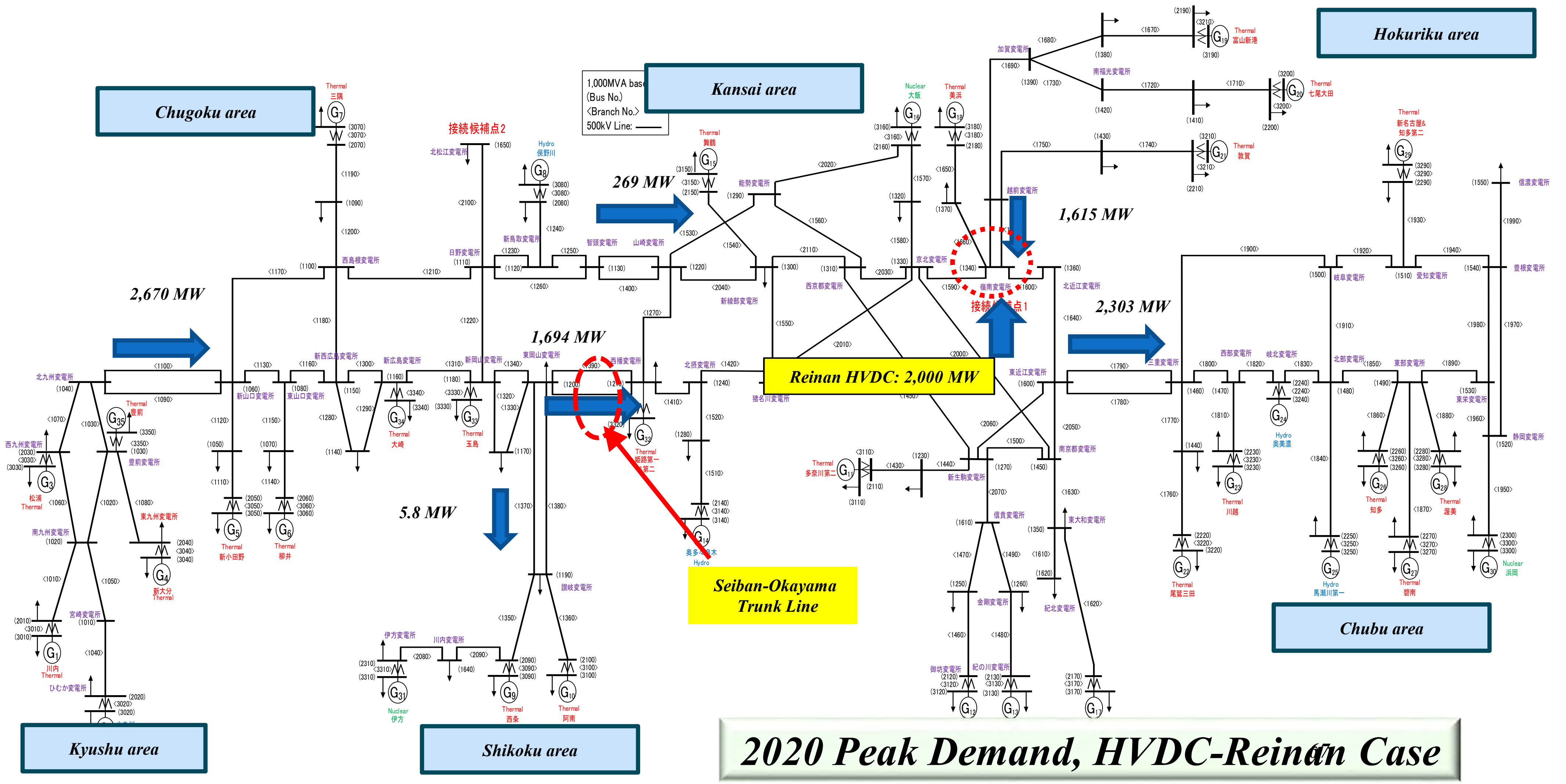


Power Flow in Tie lines between Areas (Year 2020, Peak Demand, HVDC at Matsue)



2020 Peak Demand, HVDC-Matsue Case

Power Flow in Tie lines between Areas (Year 2020, Peak Demand, HVDC at Reinan)



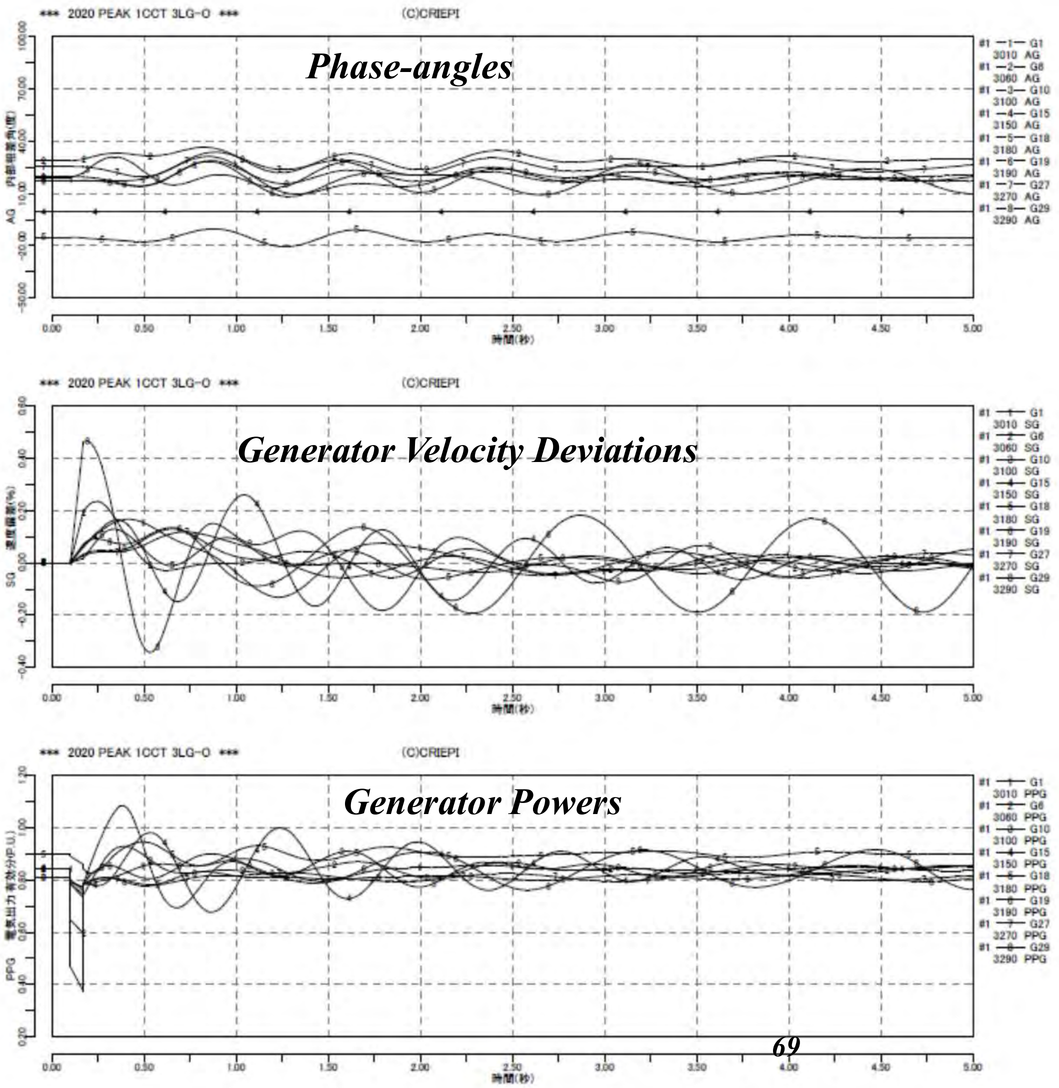
Stability Analysis for Year 2020

Transient Stability(1)
(Typical 3LG-3LO Fault Cases)

Calculation Conditions

(1) Power flow at 2020, peak/off-peak demand
(2) 3LG fault at Seiban-Okayama route
(3) Total 6 cases :

2020 **Peak Demand**	**2020** **Off-peak Demand**
No HVDC	**No HVDC**
HVDC **at Matsue s/s**	**HVDC** **at Matsue s/s**
HVDC **at Reinan s/s**	**HVDC** **at Reinan s/s**

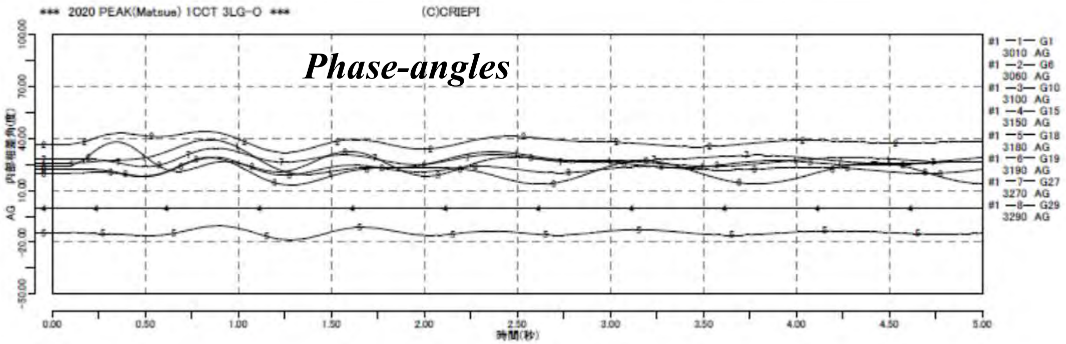


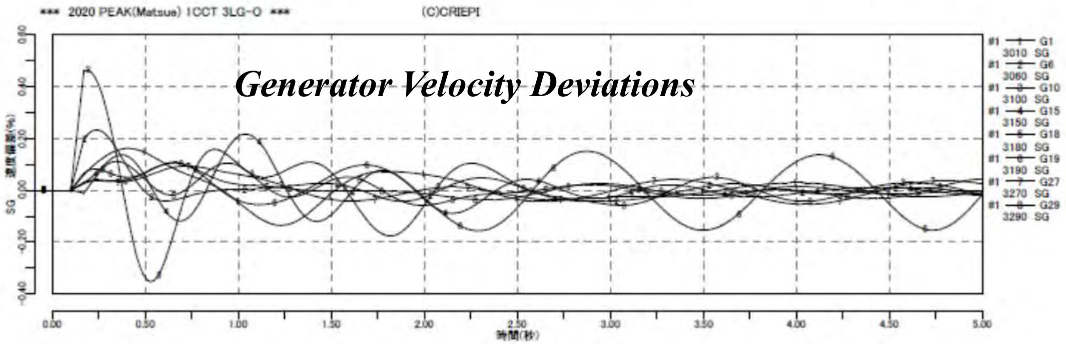
Transient Stability(2)
(Typical 3LG-3LO Fault Cases)

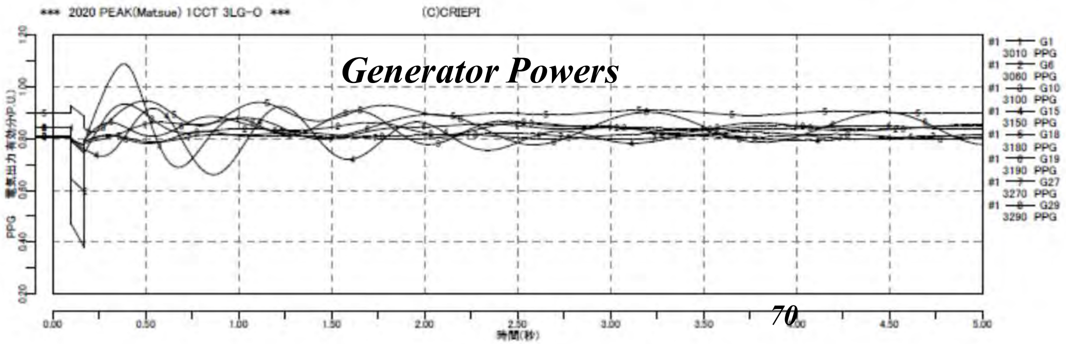
Calculation Conditions

(1) Power flow at 2020, peak/off-peak demand
(2) 3LG fault at Seiban-Okayama route
(3) Total 6 cases :

2020 Peak Demand	**2020 Off-peak Demand**
No HVDC	**No HVDC**
HVDC at Matsue s/s	**HVDC at Matsue s/s**
HVDC at Reinan s/s	**HVDC at Reinan s/s**





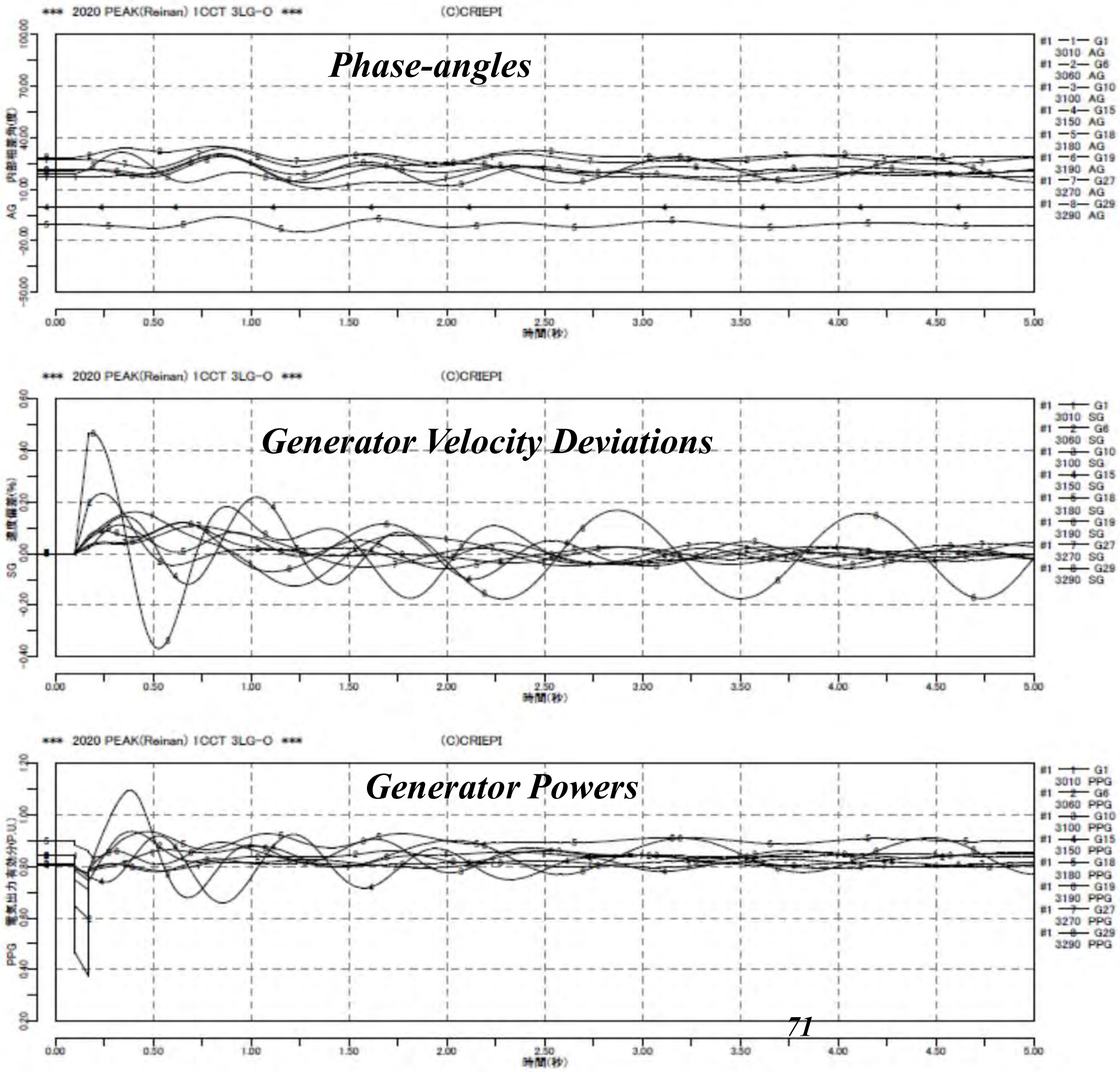


Transient Stability(3)
(Typical 3LG-3LO Fault Cases)

Calculation Conditions

(1) Power flow at 2020, peak/off-peak demand
(2) 3LG fault at Seiban-Okayama route
(3) Total 6 cases :

2020 Peak Demand	2020 Off-peak Demand
No HVDC	No HVDC
HVDC at Matsue s/s	HVDC at Matsue s/s
HVDC at Reinan s/s	HVDC at Reinan s/s

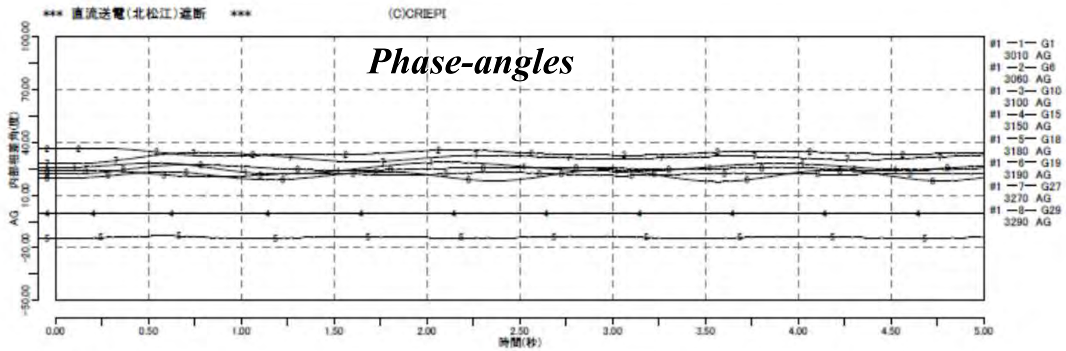


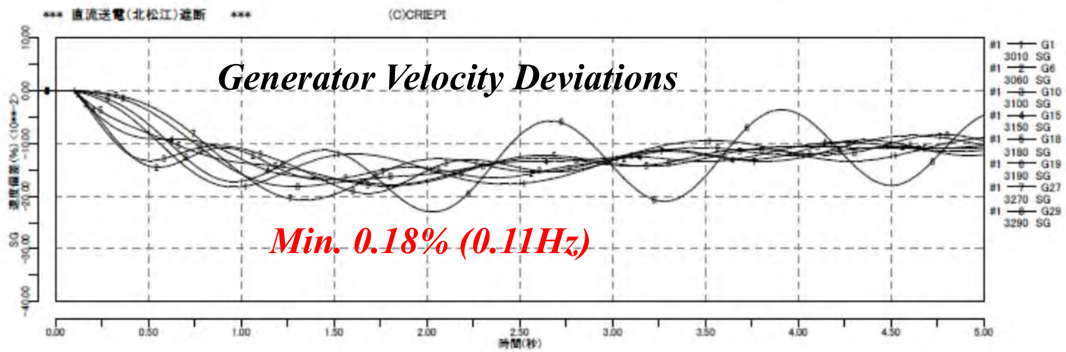
Sudden HVDC Converter Stops(1)
(Influences on grid frequency)

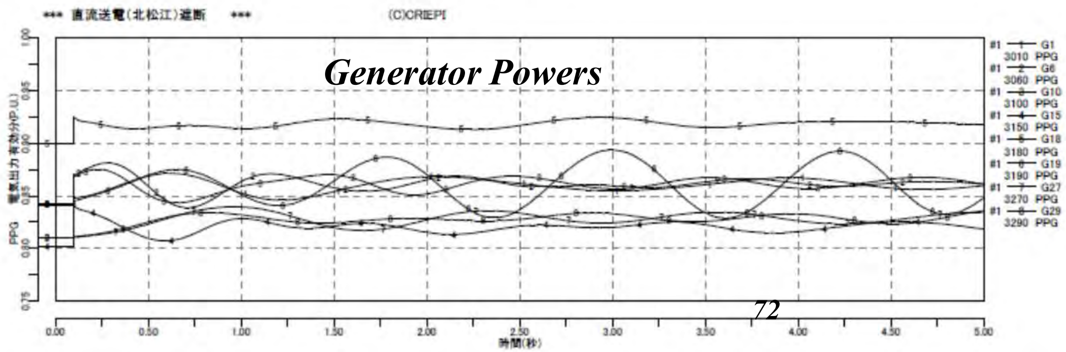
Calculation Conditions

(1) Power flow at 2020, peak/off-peak demand
(2) HVDC : 2GW operation to 0GW stop
(3) Total 4 cases :

2020 Peak Demand	2020 Off-peak Demand
HVDC at Matsue s/s	HVDC at Matsue s/s
HVDC at Reinan s/s	HVDC at Reinan s/s





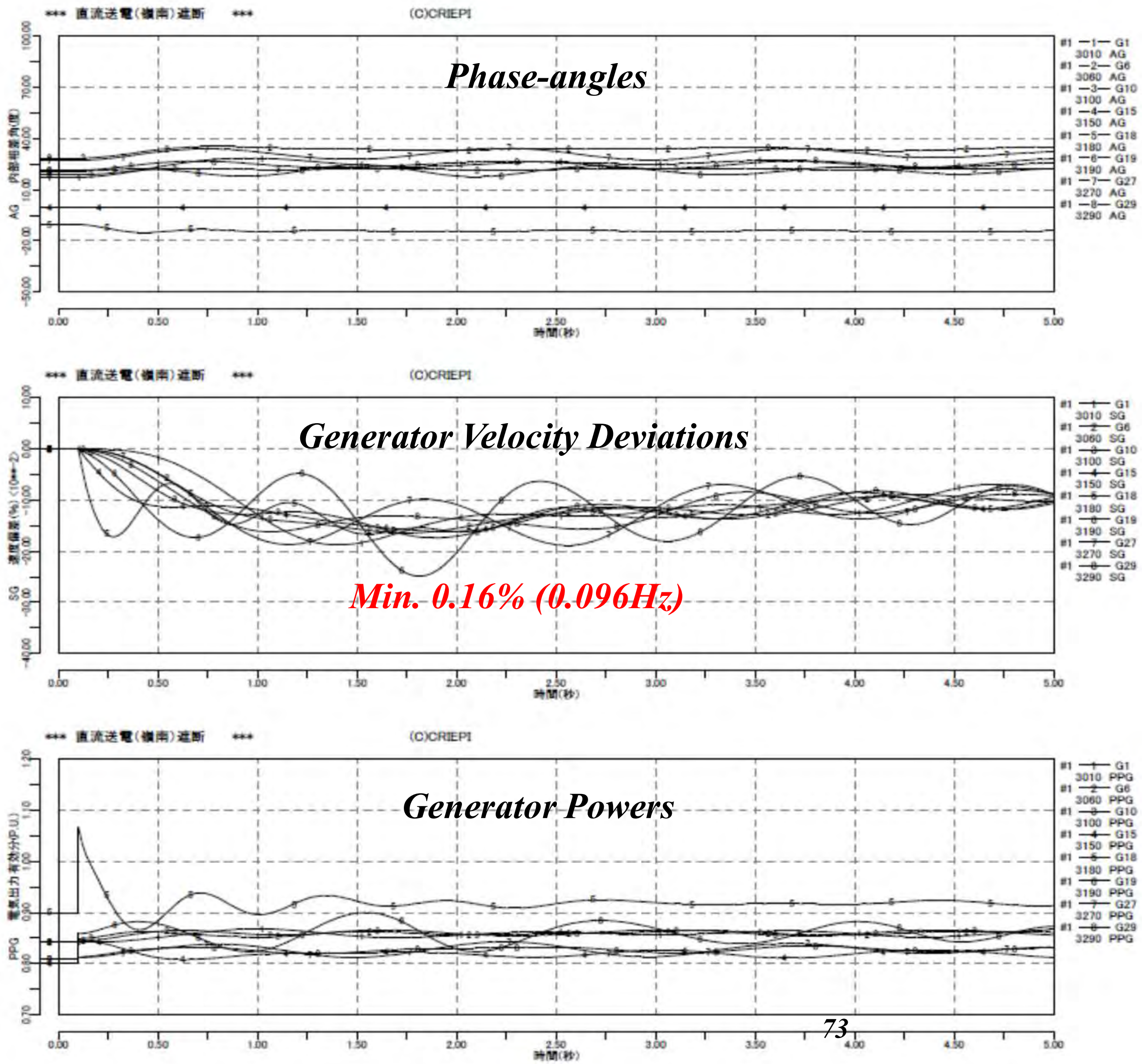


Sudden HVDC Converter Stops(2)
(Influences on grid frequency)

Calculation Conditions

(1) Power flow at 2020, peak/off-peak demand
(2) HVDC : 2GW operation to 0GW stop
(3) Total 4 cases :

2020 Peak Demand	**2020 Off-peak Demand**
HVDC at Matsue s/s	**HVDC at Matsue s/s**
HVDC at Reinan s/s	**HVDC at Reinan s/s**

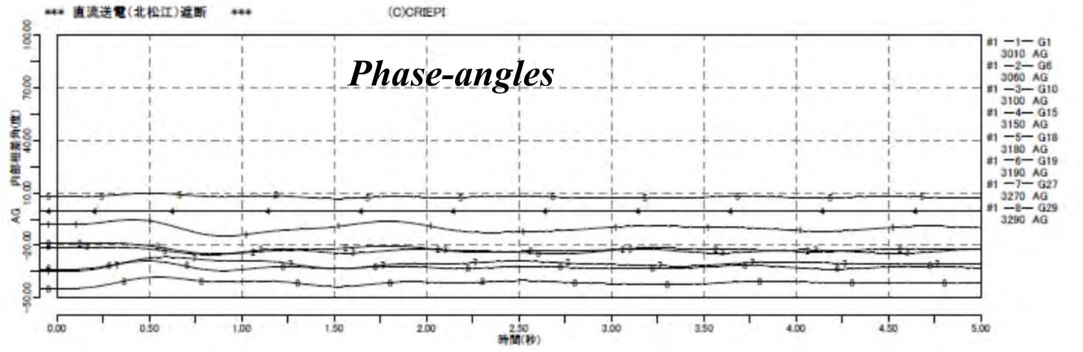


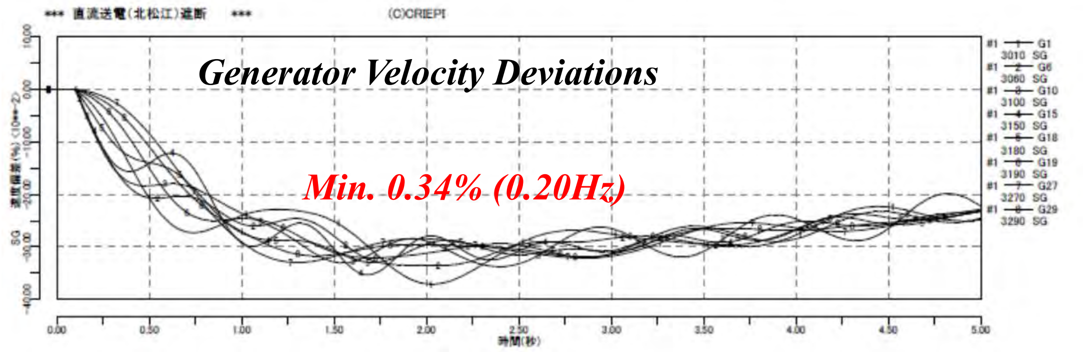
Sudden HVDC Converter Stops(3) (Influences on grid frequency)

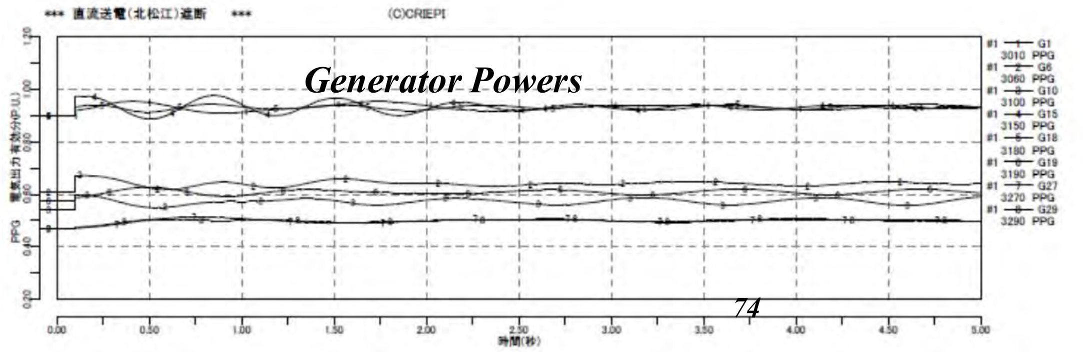
Calculation Conditions

(1) Power flow at 2020, peak/off-peak demand
(2) HVDC : 2GW operation to 0GW stop
(3) Total 4 cases :

2020 Peak Demand	2020 Off-peak Demand
HVDC at Matsue s/s	HVDC at Matsue s/s
HVDC at Reinan s/s	HVDC at Reinan s/s





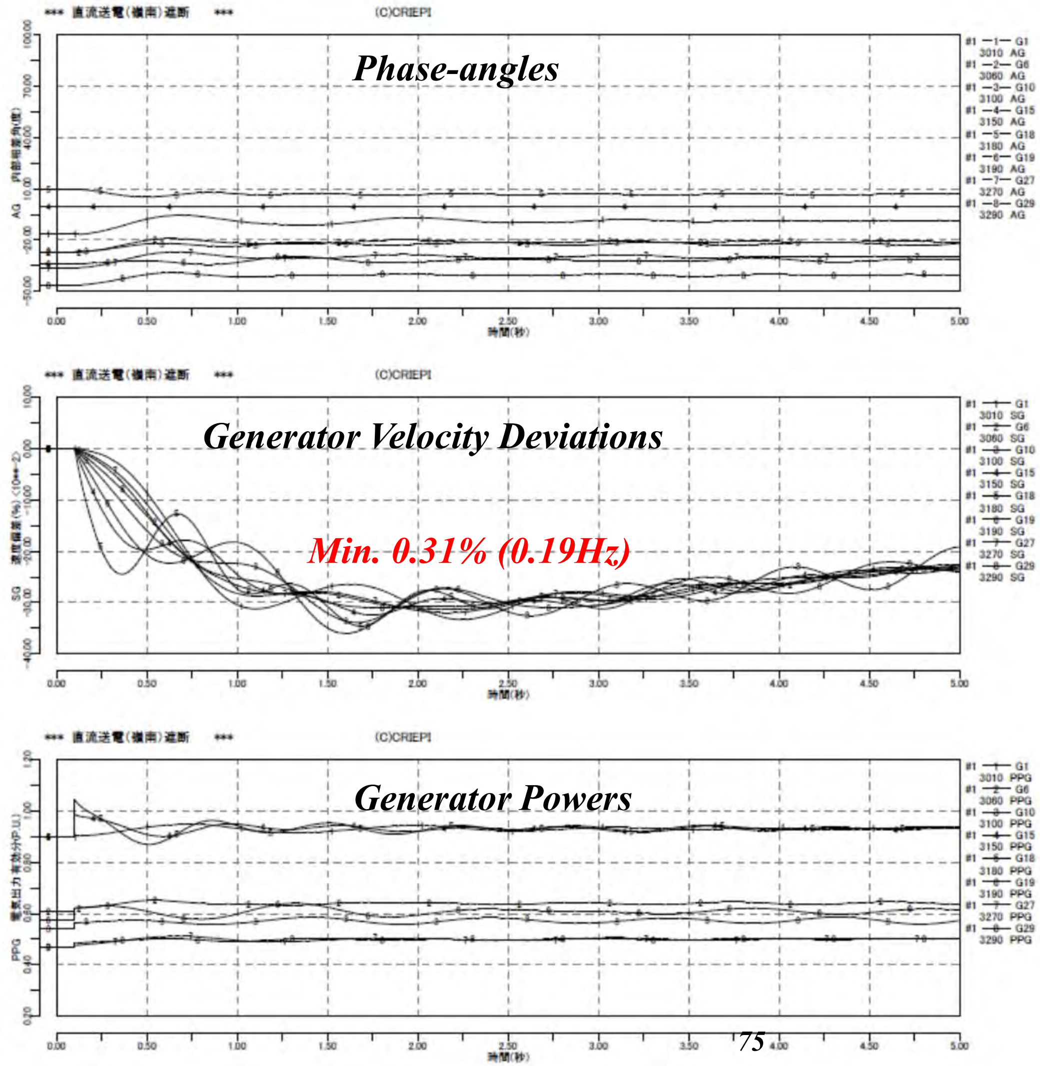


Sudden HVDC Converter Stops(4) (Influences on grid frequency)

Calculation Conditions

(1) Power flow at 2020, peak/off-peak demand
(2) HVDC : 2GW operation to 0GW stop
(3) Total 4 cases :

2020 Peak Demand	2020 Off-peak Demand
HVDC at Matsue s/s	HVDC at Matsue s/s
HVDC at Reinan s/s	HVDC at Reinan s/s



Conclusions of Power System Analysis for Year 2020

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Summary of Power System Analysis

(1) No overloads at 500kV transmission lines were observed in the results of power flow calculations in case of 2GW HVDC.

(2) No stability problems were observed in the results of transient stability calculations (3LG-3LO) in case of 2GW HVDC.

(3) The drop-off values of frequency caused by sudden 2GW HVDC stop were 0.18% for peak demand case and 0.34% for off-peak demand case.

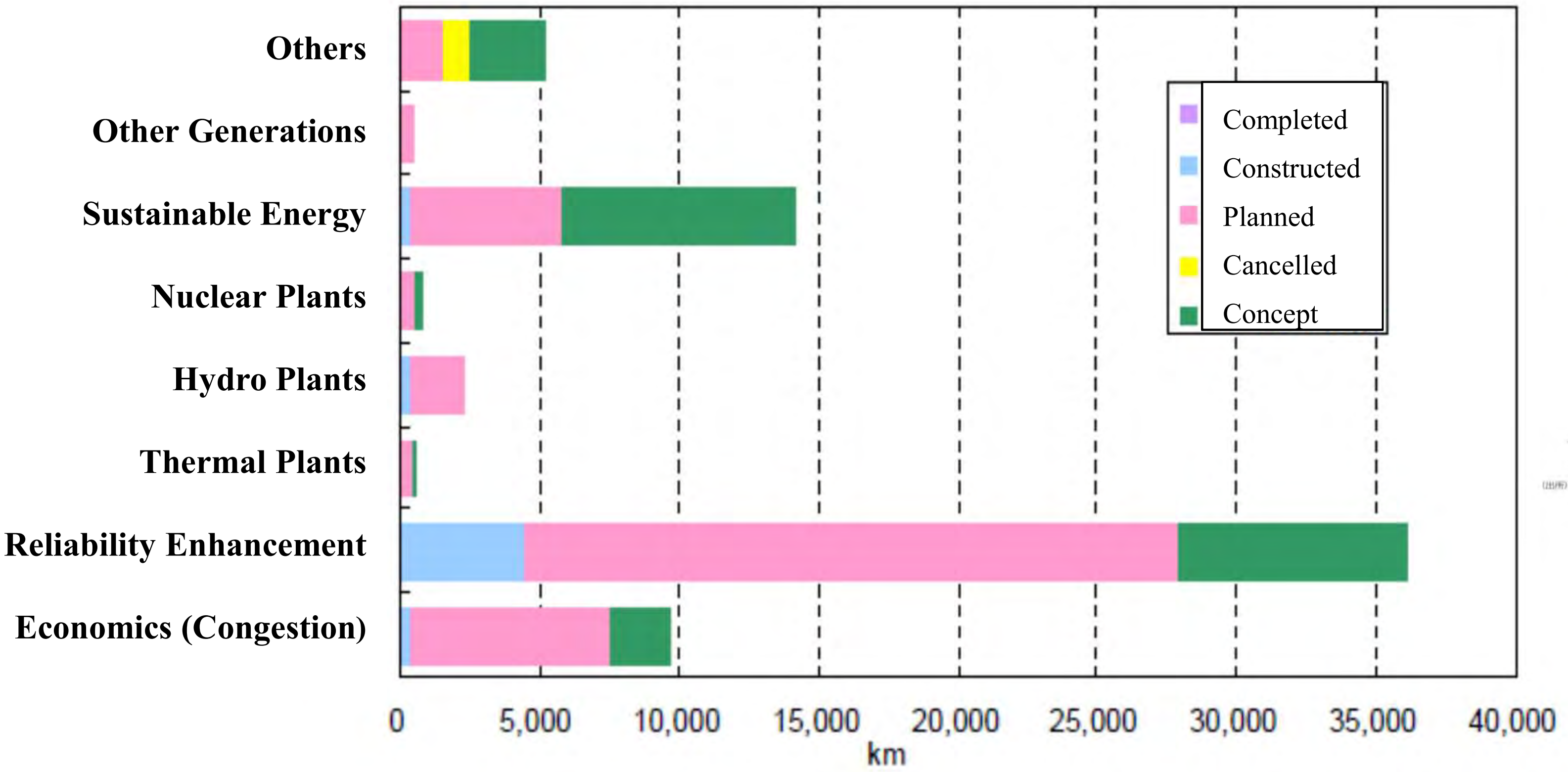
(4) Calculated SCR values were 8.5 for Kita-Matsue s/s, and 17.5 for Reinan s/s and this means the related grids are strong at resonance.

(5) If HVDC of more than 2GW is installed at Matsue, Seiban-Okayama Trunk Line must be reinforced before construction of the HVDC.

Prospects of International Grid Connections in Asian Countries

Current Situation and Purposes of Grid Interconnection in USA

- *After 2012, new transmission expansion projects includes 5,5094Km in USA, 1,3604Km and 622Km in Mexico and totally 69,320Km in NERC area*
- *66,582km by AC transmission, 2,738km by DC transmission, and many DC transmission line projects in Canada*
- *Purposes of constructions are 52% for Reliability enhancement (Resolution of reliability criteria violation, 20% for Sustainable energy installation , 14% for Economic reason (Congestion relieving) , 3% for Hydro plant connection , 1% for Thermal plant connection and 1% for Nuclear plant connection.*

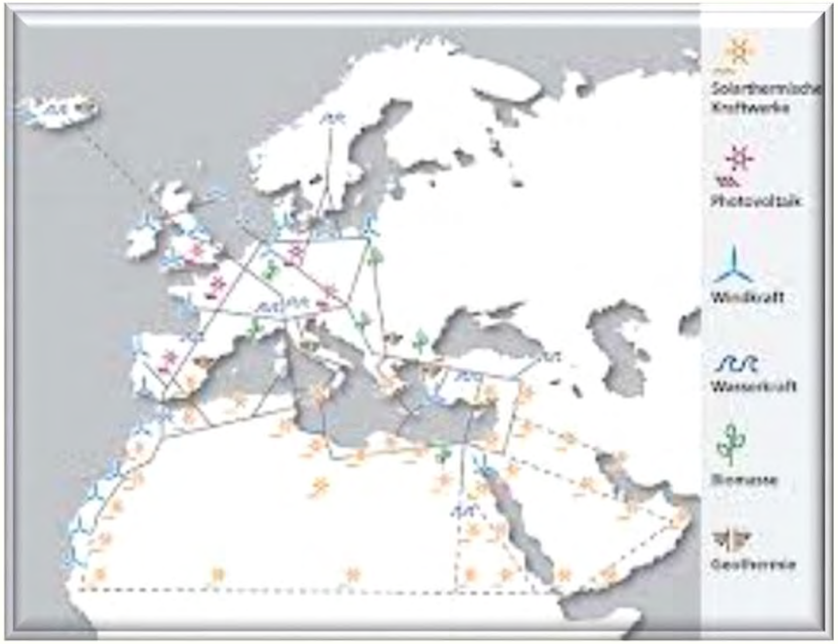


（出所）NERC

出典：国際連系に関する調査・研究、平成25年3月、一般財団法人日本エネルギー経済研究所

Mandatory Conditions for realizing Super Grid

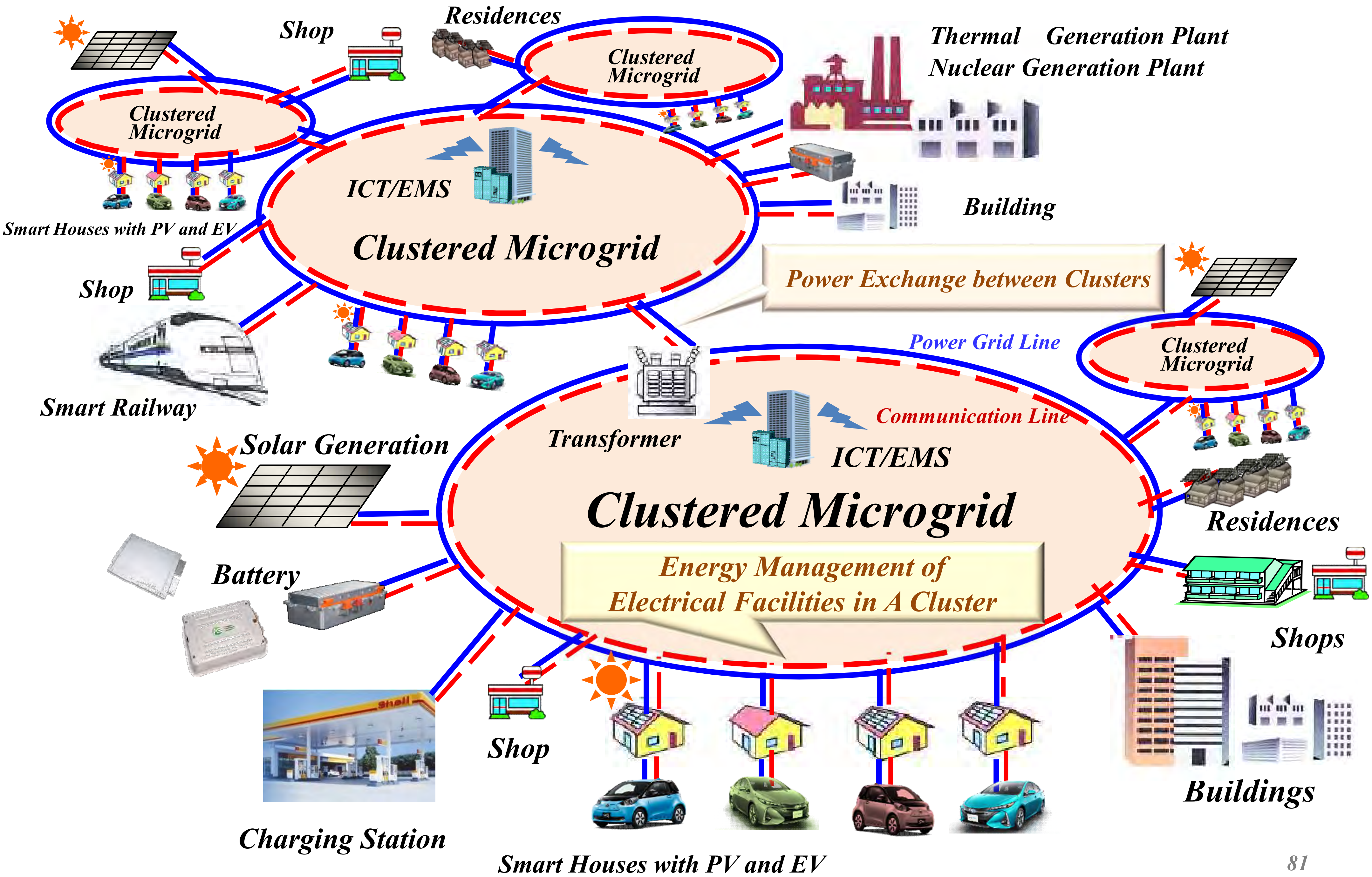
- ***In the DESERTECH Project of European countries including the Middle East and the North Africa,***
  - ***Solar Thermal energy** in deserts of the North Africa and the Middle East*
  - ***Wind power energy** in the coast of the North-West Africa, the North and West Europe*
  - ***PV generation** in strong solar radiation, such as Spain*
  - ***Hydro energy** in mountain areas of the Alps mountains, Pyrenees, Atlas Mountains*
  - ***Biomass energy** in the middle of Europe, such as, Germany and France*



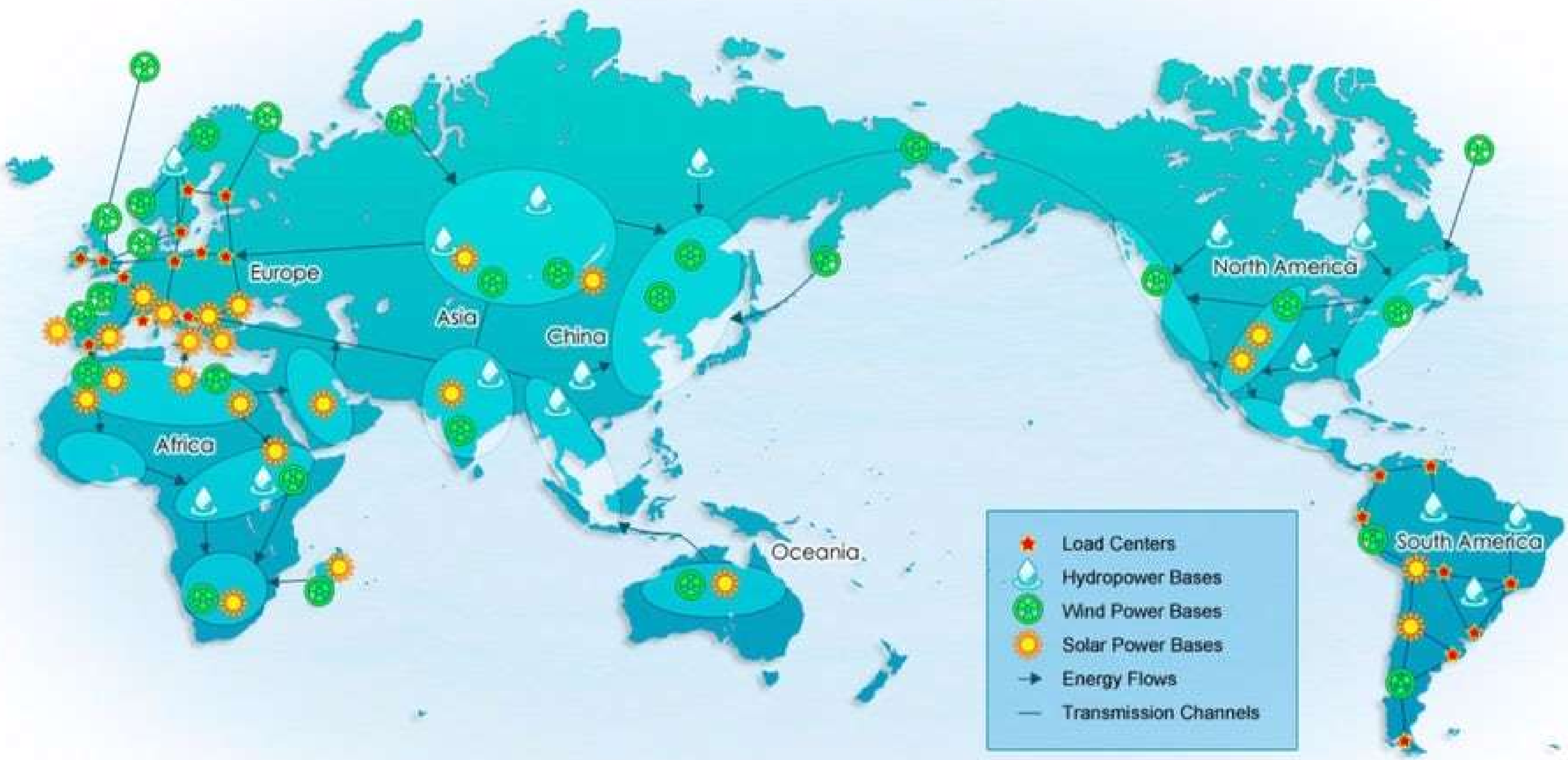
- ***International interconnections between Africa, the Middle East and Europe by low loss, long distance HVDC***

- ***Diversification of energy resources** in different areas*
- ***Countries are stable politically, Economically and Socially***
- ***Interconnecting countries have cordial relations each other***

Resilient and Expandable Clustered Grid

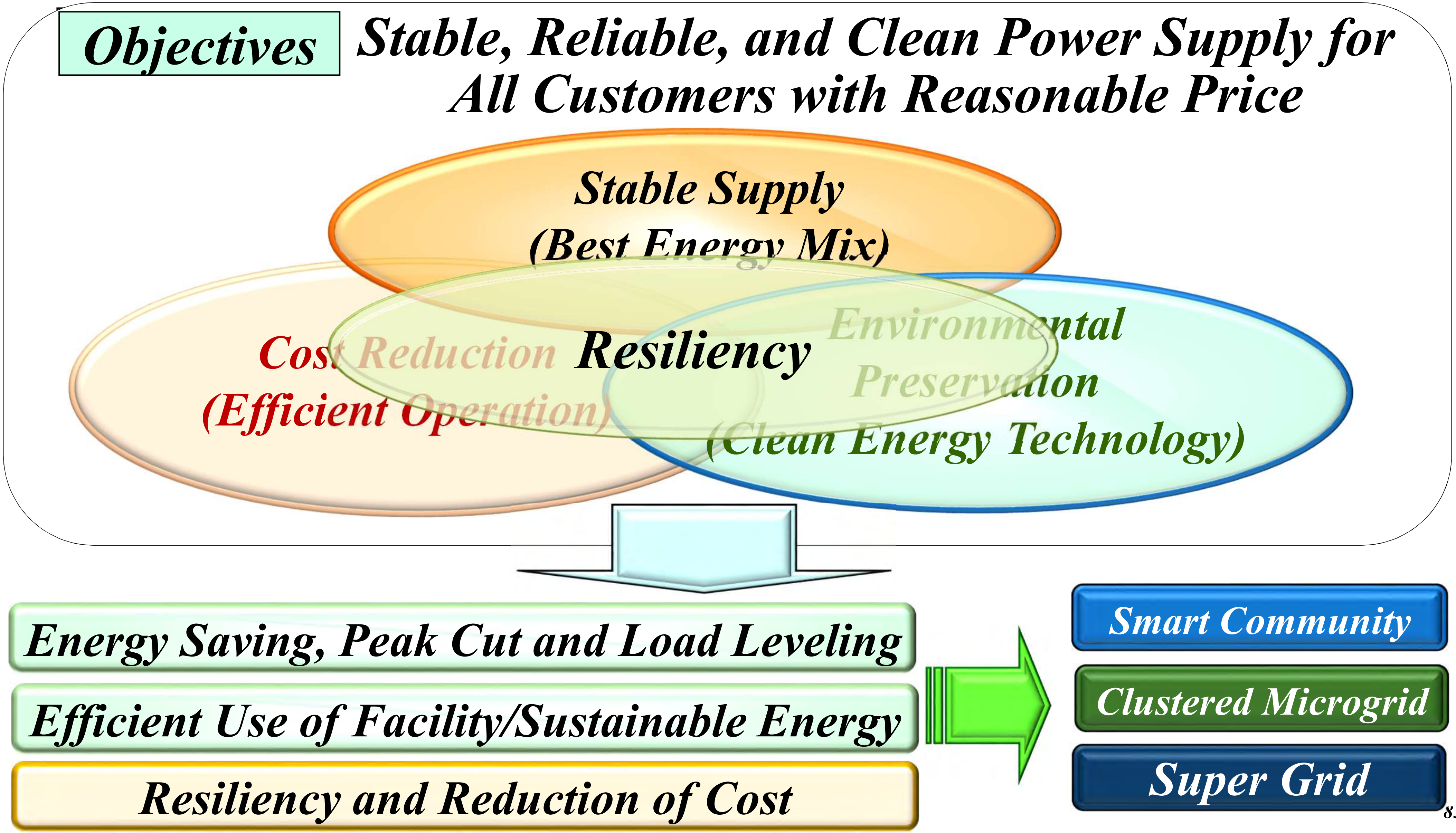


Global Energy Interconnection in the Future



Global Energy Interconnection

Coordination of Goals of Electric Power Sector for Stable Energy Supply



Thank you for your attention
謝謝

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