

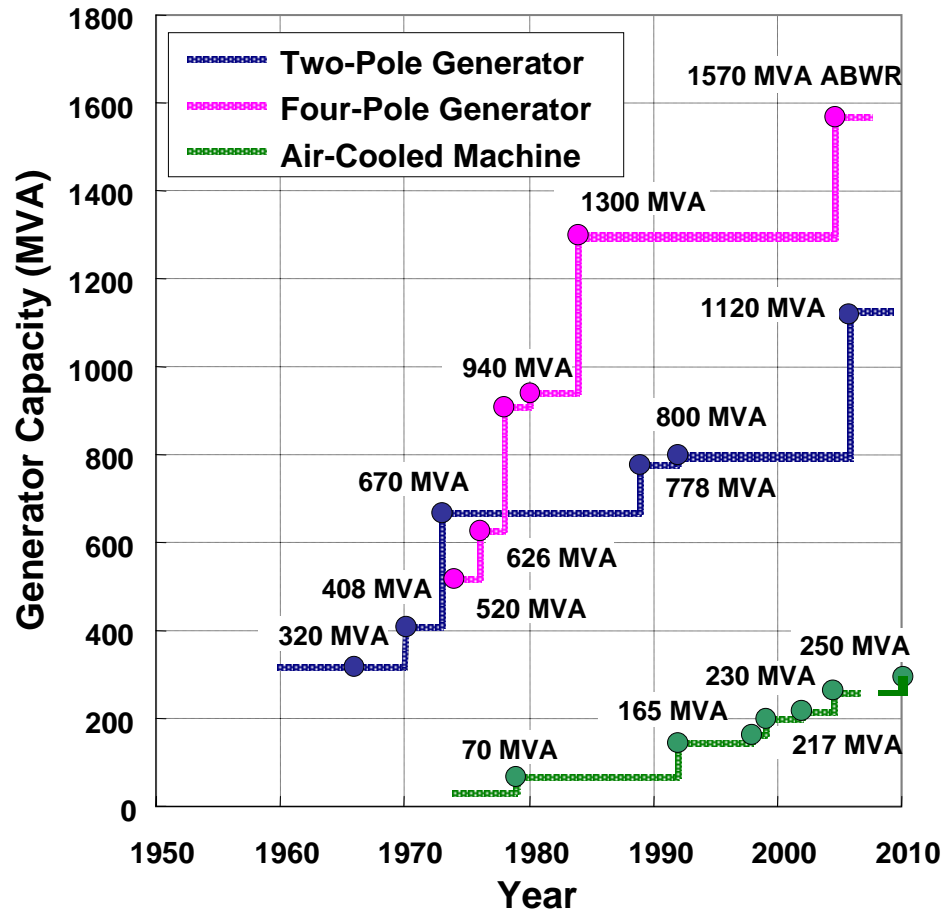
# State-of-the-art Technology for Large Turbine Generators

August, 2008

Kenichi Hattori\*, Kazuhiko Takahashi,  
Shigeki Tohnosu, and Kado Miyakawa

Hitachi, Ltd.

# Hitachi Turbine Generator Development History



## Current

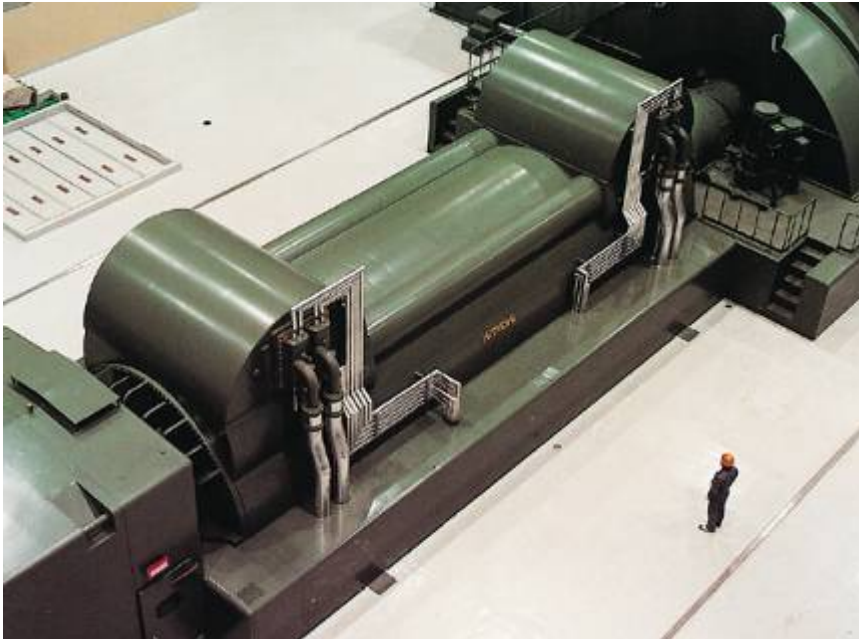
**1570 MVA – 4 pole**  
**1120 (1230) MVA – 2 pole**

## Near future

**2000 MVA ?**

# Current

## Largest Units for Nuclear Power Plants (4 poles)



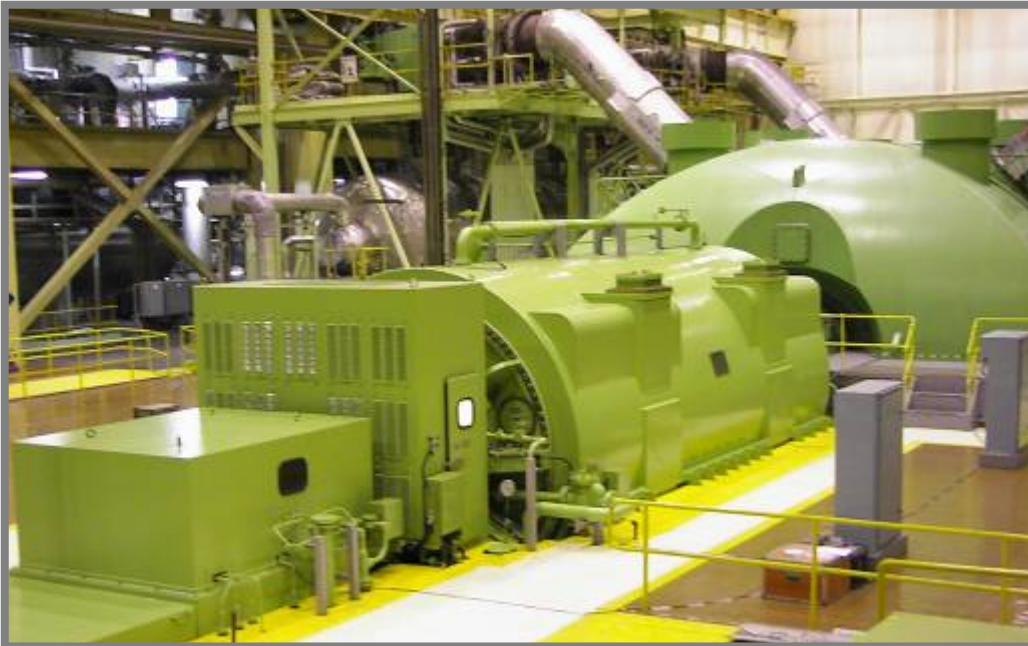
**1,300-MVA (1,500 rpm) Turbine Generator  
at Fukushima II Nuclear Power Station No.  
2 (Japan)**



**1,570-MVA (1,800 rpm) Turbine Generator  
at Hamaoka Nuclear Power Station  
No. 5 (Japan)**

# Current

## Replacement of Generators for Nuclear Power Plants

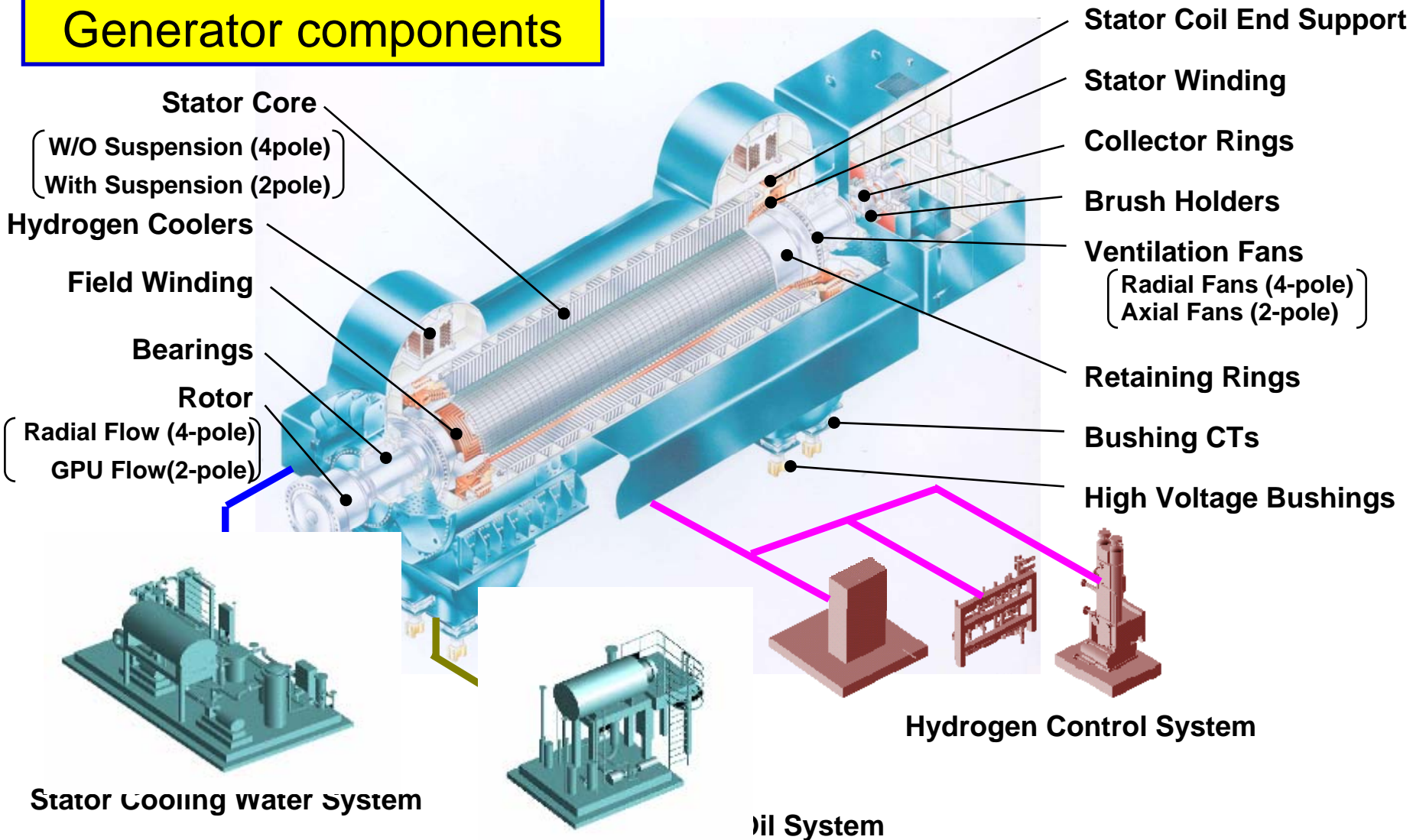


749 MVA 1,800 rpm 60 Hz  
Turbine Generator at Kori  
Nuclear Power Plant No.1  
(Korea)

Hitachi, Ltd. Power Systems

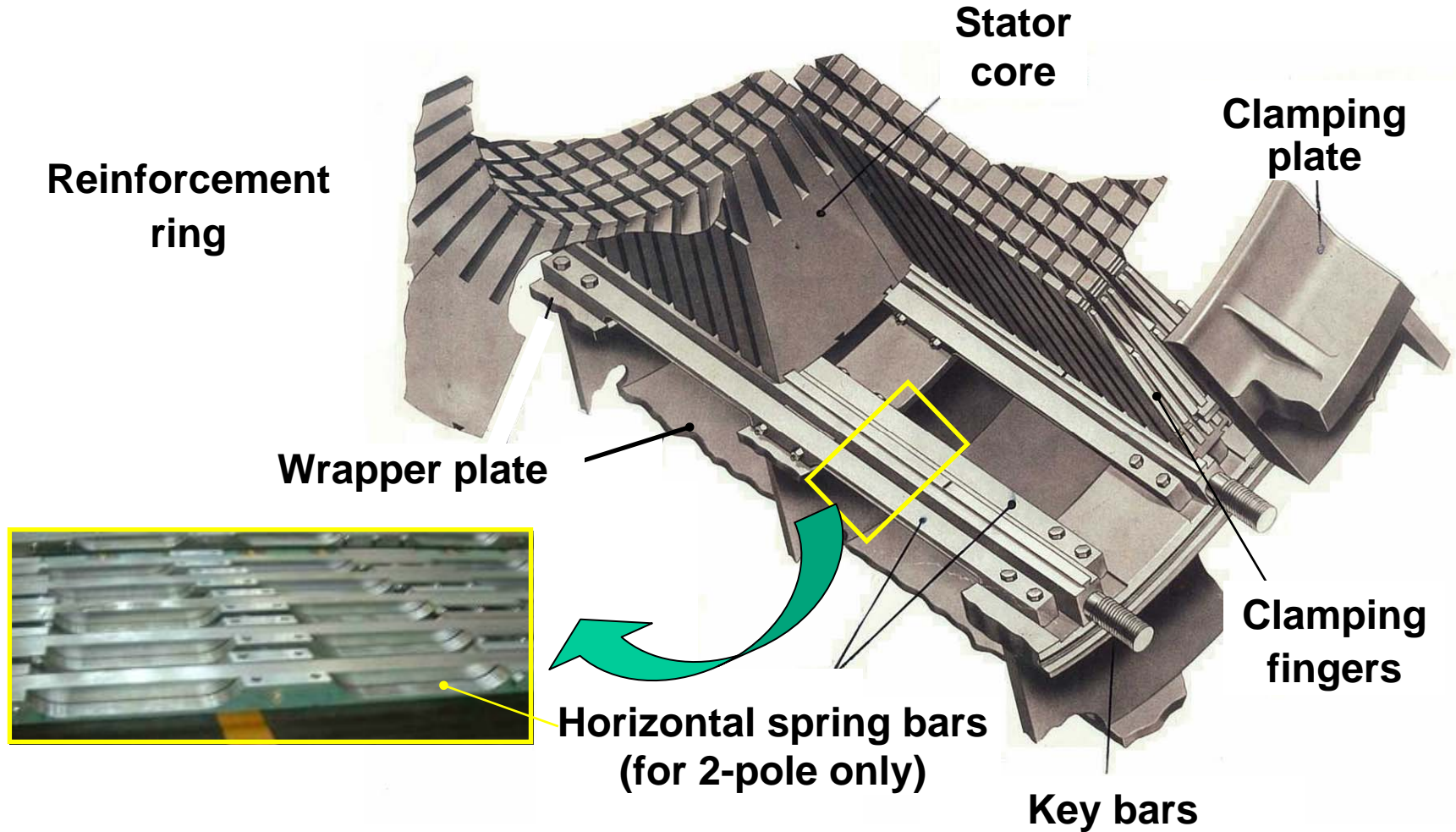
# Typical Structure of 1,000 MVA Class Generator

## Generator components



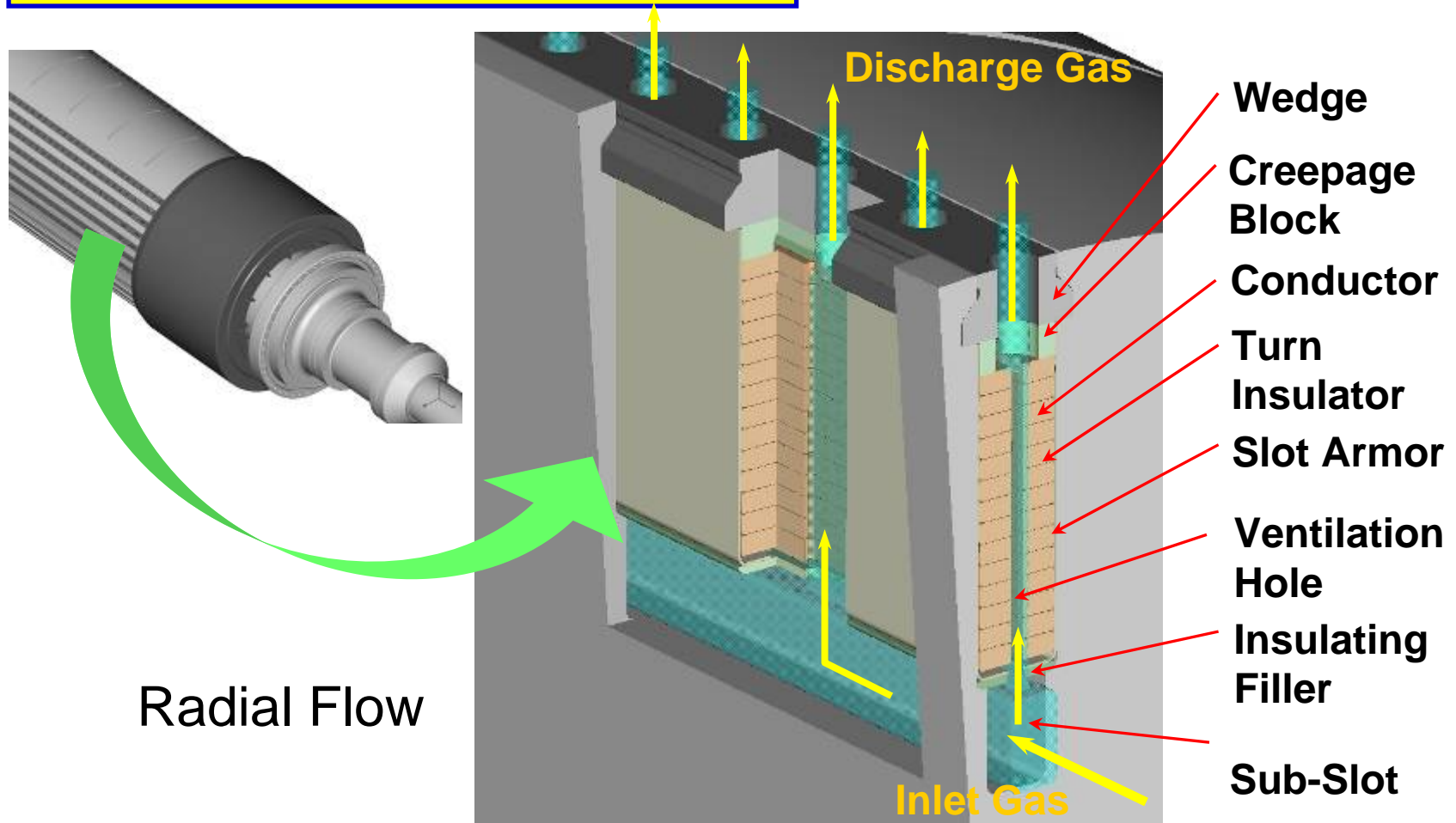
Hitachi, Ltd. Power Systems

# Stator Core - Clamping Structure -



# Ventilation of Generator Rotor (4-pole\*)

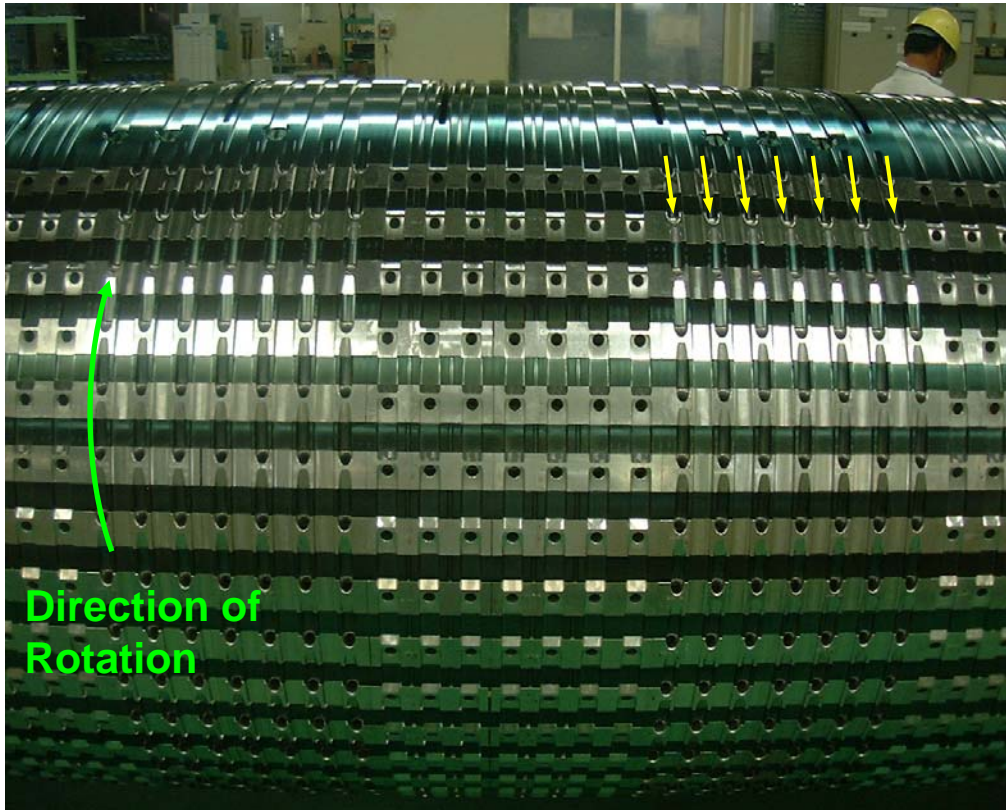
## Rotor (Radial Flow Ventilation)



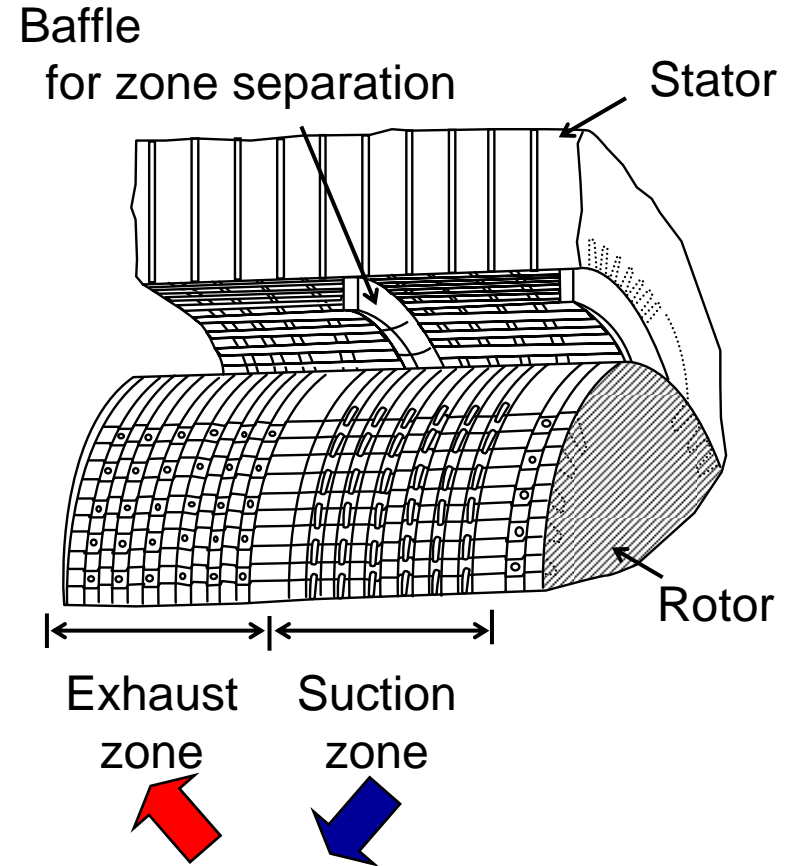
\* Used also for 2-pole generators of smaller output

# Ventilation of Generator Rotor (2-pole only)

## Rotor (Gap Pick-up Ventilation)

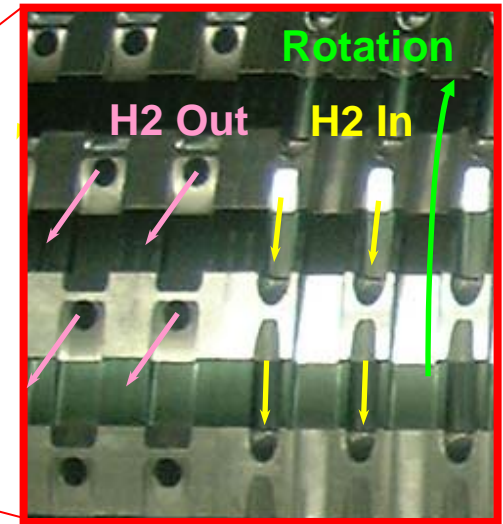
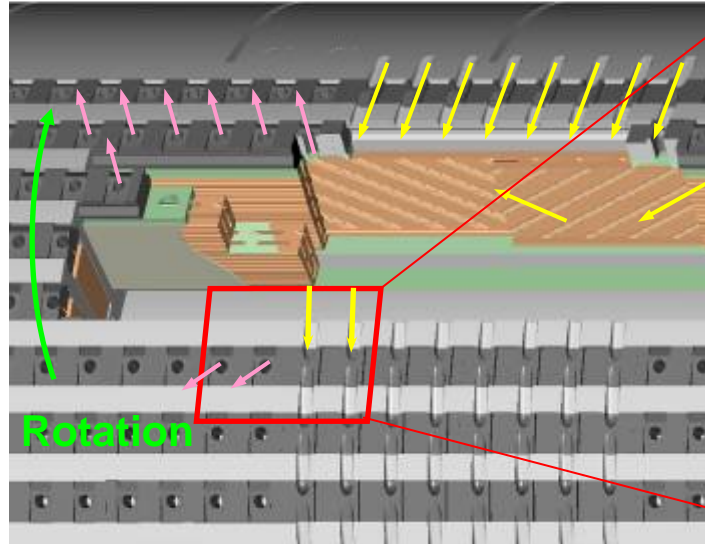
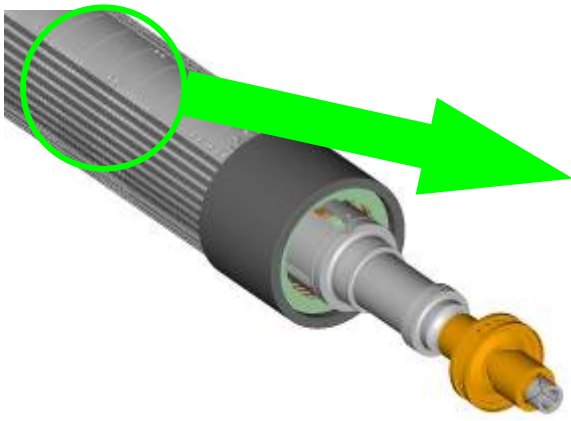


Direction of Rotation



Directly cooled  
Gap pick up flow  
(Diagonal flow)

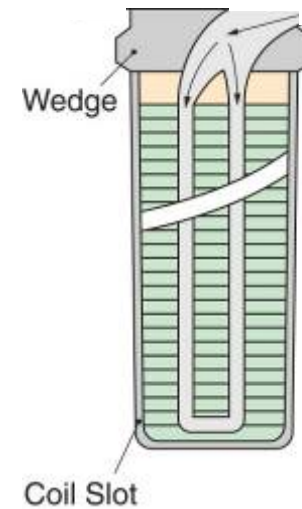
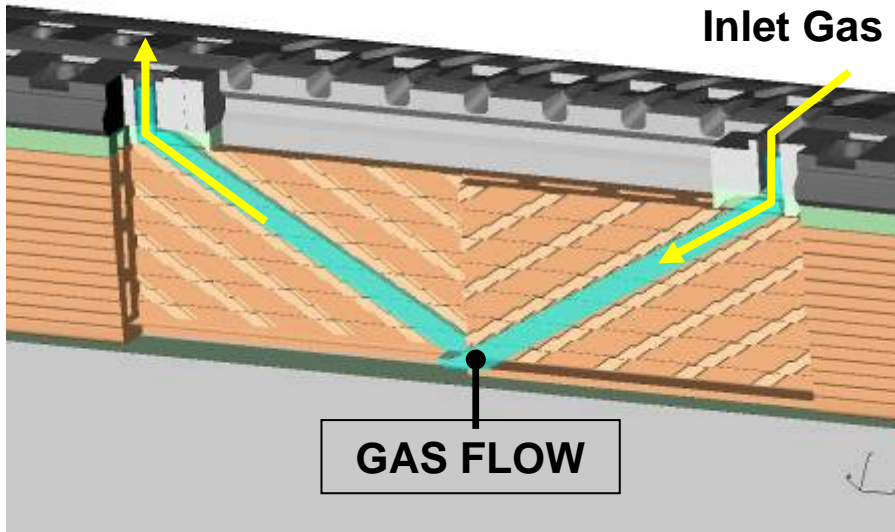
# Ventilation of Generator Rotor (Gap pick-up)



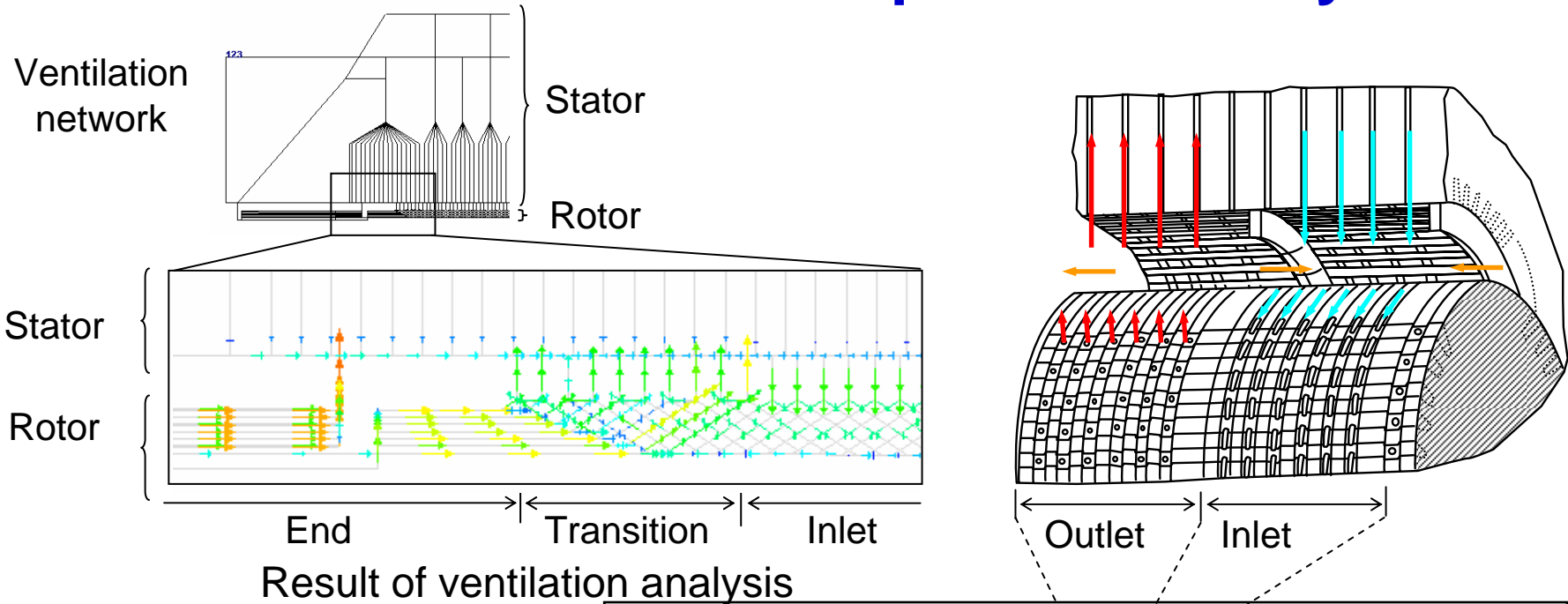
Discharge Gas

Inlet Gas

Direction of Rotation



# Example of Rotor Temperature Analysis



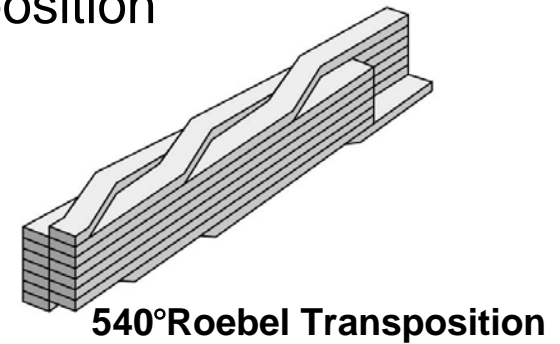
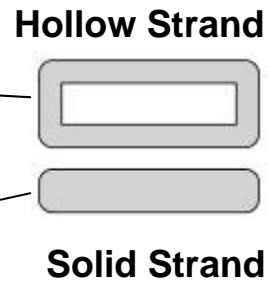
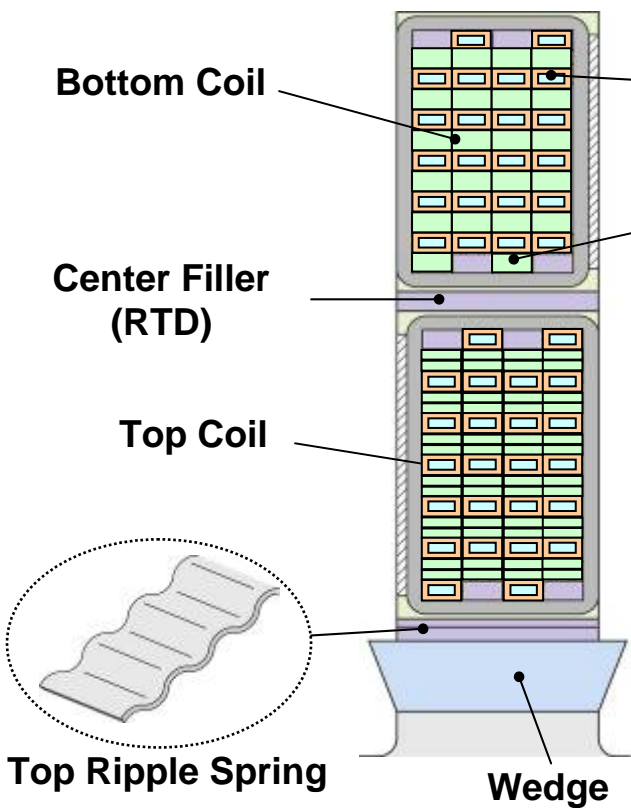
We

- Investigate interaction of stator and rotor
- Control both hot spot and average temperature

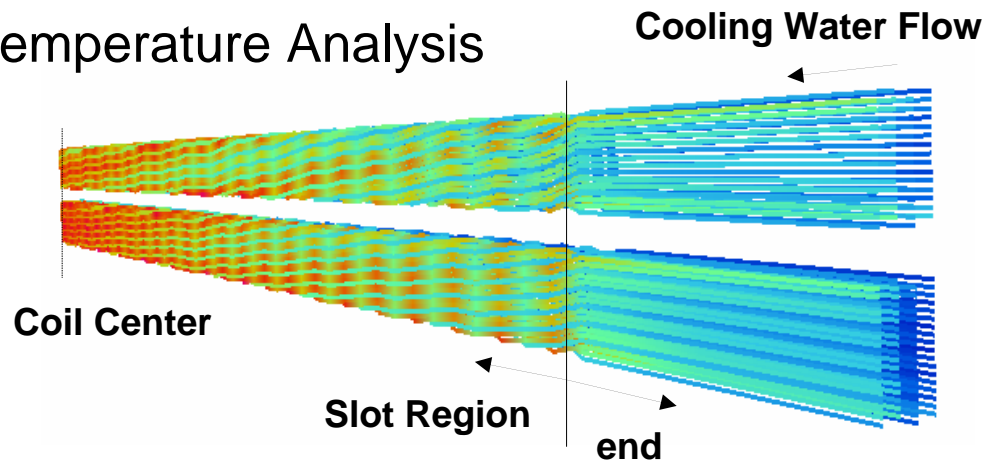
# Stator Coil - Strand -

## Stator Coil and Cooling System

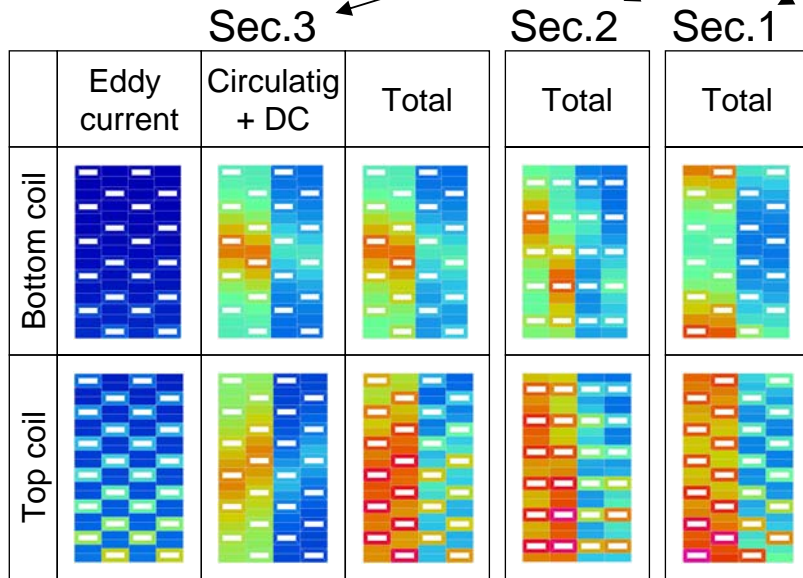
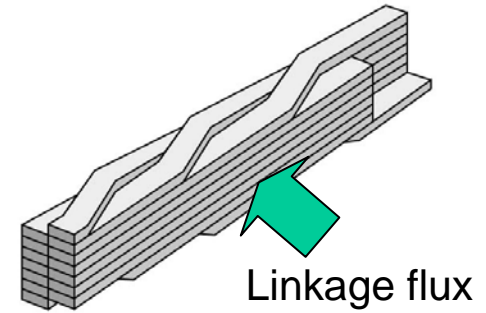
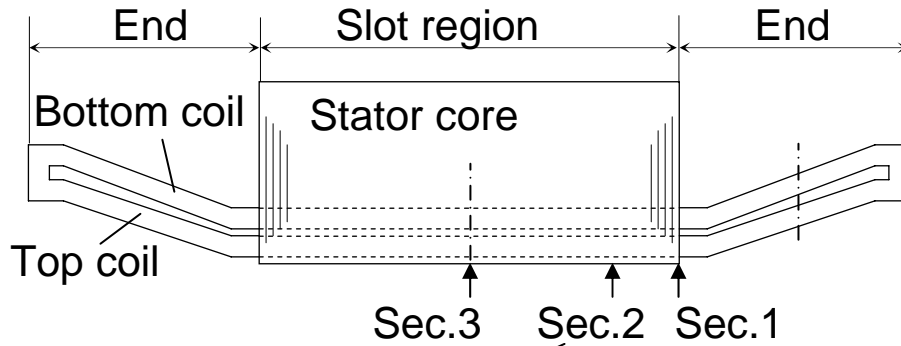
Cross Section of Stator Slot      Strands and Transposition



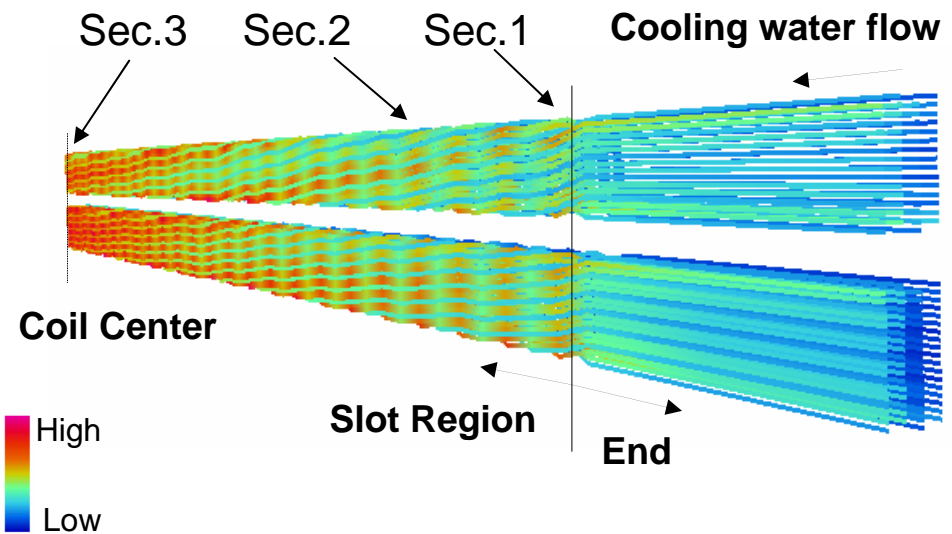
Temperature Analysis



# Example of Stator Coil Temperature Analysis



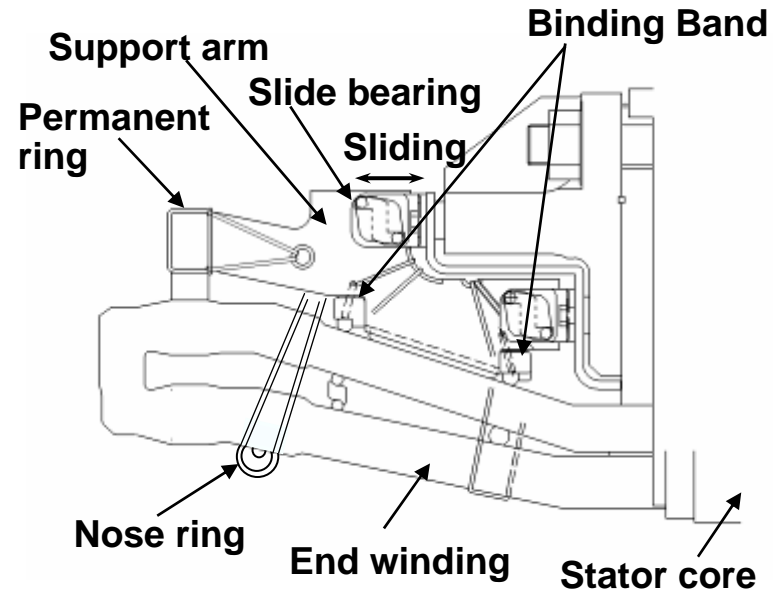
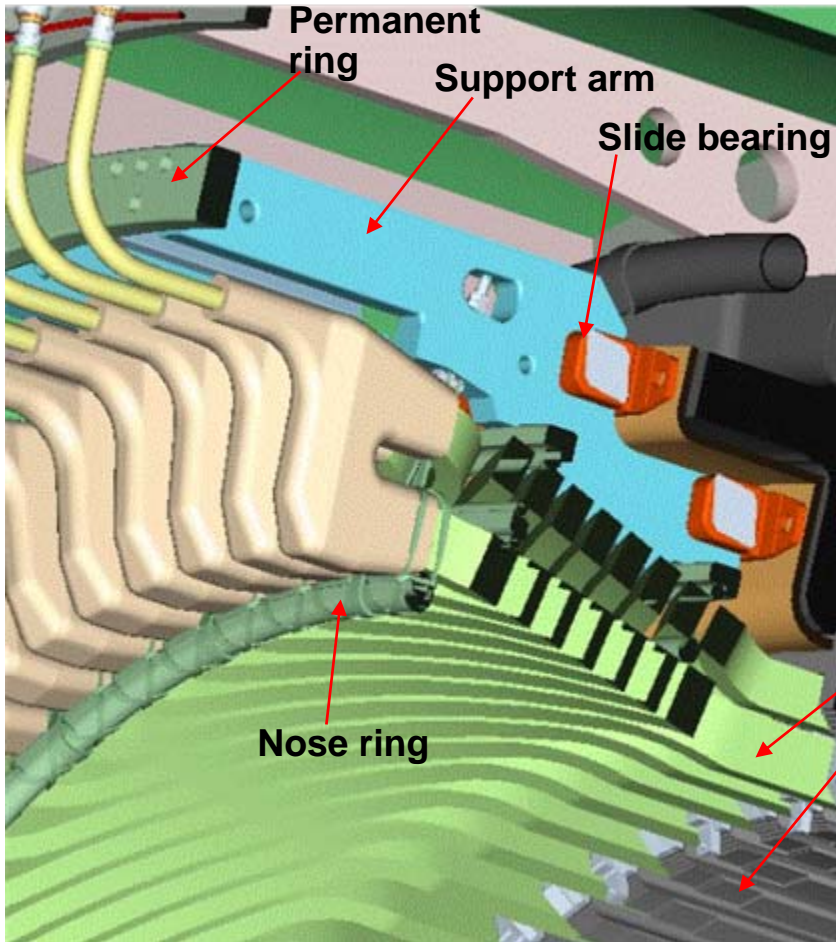
Loss distribution



Temperature distribution

# Stator Coil - Coil End Support System -

## Sliding support

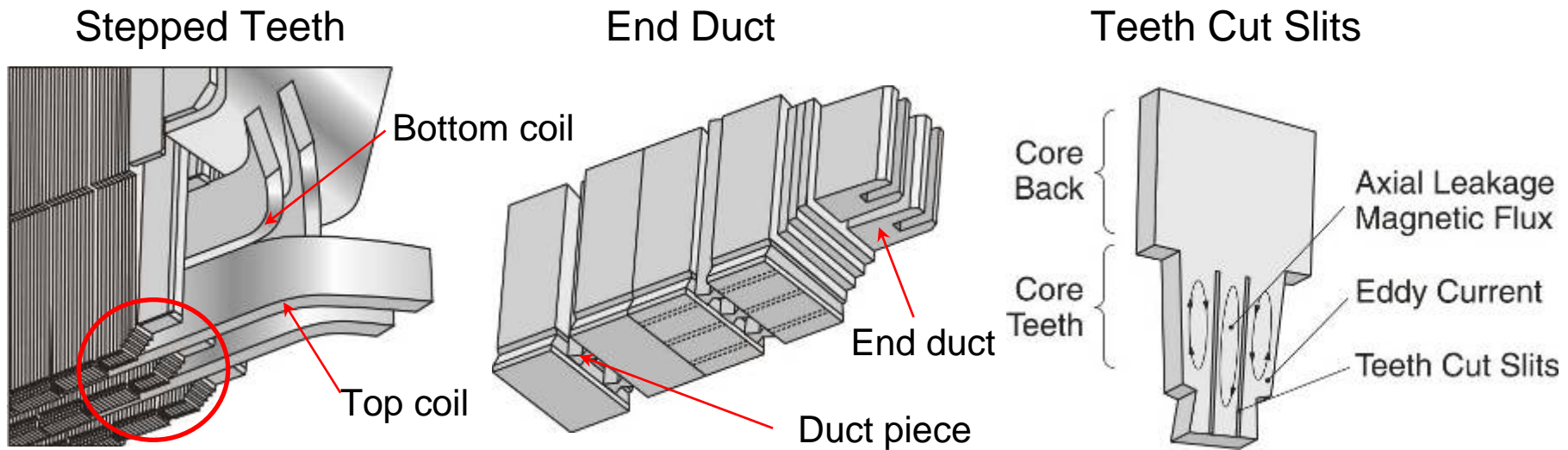


End winding  
Stator core

- Secured from radial and circumferential movement
- Free for axial movement

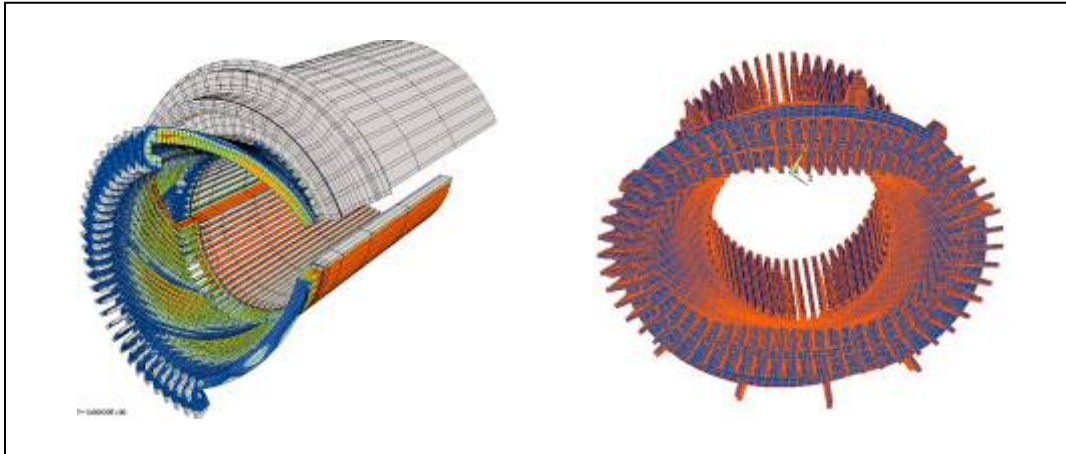
# Stator Core - Measures against Overheating -

## Stator core

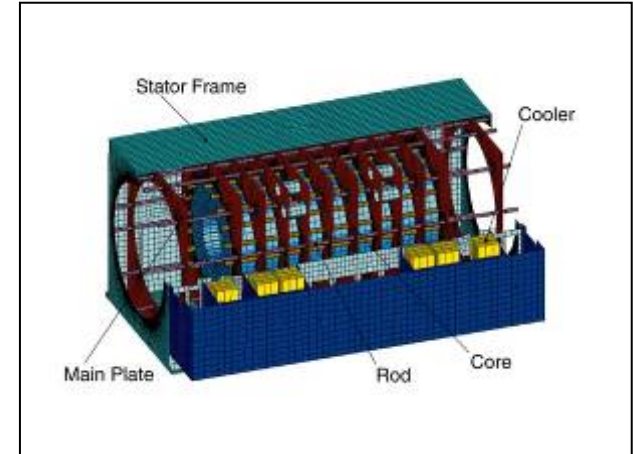


Arrangement of the stator core end is designed to reduce detrimental heating effect (eddy current loss) due to axial leakage magnetic flux.

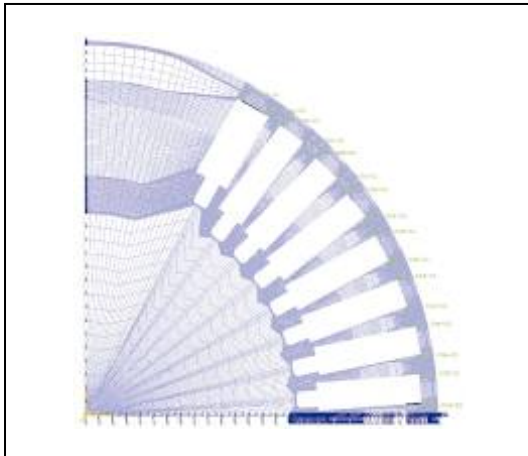
# Advanced Technology for Optimum Design



*Electro-Magnetic Force and Vibration Analysis on Stator End Windings*



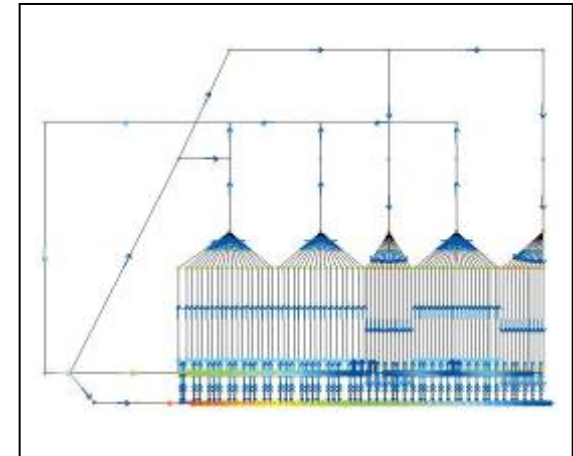
*Vibration Analysis of Stator Casing*



*Mechanical Analysis of Rotor Shaft*

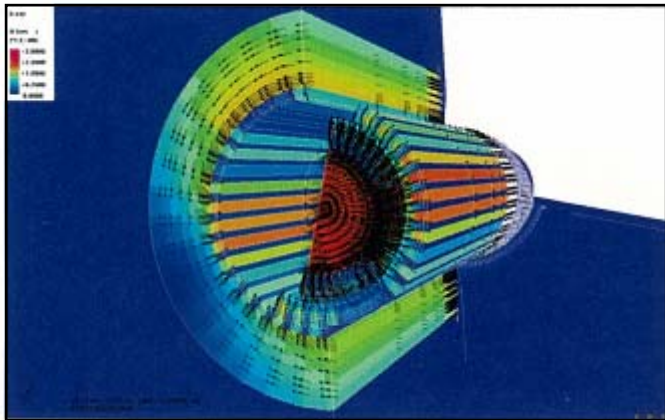


*Fan Characteristics Analysis*

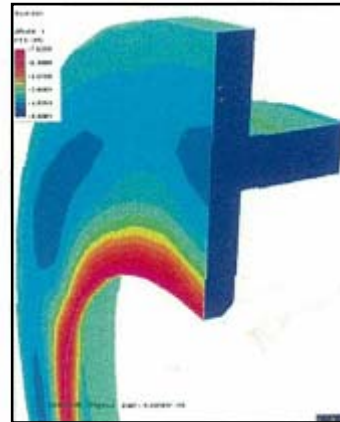


*Ventilation Analysis*

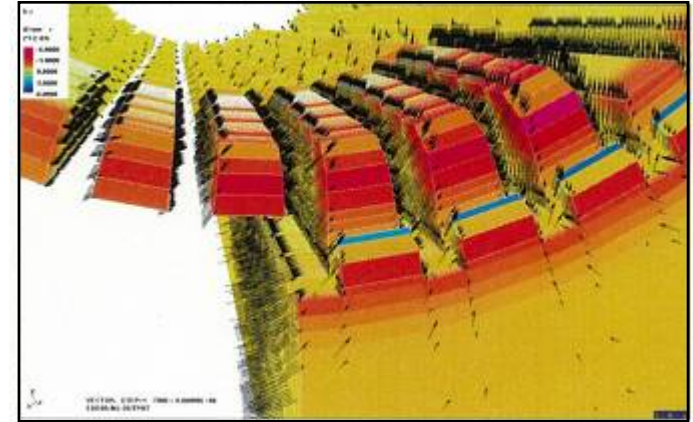
# Advanced Technology for Optimum Design



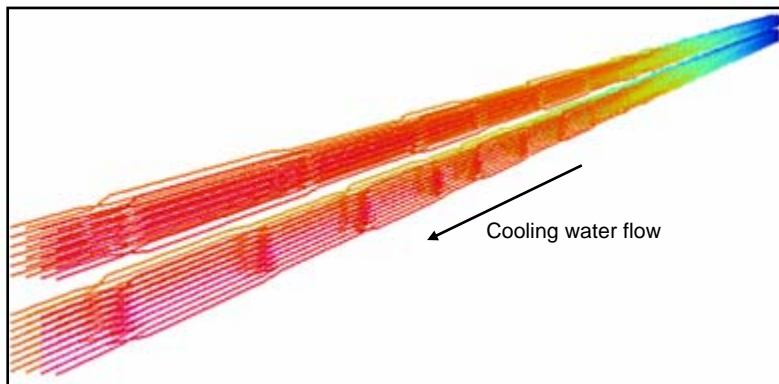
**Generator magnetic flux analysis**



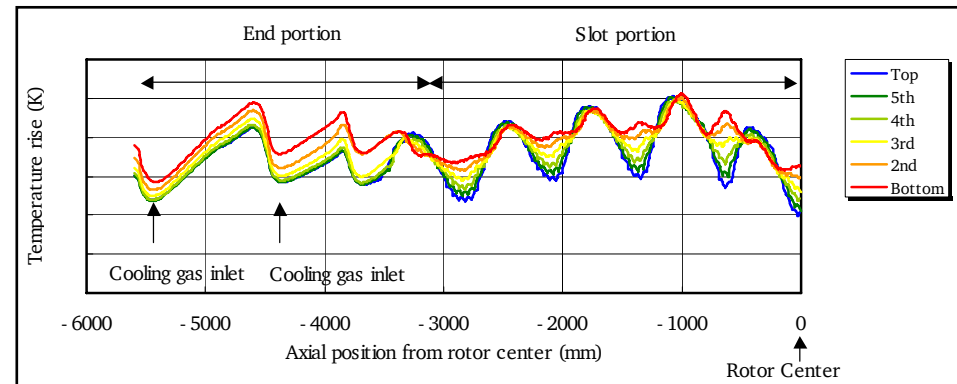
**Magnetic field analysis at stator core end plate**



**Magnetic field analysis at stator core end**



**Stator coil temperature distribution**



**Rotor coil temperature distribution**

# Quality Assurance and Tests for Development



Stator Inspection

Stator End Winding Vibration Test Equipment



Clean Room for Stator/Rotor Assembly

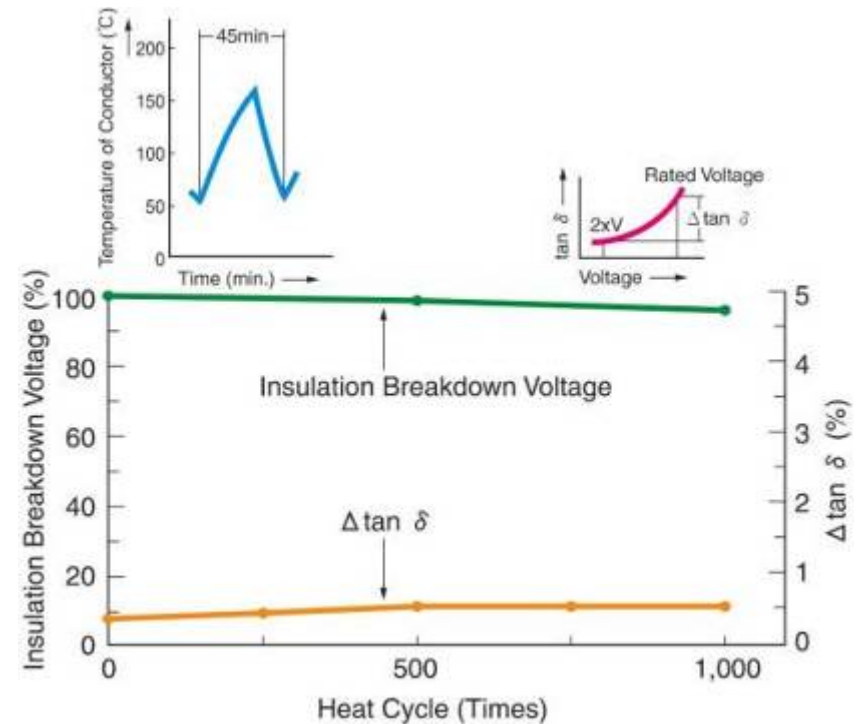


Spinning Burst Test Using Full -Size Rotor

Quality control and inspection of components

# Quality Assurance and Tests for Development

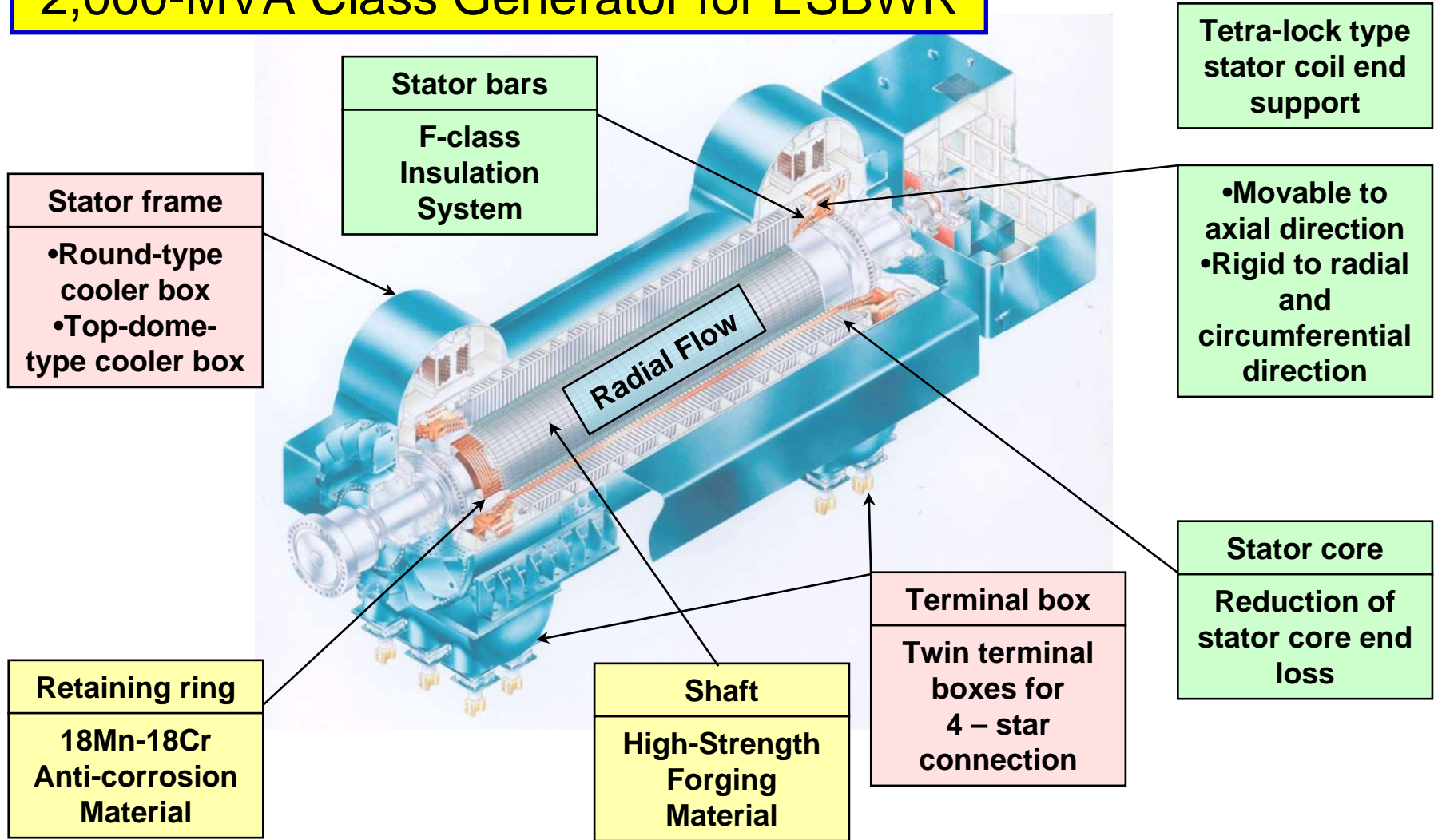
## Stator coil (Insulation for Class F)



High performance of the insulation system confirmed from thermal cyclic endurance test

# Proven Technology for High-performance Generator

## 2,000-MVA Class Generator for ESBWR



# Future Design Philosophy

## Comparison of Parameters

Item	Country	China	Japan	ESBWR
Capacity	MVA	1,120 (Max 1,230)	1,570	App. 1,900 – 2,000
Output	MW	1,000 (Max 1,083.5)	1,413	App. 1,700 – 1,800
Power factor	-	0.9	0.9	0.9
SCR	-	NLT 0.50	NLT 0.58	NLT 0.35 (*1)
Voltage	kV	27	22	24 - 27
Current	A	23,949 (Max 26,302)	41,202	App. 44,000 - 38,000
Connection	-	2Y	4Y	4Y
H2 Pressure	MPa-g	0.52	0.52	0.52 – 0.62
Rotating speed	rpm	3,000	1,800	1,800
<b>No. of Poles</b>	-	<b>2</b>	<b>4</b>	<b>4</b>
Stator cooling	-	Water Direct	Water Direct	Water Direct
<b>Rotor cooling</b>	-	<b>H2 Direct (GPU Flow)</b>	<b>H2 Direct (Radial Flow)</b>	<b>H2 Direct (Radial Flow)</b>
Exciter	-	Static	Static	Static

\* 1: According to IEEE C50.13 - 2005

# Features of Large Turbine Generators

- Difference between 4 and 2-pole generator discussed
- The main technique that characterize our generator is the minute temperature analysis where the rotor and the stator interaction was fully incorporated.
- The stator strand loss and temperature are examined full 3-D scale while physically considering transposition.
- From the above, the current maximum rating is 1,570 MVA (4-pole) and 1,230 MVA (2-pole). We foresee future 2,000 MVA in the future.

**Thank you**

## Current - 4 pole generators -

### Current 4-pole generator for NPP including AVR

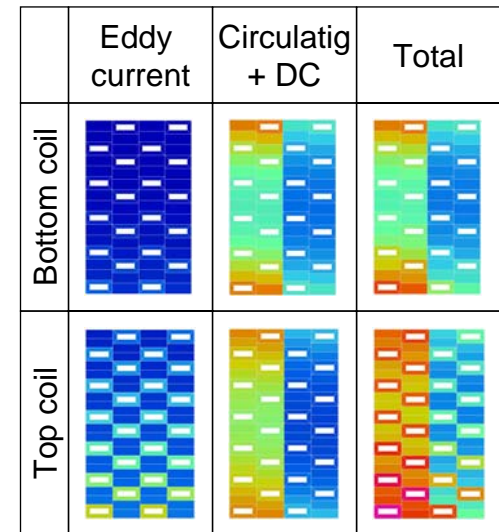
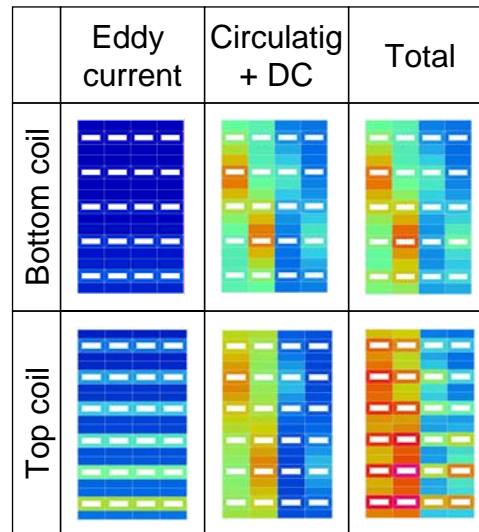
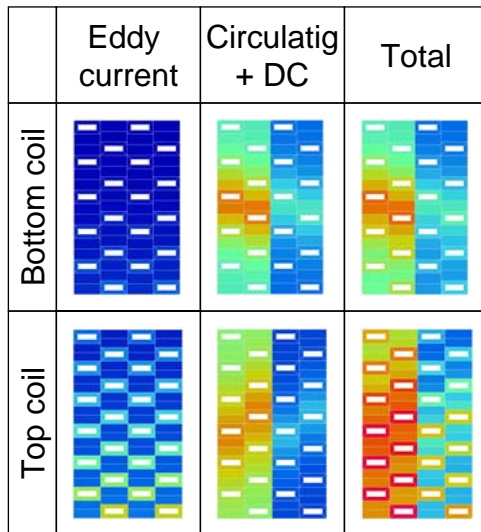
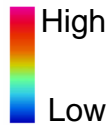
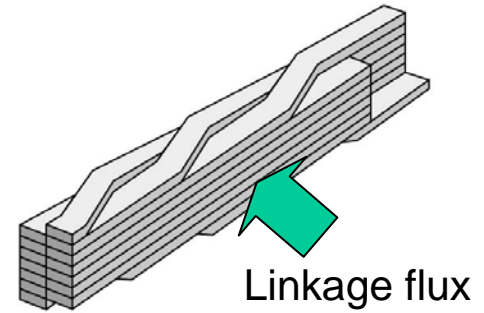
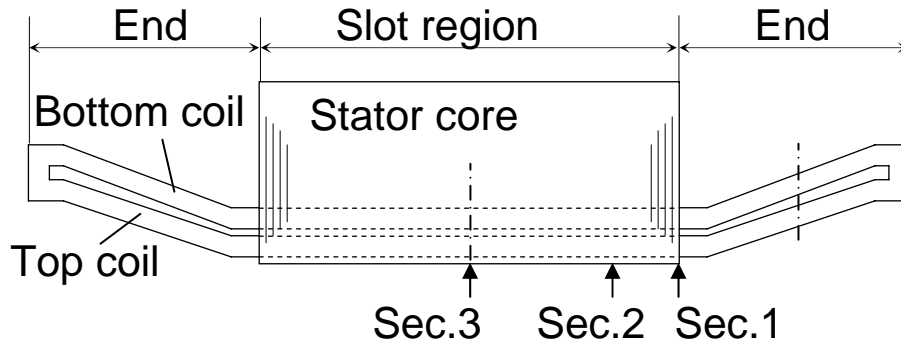
Country	Capacity(MVA)	RPM	Voltage(KV)	Service Year
Japan	1570	1800	22	2005
Japan	1540	1800	24	2006
Japan	1530	1800	22	2011
Japan	1300	1500	19	1984
Japan	1300	1500	19	1987
Japan	1300	1500	19	1990
Japan	1300	1500	19	1994
Japan	1280	1800	22	1993
Japan	1280	1800	22	1987
Korea	1222	1800	22	2009
Korea	1222	1800	22	2009

## Current - 2 pole machine -

### Current 2-pole generator (latest upgrade)

Country	Capacity(MVA)	RPM	Voltage(KV)	Service Year
China	1230	3000	27	2006
Korea	1028	3600	25	2008
Korea	1028	3600	25	2009
USA	1025	3600	24	2007
USA	986	3600	24	2010
Germany	962	3000	21	2009
Germany	962	3000	21	2012
Netherland	962	3000	21	2012
Germany	962	3000	21	2013
USA	828	3600	25	2009
USA	825	3600	25	2008
USA	825	3600	25	2009
Japan	800	3600	25	1992

# Example of Stator Coil Loss Analysis



Loss distribution