

Evolution of Large Fossil Fired Turbo-generator



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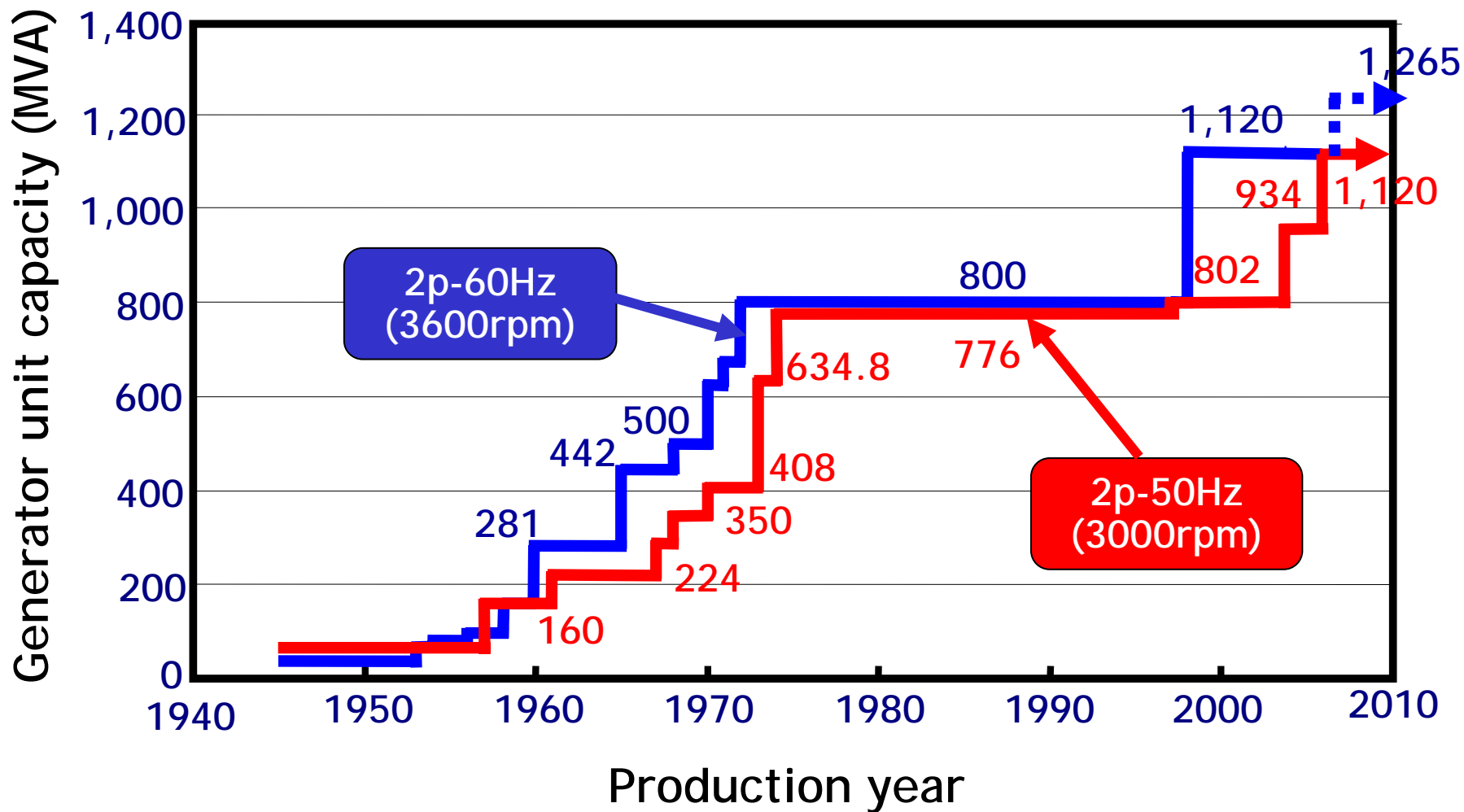
27 August, 2008

Topics presented and discussed

- ❖ Experience and development history of 1000MW size generator
- ❖ What drives the development of 1000MW size generator
- ❖ The world's largest 2-Pole, 50/60Hz, 1120MVA generator
- ❖ Concept of turbo-generator in the next generation
- ❖ Experience and development history of large capacity indirectly hydrogen-cooled generator
- ❖ The world's largest 2-Pole, 50/60Hz, 700MVA class indirectly hydrogen cooled generator
- ❖ Hydrogen vs. water cooled generator
- ❖ Summary



Growth in generator unit capacity



The world's largest 2P-1000MW size generator

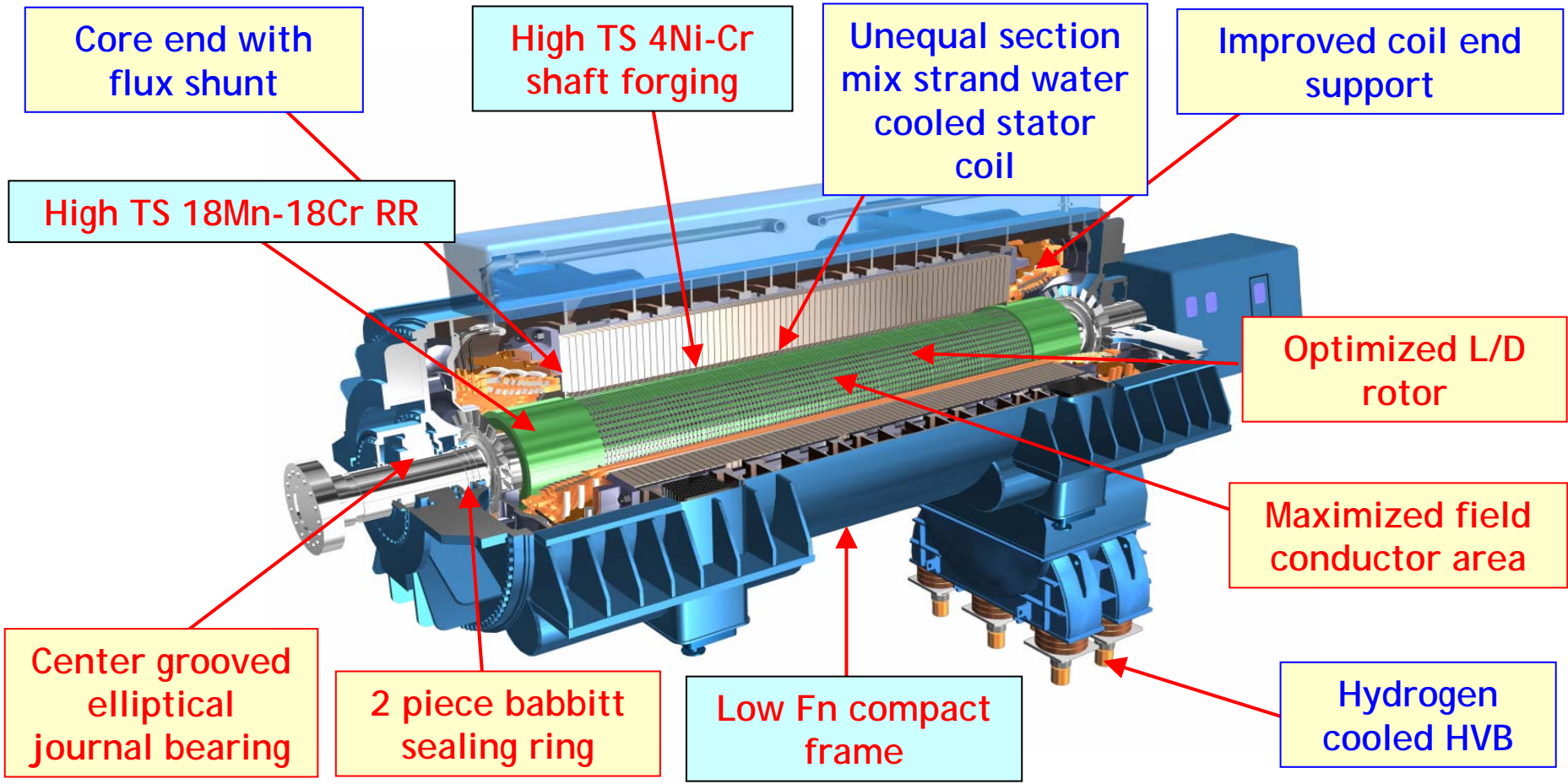
	1265MVA	Hekinan #4 (Japan)	Taizhou #1 (China)
Output (kW)	1,063	1,000	1,000 ^(1,100)
Capacity (MVA)	1,265	1,120	1,120 ^(1,230)
Voltage (V)	27,000	25,000	27,000
Current (A)	27,050	25,866	23,950 ^(26,302)
Frequency (Hz)	60	60	50
Power factor	0.85	0.9	0.9
H2 pressure (kPag)	520	520	500
Temperature rise	Class B	Class B	Class B
COD	-	2001	2007

What drives the development of 1000MW size generator

- **Evaluation for economy of larger thermal power plant**
 - Lower initial cost and reduced plant space
 - Push for higher efficiency plant
 - Less maintenance and ease of operation
- **Turbine is comprised of multi-sections (HP-IP-LP)**
- **A single machine is required for generator**
 - Large high-speed rotating machine for thermal units
(Single rotor)
 - Limitation in large rotor manufacturing
 - Reduction of machine (stator) size

Employed technologies to 1,000MW class generator

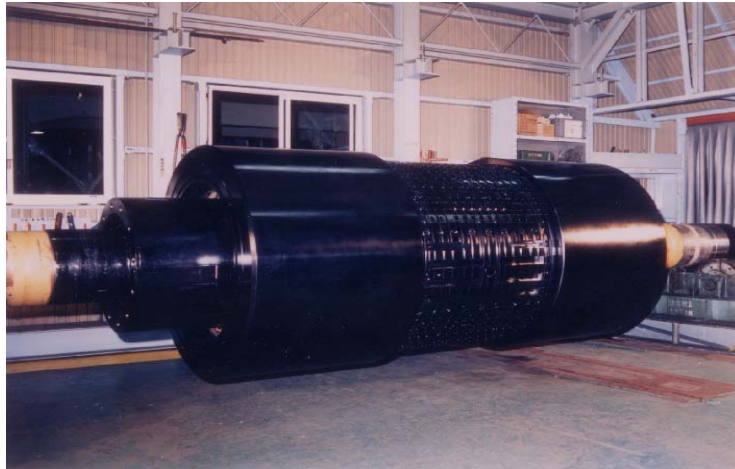
$$P = K \cdot D \cdot I^2 \cdot L \cdot n$$



R & D issues for 1,000MW size generators

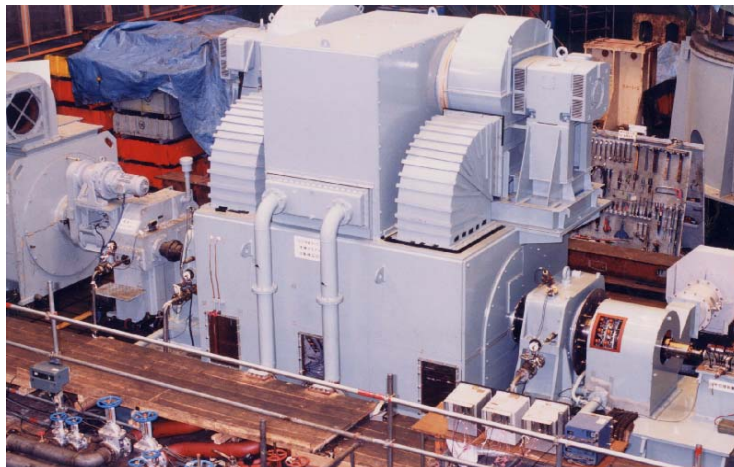
- **High strength and toughness large rotor shaft forging**
Successfully developed a large size generator shaft forging of min. 1000MPa (145ksi) for TS with comparable toughness to conventional ones.
- **High strength and toughness, and non-magnetic retaining ring material**
Successful development of 18%Mn-18%Cr non-magnetic retaining ring material of min. 1300MPa (188ksi) for TS with high SCC resistance
- **Compact stator structure**
Introduction of new stator structure design concept with a low natural frequency stator

Verification by a full size but short model rotor



Short production size model rotor

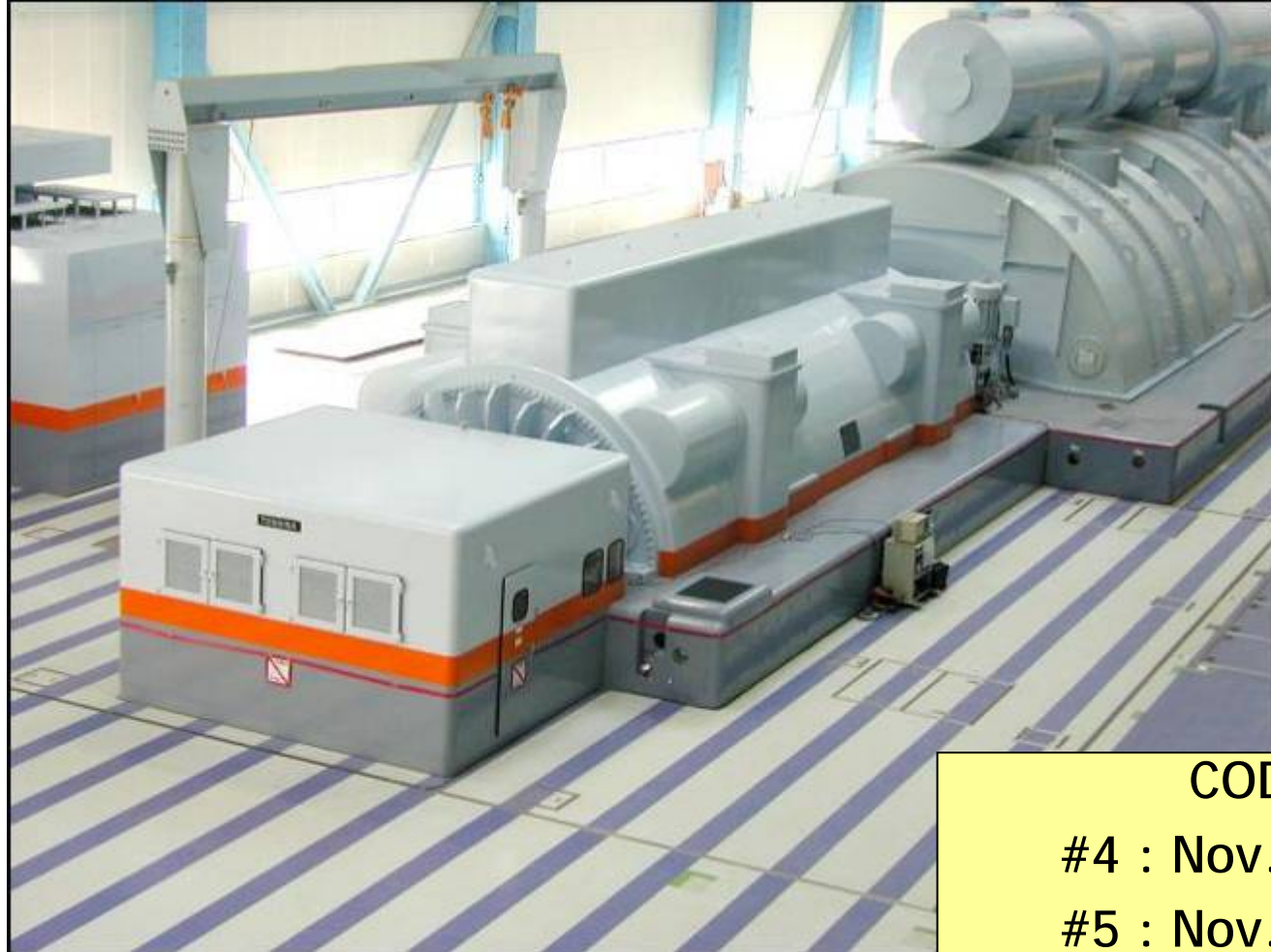
- Same diameter as 1000MW rotor but shorter rotor length
- Same materials and configuration as 1000MW rotor design



Verification tests

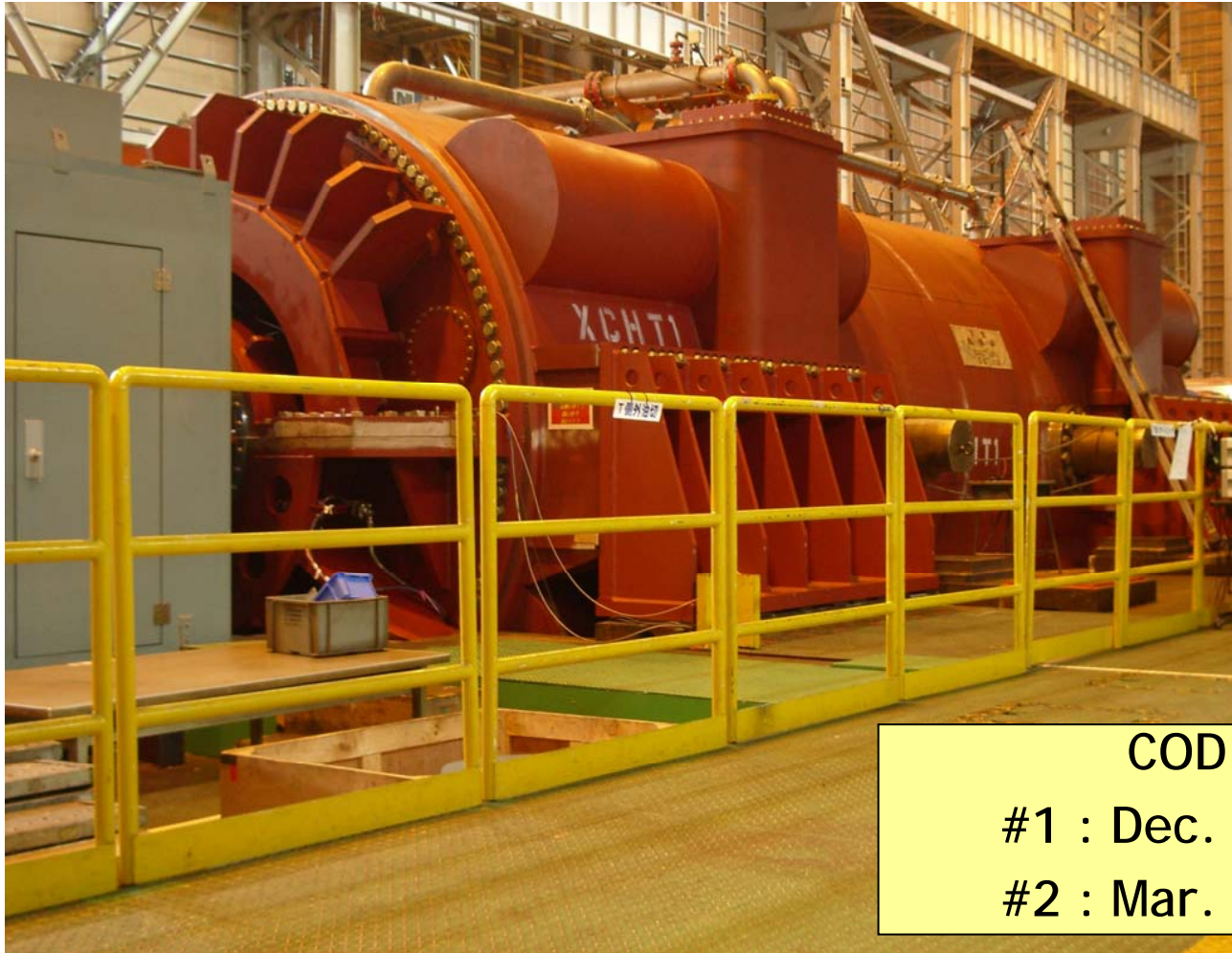
- Rotating tests including 120 % over speed test
- Stress and displacement measurements of over 100 points
- Start and stop operation test of 500 times
- Excitation tests simulating working temperature rise
- Dismantling and inspections after rotating tests

*2P, 60Hz, 1,000MW generator for
Chubu/Hekinan #4, #5*



COD
#4 : Nov. 2001
#5 : Nov. 2002

2P, 50Hz, 1,000MW generator for
China/Taizhou #1



COD
#1 : Dec. 2007
#2 : Mar. 2008

Concept of turbo-generator in the next generation

New concept to the next generation

Voice of customers

- Low initial cost
- Short cycle time
- Low CO2 emission
- Ease of operation
- Low maintenance cost

Low life time cost



Generator manufacturers

- Easy & cost effective procurement
- Easy design and production
- Short production time
- Machine integrity

Simplified generator

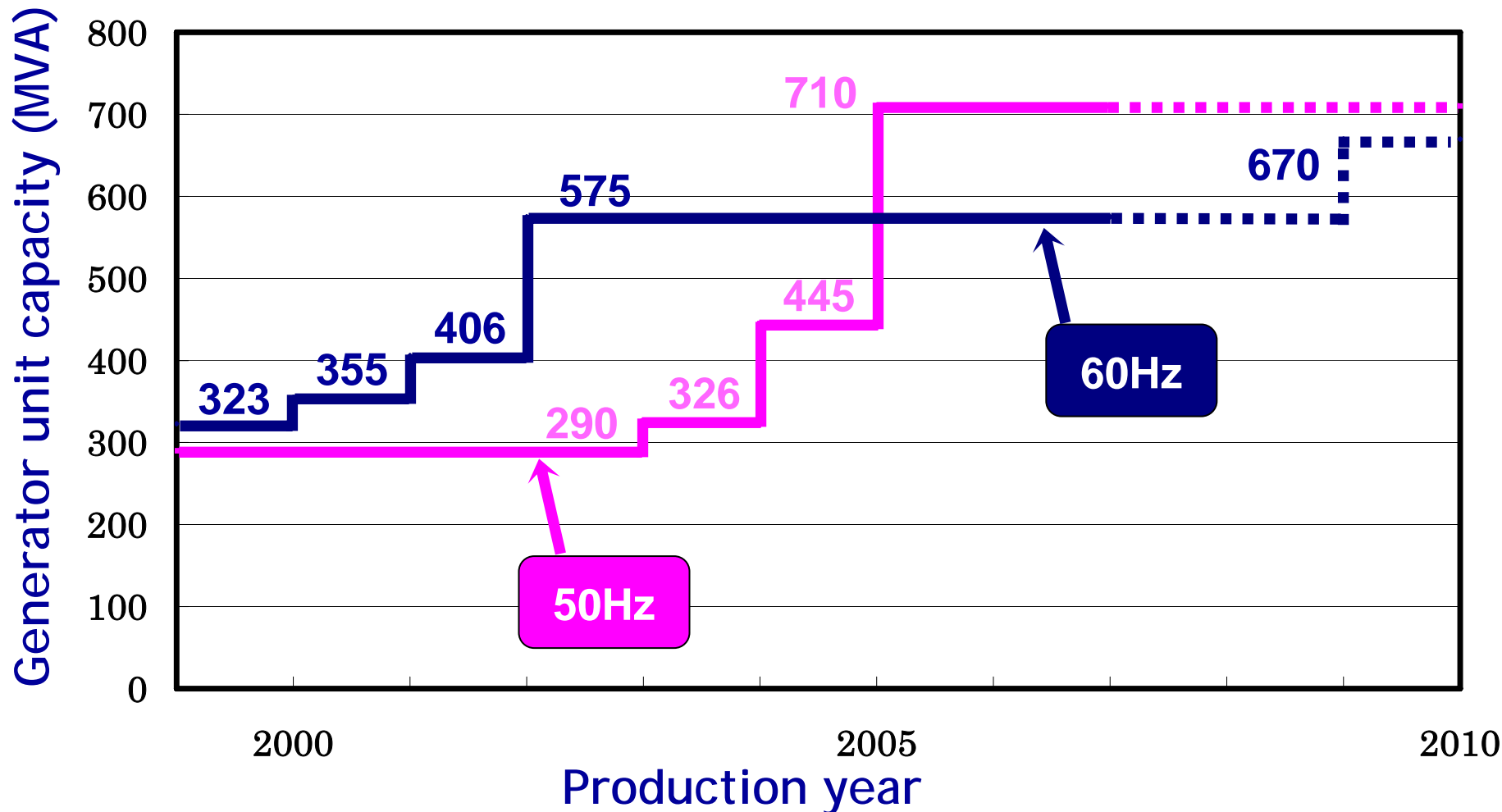
Solution: Simplified cooled generator

Directly H₂O/H₂/Air cooled generator



Indirectly H₂/Air cooled generator with innovative technology

Growth in generator unit capacity
 Indirectly hydrogen-cooled generators



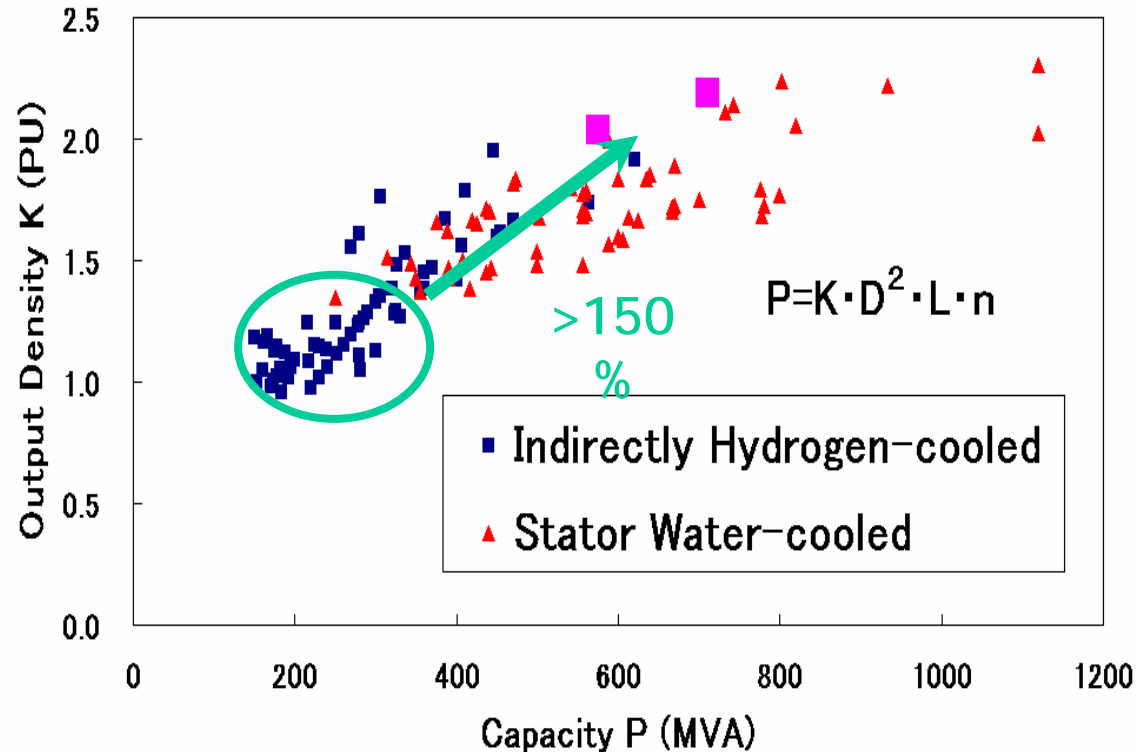
The world's largest indirectly hydrogen-cooled generators

	60Hz		50Hz
Capacity (MVA)	670	575	710
Voltage (kV)	19	19.5	20.5
Current (A)	20,360	17,025	19,997
Rotating speed (rpm)	3,600	3,600	3,000
Power factor	0.9	0.85	0.85
H2 pressure (kPag)	520	412	412
Insulation class	Class F	Class F	Class F
Temperature rise	Class B	Class B	Class B
Production year	(2008)	2002	2005

Remarkable increase in the output density

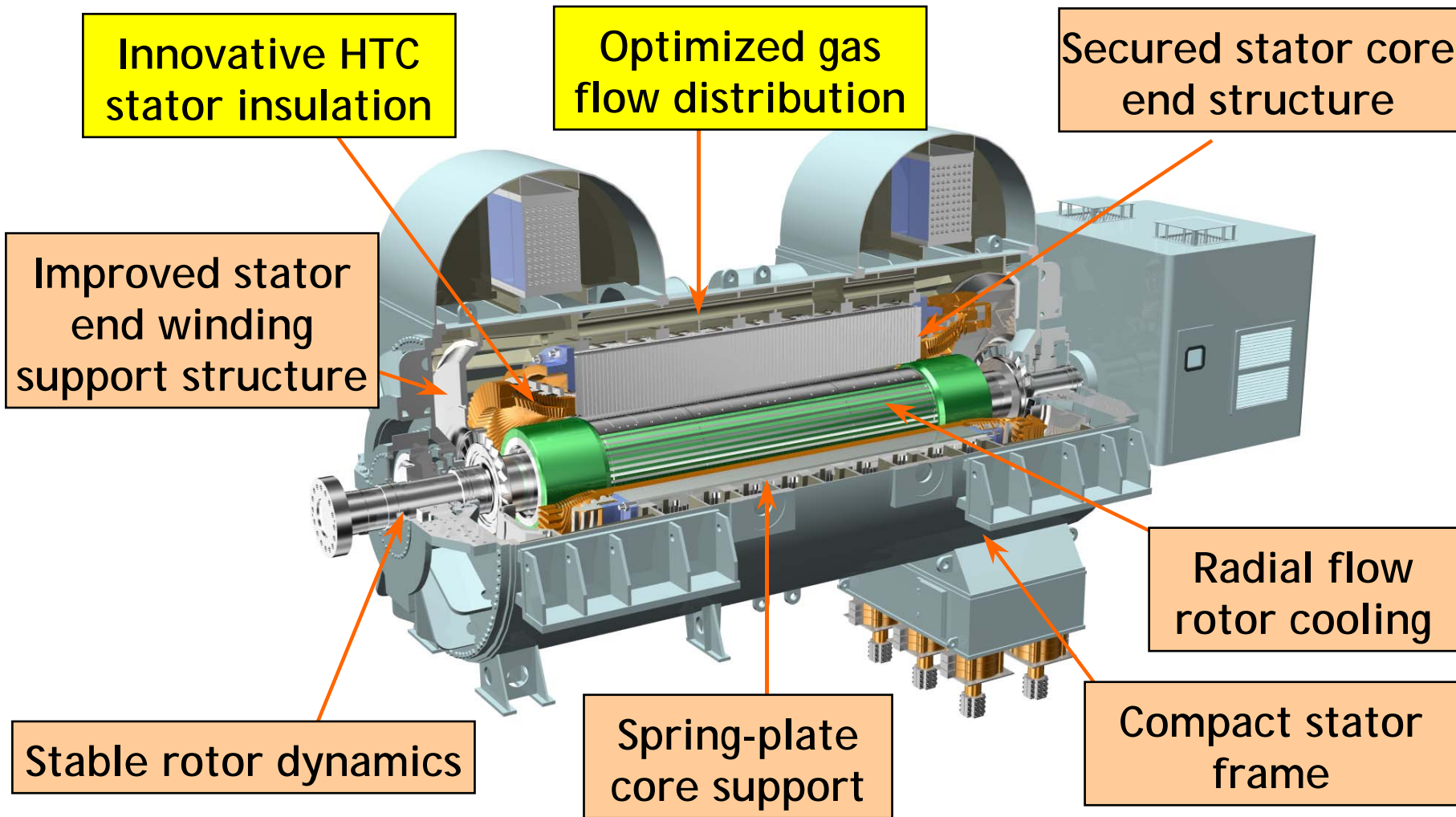
Output density : >150 %
as experienced

- HTC(High Thermal Conductivity) stator insulation
- Optimized gas flow distribution in ventilation circuit
- Increased hydrogen gas pressure



Indirectly hydrogen cooled generators can supersede water-cooled generators by innovative technologies.

Employed technologies to the developed generator



Shop test results



Capacity	710MVA
Speed	3000 rpm
Power factor	0.85
Temp. rise	B class
Test year	2005



Capacity	575MVA
Speed	3600 rpm
Power factor	0.85
Tem. rise	B class
Test year	2002

Comparison between indirect hydrogen cooling and direct water cooling

(A): Indirect hydrogen cooling (B): Direct water cooling

	(A)	(B)
Apparent power(MVA)	563.3	566
Power factor	0.9	0.9
Terminal voltage(kV)	20.5	19
Frequency(Hz)	50	50
Hydrogen pressure(kPa _g)	410	410
Rotor diameter & Core length	Same	
Stator core outer diameter (pu)	1.09	1
Stator core volume (pu)	1.12	1
Efficiency (pu): test result	1.001	1

More volume, but higher efficiency

Summary

- In recent years, there has been a growing tendency for larger thermal units due to scale benefits.
- In addition power market demands simple system from the view point of ease operation and maintenance, and higher efficiency as well.
- To meet these requirements, the water-cooled 2-pole 1000MW size and indirectly hydrogen-cooled 2-pole 700MVA size generators have been developed.
- Combination of high efficiency and compact design technology has achieved both a reduction weigh and a guaranty efficiency of 99.00%.

END of Evolution of Large Fossil Fired Turbo-generator

