Impact of Fusion Reactor on Electricity Grids

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Nuclear Fusion Reactor

Nuclear fusion reactor is one of candidates for sustainable energy source in the future without carbon dioxide emission.

In conceptual studies,

fusion reactor is assumed to be used as a base load machine in industrial countries with unit capacity of > 1GWe,

- continuous operation with maximum power
- > 200MWe startup/operation power

Startup scenario with inductive current drive requires very large dP/dt value and large Q

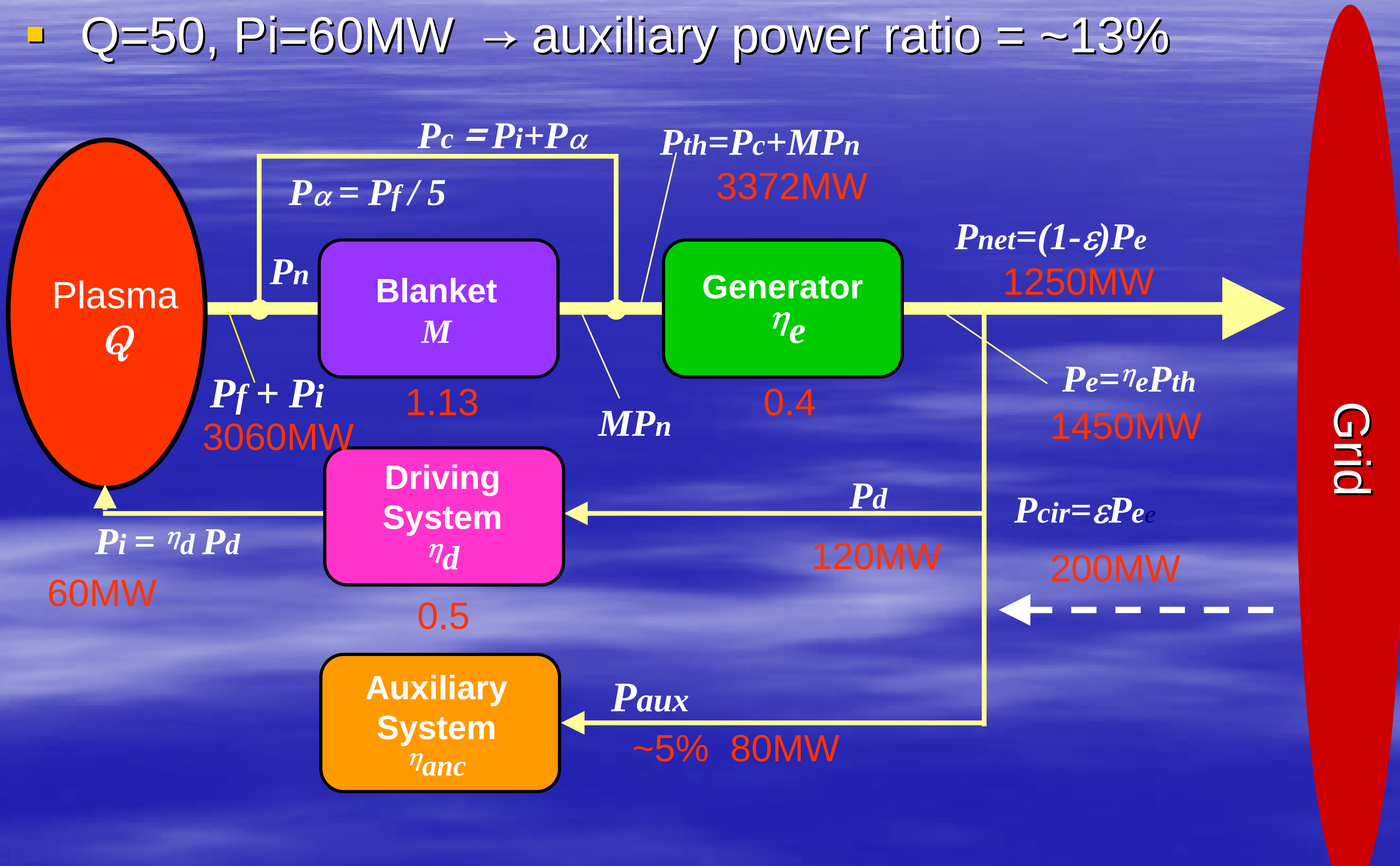
Our question is

can the fusion reactor be installed in the small electric grid ?

→ calculate the influence of startup power in the small electric grid

Energy flows in fusion reactor

- Q=50, Pi=60MW → auxiliary power ratio = ~13%



Auxiliary power in power plants

Coal | Oil | Nuclear | Fusion

Current drive / Auxiliary heating

Coal crusher

Coal feeder

Oil feeding pump

Tritium handing

Exhaust gas treatment system

Recirculation pump

Magnet cooling

Condensate water pump

Cooling water pump

Control system

Others

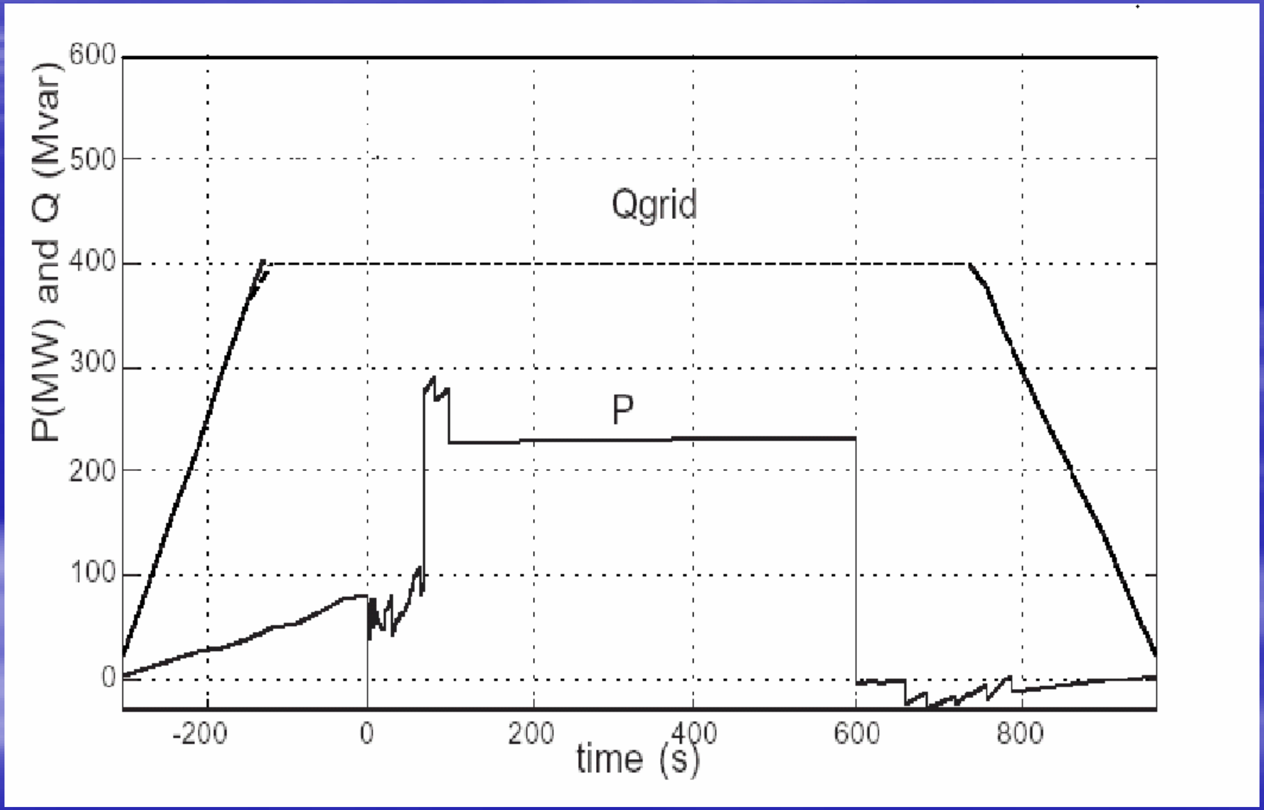
Auxiliary power ratio of various system

System	Capacity [MW]	utilization of facilities [%]	Auxiliary power ratio [%]
Fusion	1,000	75	~13.0
Nuclear Fission	1,000	75	3.4
Oil thermal	1,000	75	6.1
LNG thermal	1,000	75	3.5
Coal thermal	1,000	75	7.4
Hydro	10	45	0.25
geothermal	55	60	7.0
wind power	0.1	20	10
Photovoltaic			
utility	1.0	15	5
home	0.003	15	0

Source： 内山洋司；発電システムのライフサイクル分析，研究報告，（財）電力中央研究所(1995)

Influence to the electric grid

Power demand in ITER standard operation scenario



Active power

P = ~300MW

dP/dt = ~230MW/s

Reactive power

Q > 600MVA

by on-site compensation

Qgrid = ~ 400MVA

Influence to the electric grid

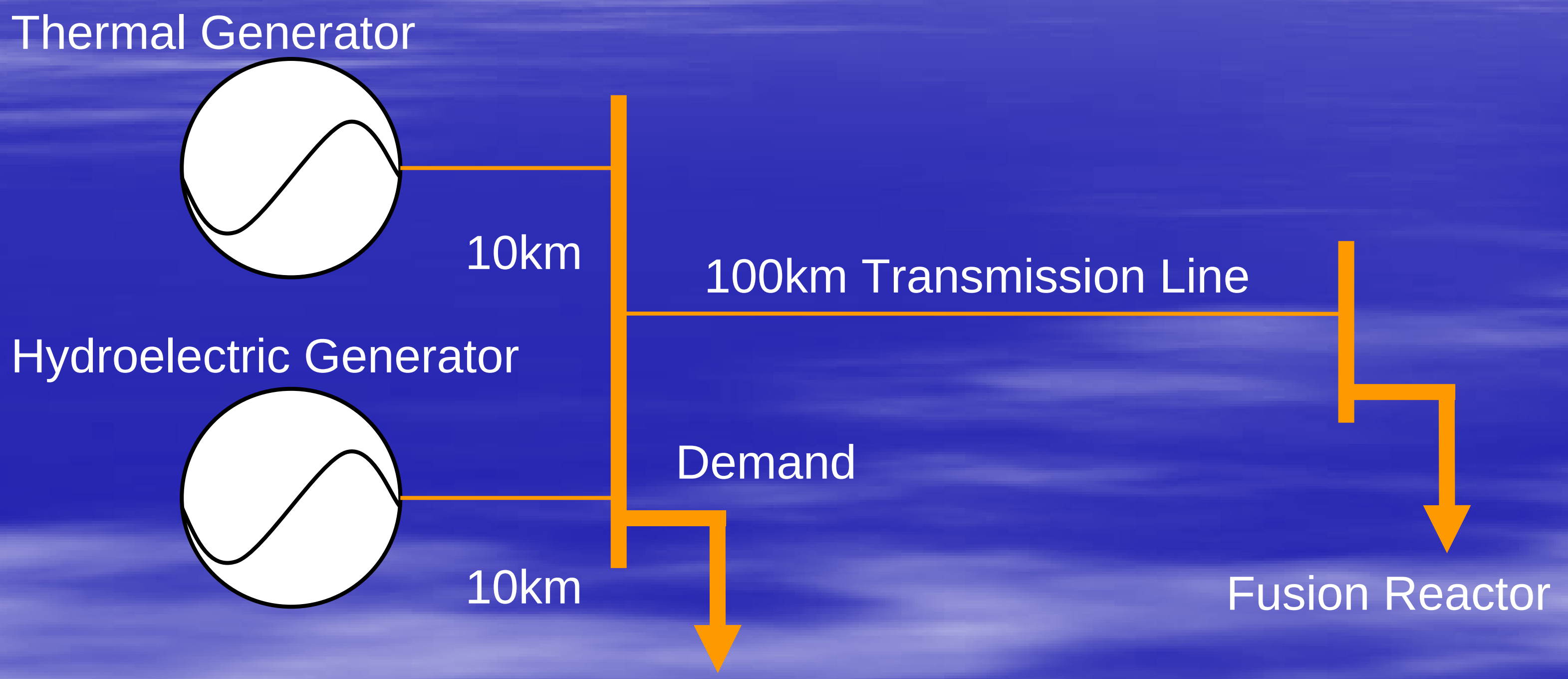
- Power generation is controlled by

Time scale	method
> ~10min	ELD or manual
3min< t < 10min	AFC
< ~3min	governor of each UNIT (spinning reserve)

In Japan, usual value of spinning reserve is 3% of total generation

Influence to the power grid

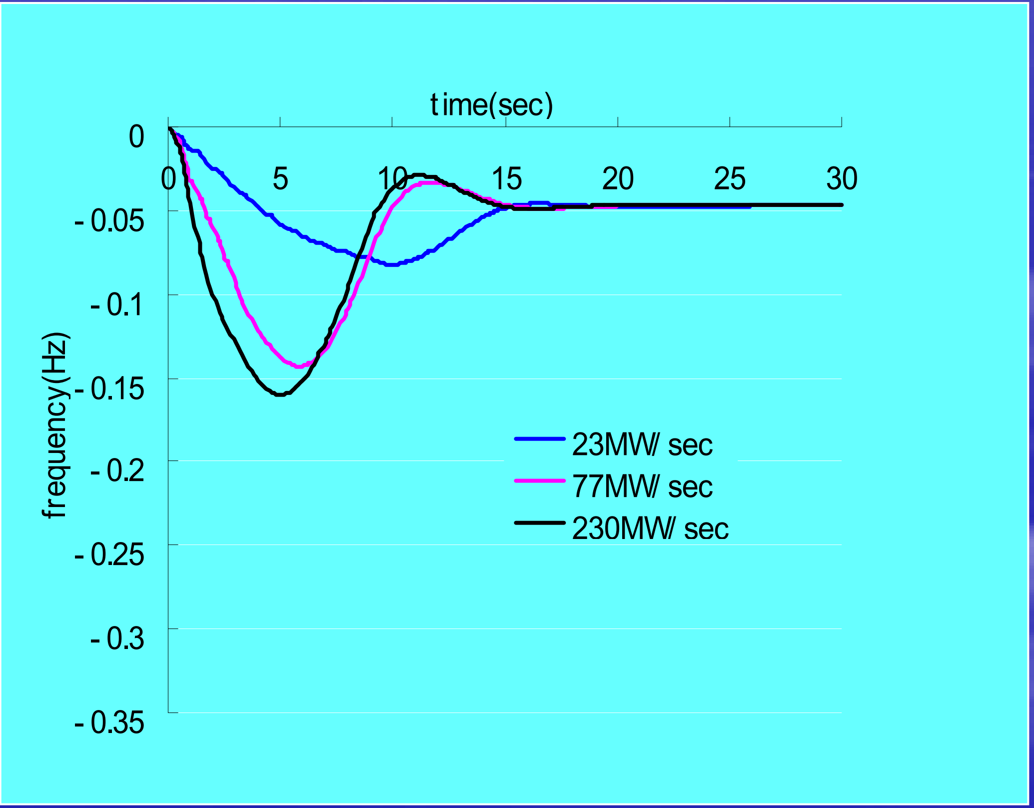
- Calculation model



Reference Capacity	: 1000MVA
Transmission Voltage	: 115kV
System capacity	: 7-15GWe
Impedance per 100km	: 0.0023+j0.0534[p.u.]
Capacitance	: jY/2 = j0.1076[p.u.]

Influence to the power grid

- Frequency fluctuation



Influence to the power grid

- Maximum Frequency Fluctuation [Hz] for 7GW grid

		Load change rate [MW/s]		
		23	77	230
Peak Load [MW]	130	0.05	0.07	0.08
	230	0.08	0.15	0.16
	330	0.11	0.30	0.33

- Maximum Frequency Fluctuation [Hz] for 15GW grid

		Load change rate [MW/s]		
		23	77	230
	330	0.03	0.05	0.06

Influence to the power grid

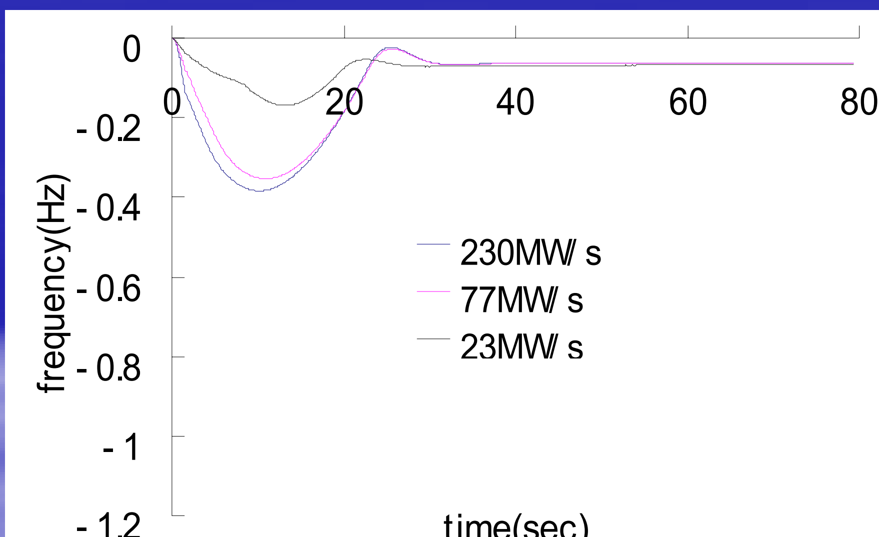
- The grid capacity of 10-20GW is required to supply startup power of ITER like fusion reactor. In the small grid, more than the usual value (3% of total capacity) of spinning reserve is required
- The influence also depends on the grid configuration, as response time of each power unit is different.

	Response speed
Hydro	fast 10~50%/min
Oil	5%/min
Coal	slow 1%/min
Nuclear	not allowed now in Japan
Solar/Wind	No response

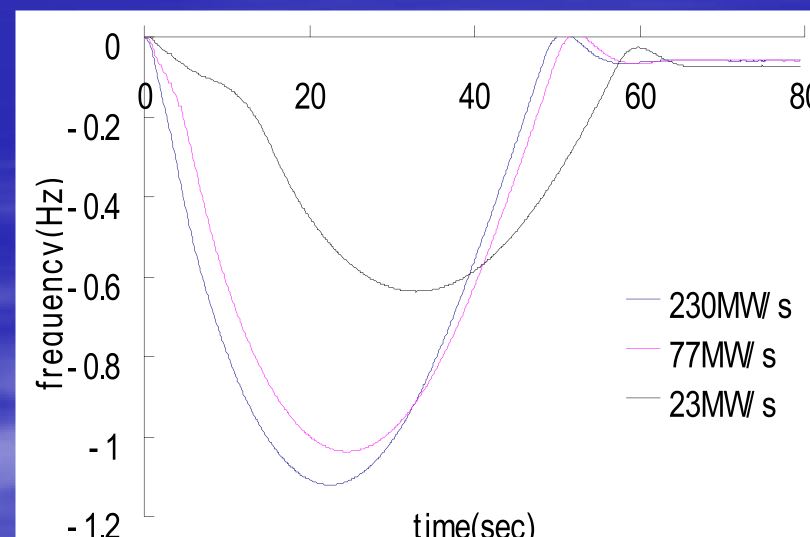
Influence to the power grid

- 8GW Grid with plant capacity ratio
  Nuclear:Thermal:Hydro = 28:58:14

- 230MW

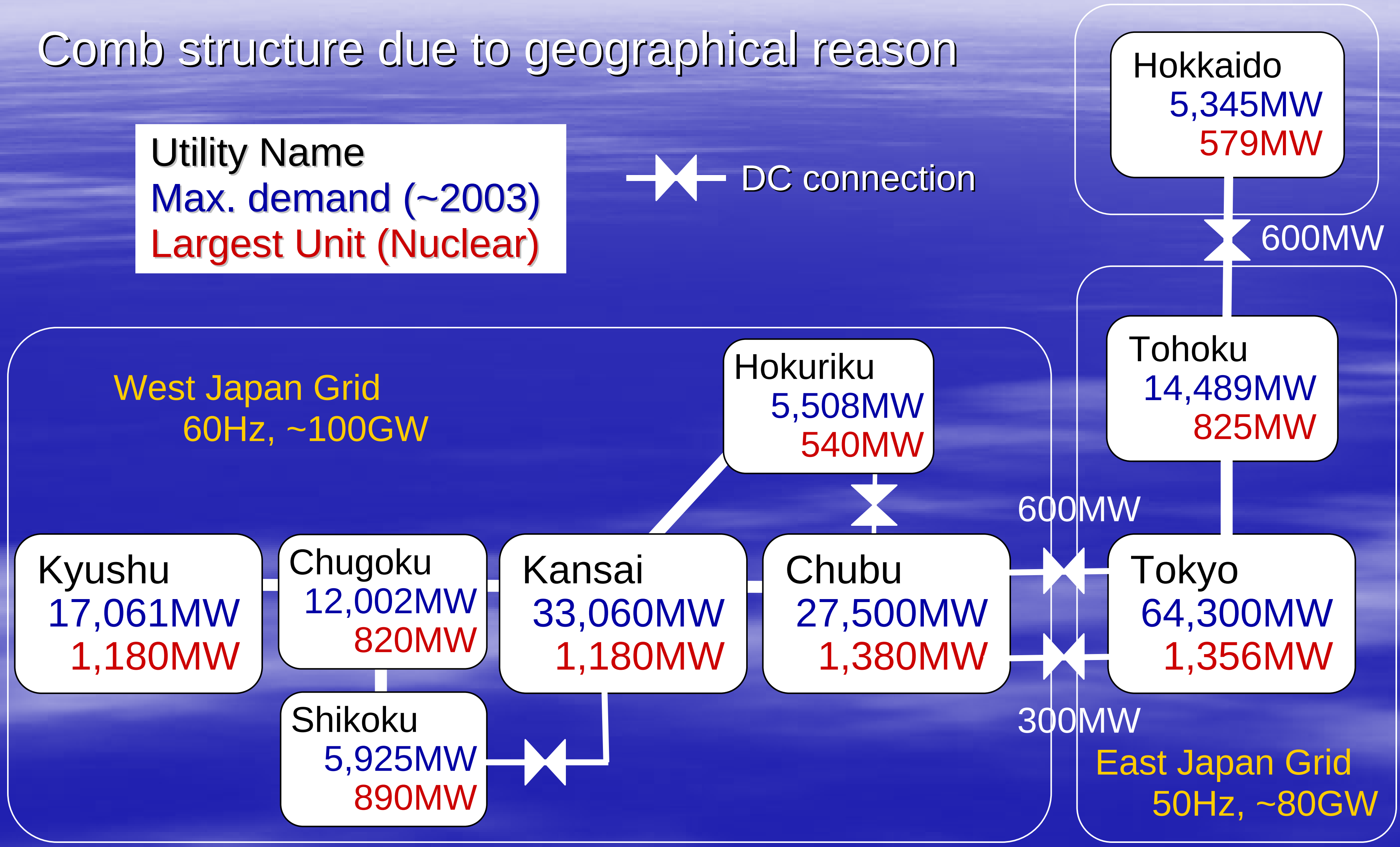


- 330MW



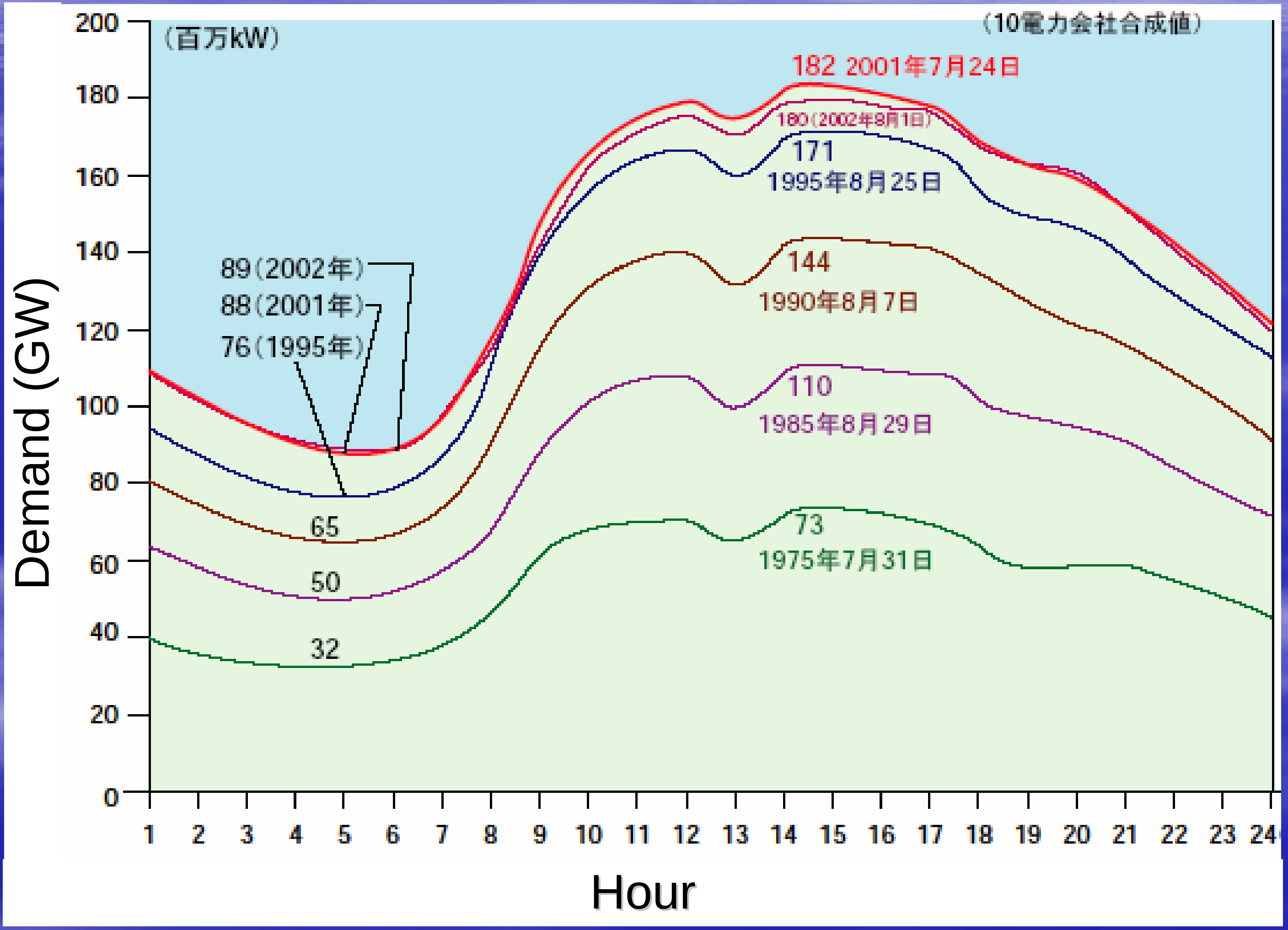
Electric Grid in Japan

Comb structure due to geographical reason

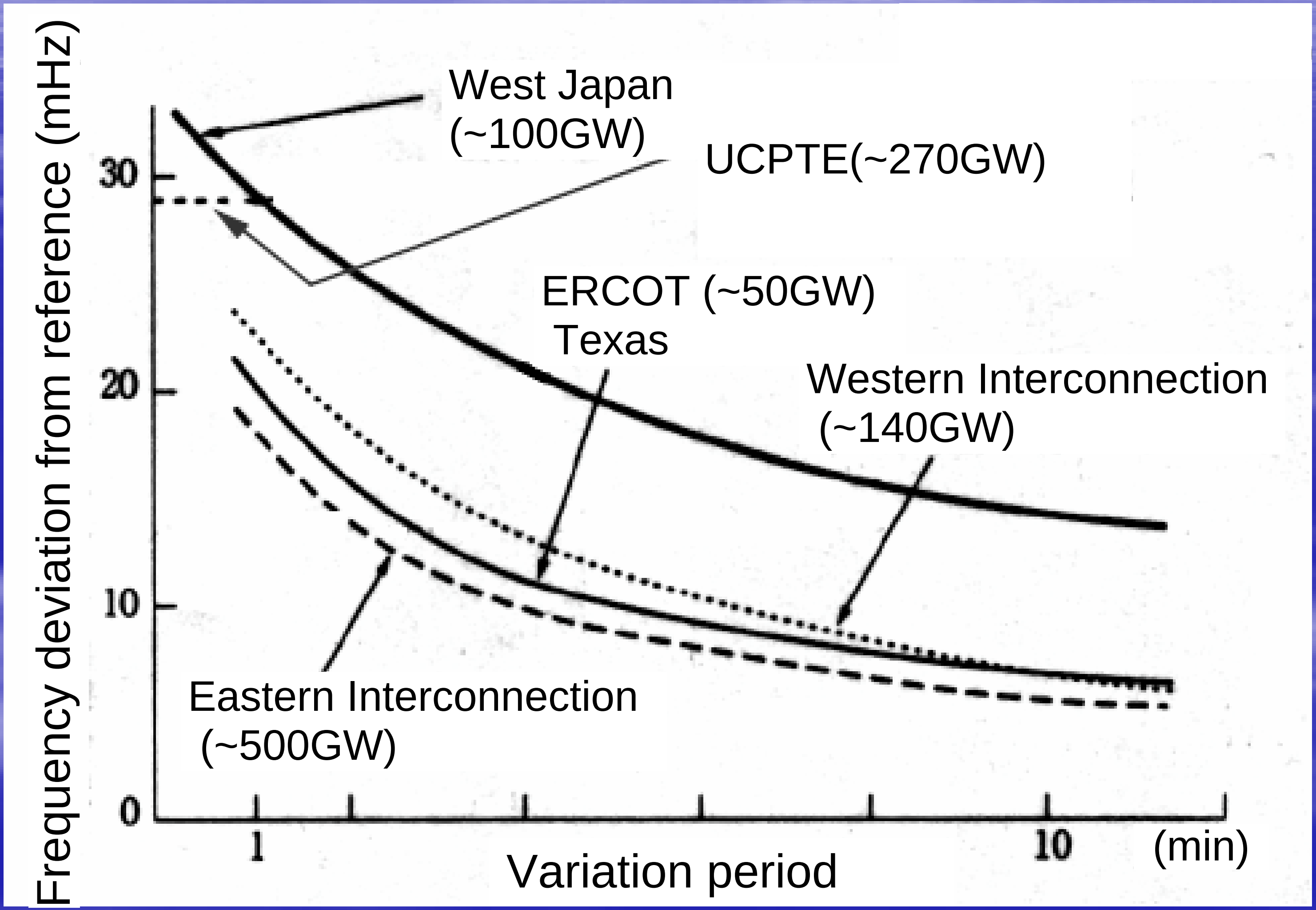


Demand change within the day in the summer

- Grid capacity is almost a half of maximum at early morning



Frequency deviation and grid capacity



Conclusion

- The rate of change of active power requirement for additional heating is faster than the response time of electric grid.
- For a Fusion rector with 1GWe output, the grid capacity of 10~20GWe is required for safely supplying startup power.
- By develop the slower increase of additional heating power (NBI, ECH, ICRF …) and L-H transition scenario, which matches the response time of electric grids, fusion reactor can be installed into more smaller grids.
- Developing above scenario also help the fusion reactor can be used as middle load plants in the countries where there are many nuclear fission reactors for base-load plants.
- In current calculation, reactive power is assumed to be supplied locally. We will estimate the influence of it.