Study of local heating on by IPB connection box and around metallic parts of large power transformer by 3-D Magnetic field analysis

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Abstract :
Large power transformer for a power station is generally applied Isolated Phase Bus (IPB) between the transformer and the generator, and IPB connection box is mounted on the low voltage side of the transformer. Because very large current flows through the IPB, there is a concern of local heating on the metallic parts around the IPB due to the influence of the magnetic flux. In this paper, it is reported that 3-D magnetic analysis is performed to grasp the phenomenon visually and numerically by using JMAG and evaluate it.

JMAG User Conference 2010

Study of Local Heating on by IPB Connection Box and Around Metallic Parts of Large Power Transformer by 3-D Magnetic Field Analysis

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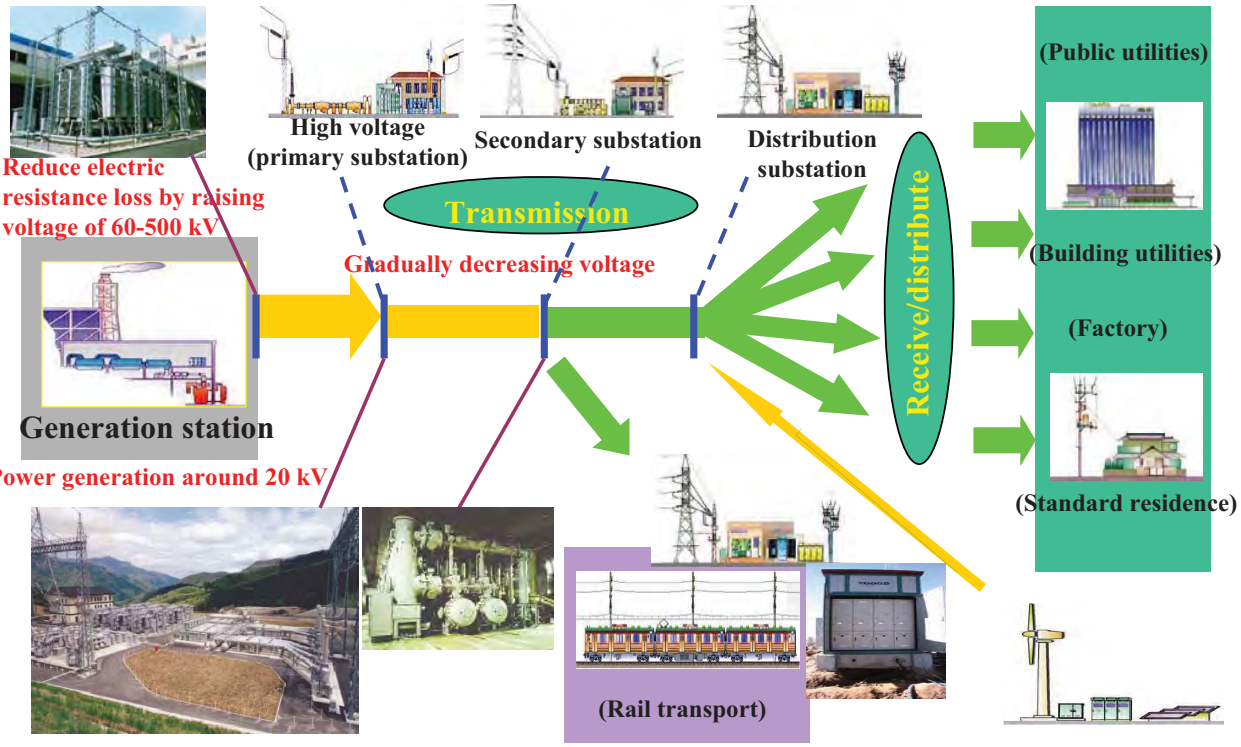

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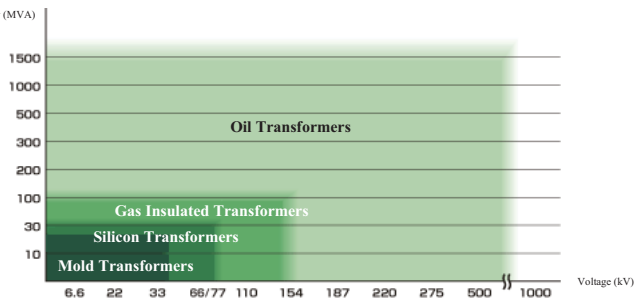
Preface [Product Introduction]

Product Lineup

There are a wide range of applications for transformers and a large current of several kA flows on the low voltage side depending on the required specifications.

Transformer theory is electromagnetics

Therefore, the magnetic field produced in transformers needs to be understood.



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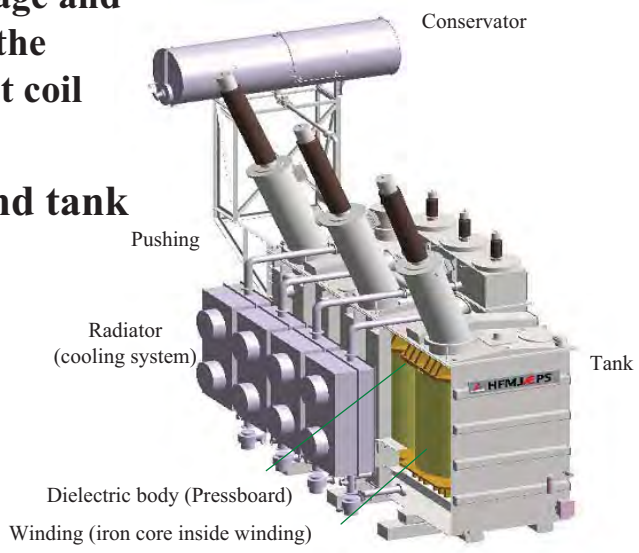
Preface [Product Introduction]

- **Primary Functions: Raising/reducing electric voltage**
- **Role: Efficient transmission of electric energy**
- **Principles: Transform the voltage and current of electricity based on the ratio of turns between the input coil and the output coil.**
- **Structure: Coil, iron core, and tank**

  Radiator (cooling system)/ conservator/dielectric body (pressboard, oil, gas, resin)/ Tap charger/pushing, etc.



Structure of a core type transformer

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Magnetic Field Analyses for Transformers

Transformer loss

No-load loss (iron loss)
- Hysteresis loss → Caused by hysteresis properties
- Eddy current loss → Caused by current canceling primary flux in the core

Load loss
- Resistance loss → Caused by resistance of conductors
- Eddy current loss → Caused by leakage flux between windings
- Stray load loss → Caused by the material of each part

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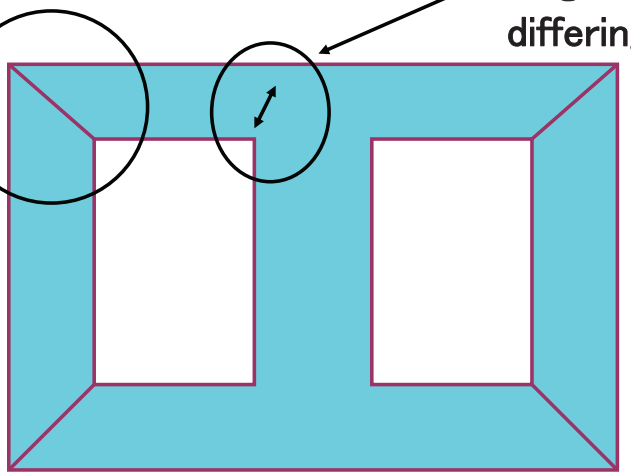
Magnetic Field Analyses for Transformers

No-load loss

(Iron loss)

Flux concentrating in magnetic pathways of differing widths

Evaluating magnetic flux distribution of joints



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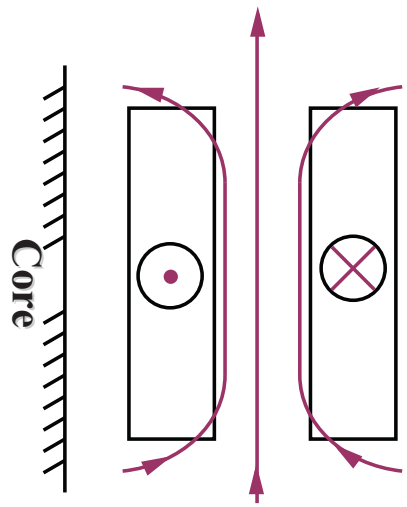
Magnetic Field Analyses for Transformers

Load loss

Eddy current loss



Eddy currents produced by the magnetomotive force in conductors flow to eliminate the leakage flux because the leakage flux cuts the windings horizontally. This leakage flux, also called reactance, needs to be accurately calculated even when calculating the % of impedance.

(Usually analyzed in 2D based on symmetry)

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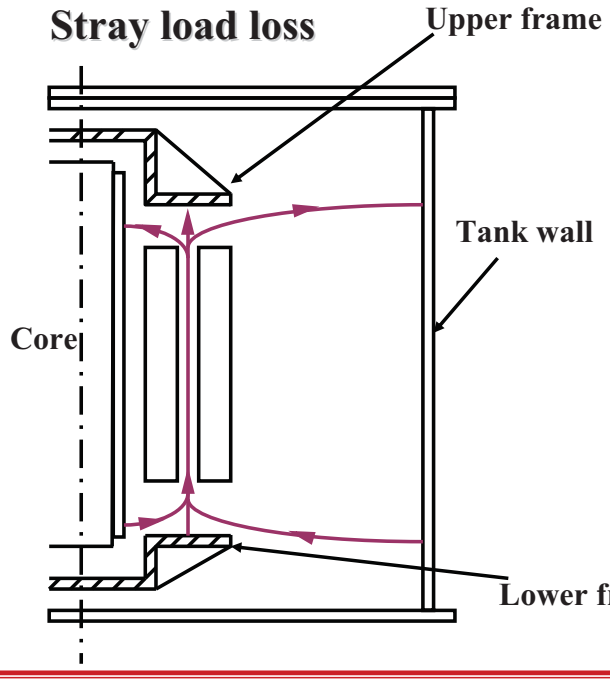
Magnetic Field Analyses for Transformers

Load loss



Metal structural parts are used on the inside and outside of transformers to restrict the transformer behavior. Heat can be produced in metal structural parts by leakage flux.

The structure around the windings needs to maintain mechanical strength while preventing overheating.

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Magnetic Field Analyses Around IPB Connection Boxes

Transformer

Transformer connected directly to generator

A large current of several kA flows in the low voltage side of the transformer in the transformer connected directly to the generator.

The leakage flux around the system is restricted by the exterior metal covering of the IPB (Isolated Phase Bus)

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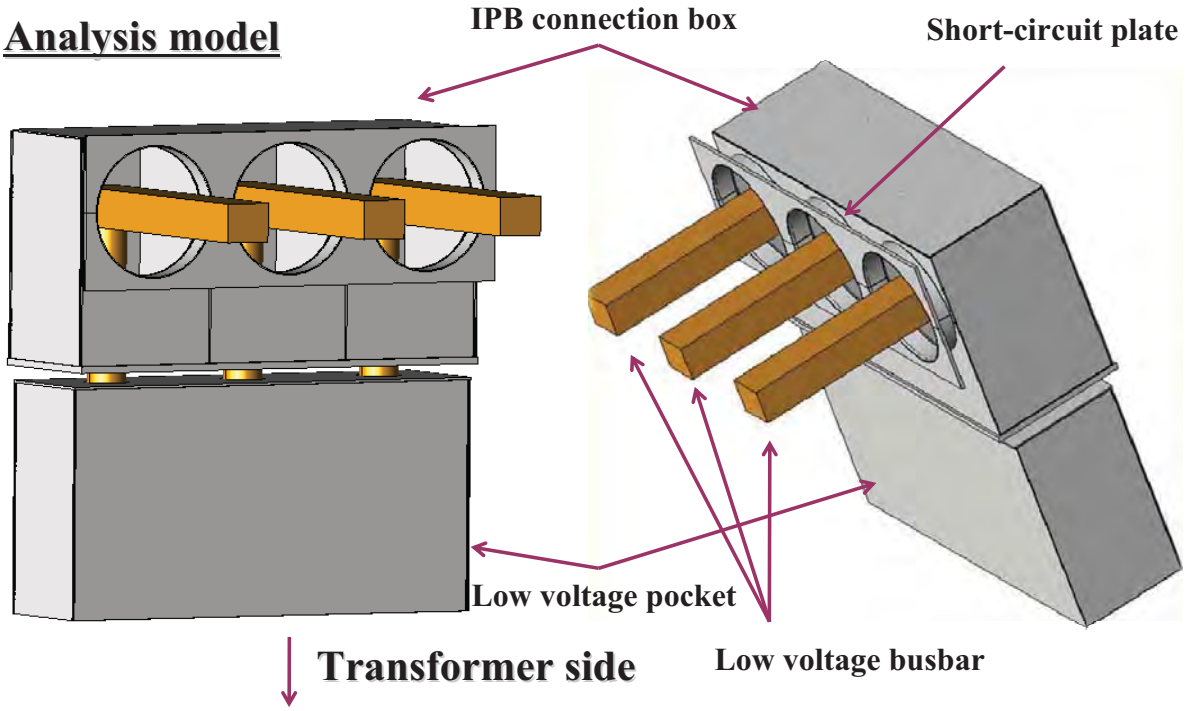
Magnetic Field Analyses Around IPB Connection Boxes

Analysis model



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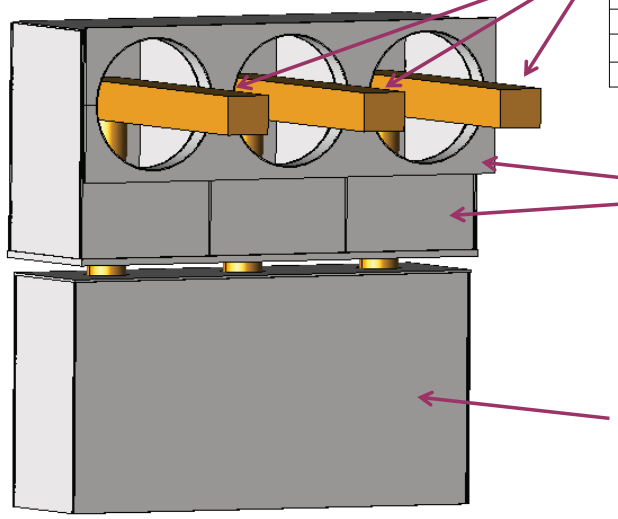
Magnetic Field Analyses Around IPB Connection Boxes

Materials used



Part name	Primary busbar
Material	Copper
Material type	Soft magnetic
Magnetic properties	Linear (constant)
	Isotropic
Relative permeability	1
Resistivity	1.673×10^{-8}
3-phase power supply	約20kArms

Part name	IPB connection box/short circuit plate
Material	Aluminum
Material type	Soft magnetic
Magnetic properties	Linear (constant)
	Isotropic
Relative permeability	1
Resistivity	2.655×10^{-8}

Part name	Low voltage pocket
Material	SUS304
Material type	Soft magnetic
Magnetic properties	Linear (constant)
	Isotropic
Relative permeability	1
Resistivity	7.2×10^{-7}

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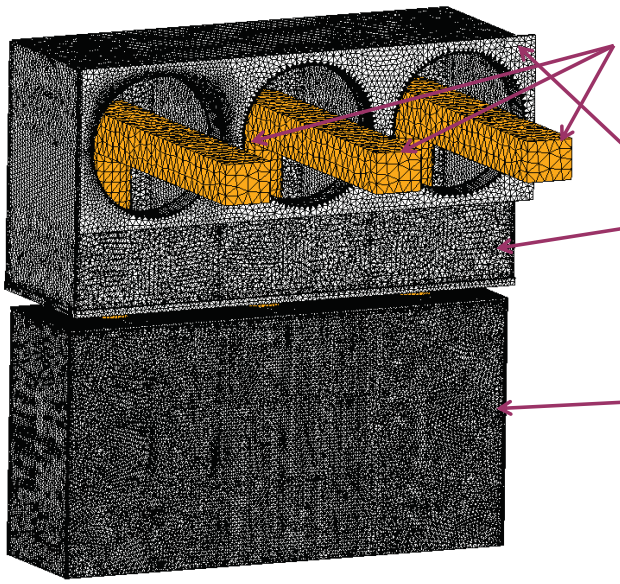
Magnetic Field Analyses Around IPB Connection Boxes

Mesh settings



Part name	Primary busbar
Element size	100 mm
Skin depth	-
Divisions	-

Part name	IPB connection box/ short-circuit plate
Element size	40 mm
Skin depth	1 mm
Divisions	3 divisions

Part name	Low voltage pocket
Element size	SUS304
Skin depth	0.5 mm
Divisions	3 divisions

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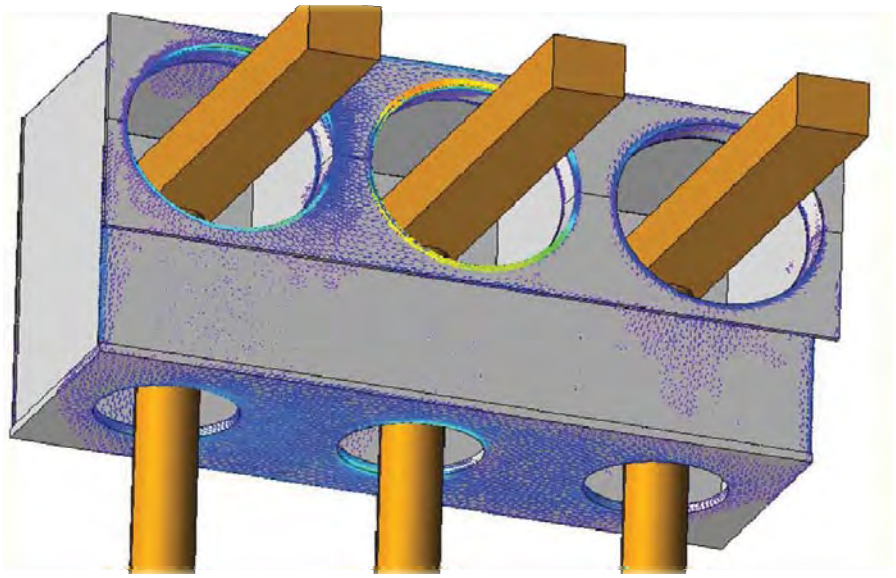
Magnetic Field Analyses Around IPB Connection Boxes

Analysis results (current distribution)



Eddy current vector plot of IPB connection box

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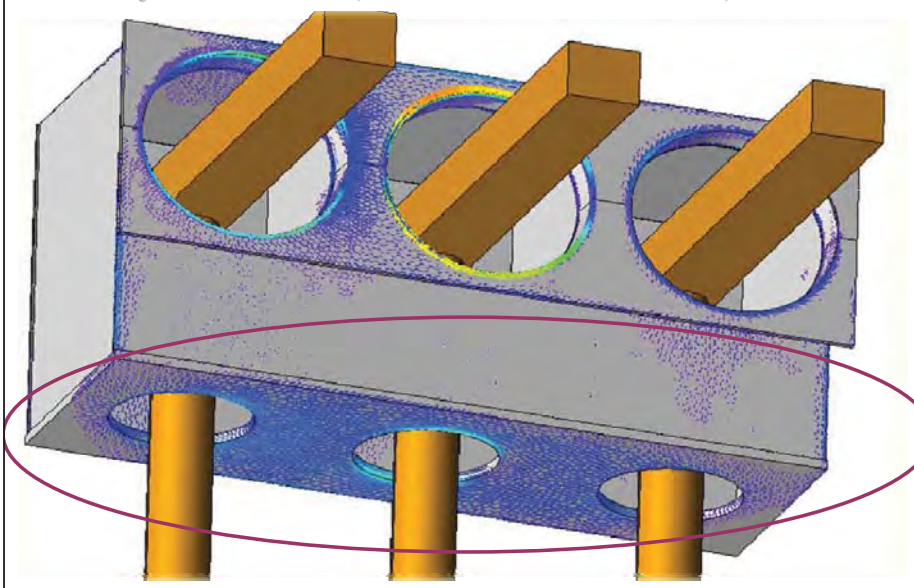
Magnetic Field Analyses Around IPB Connection Boxes

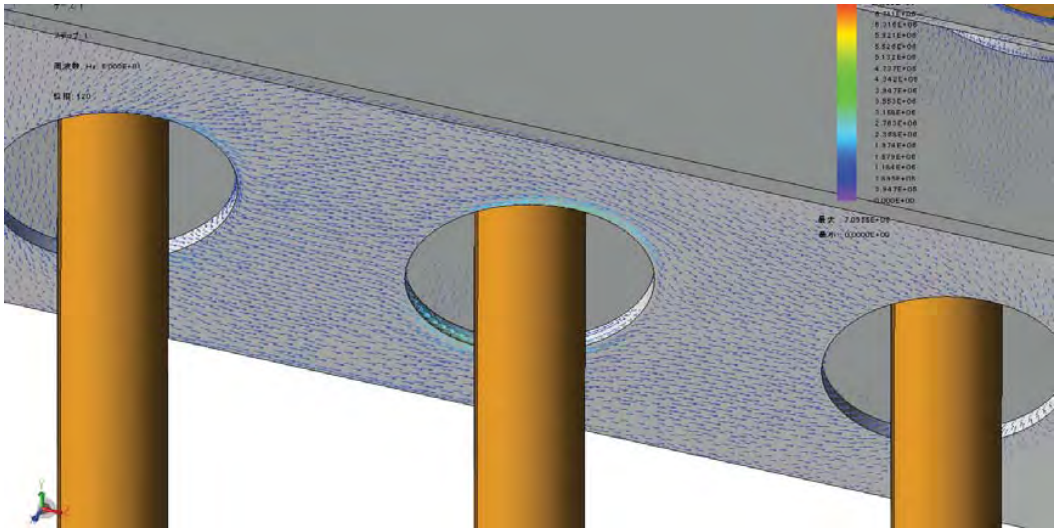
Analysis results (current distribution)



Eddy current vector plot of IPB connection box

Magnetic Field Analyses Around IPB Connection Boxes

Analysis results (current distribution)



The eddy currents produced by each phase causes reflux flow through the lower plate of the IPB connection box

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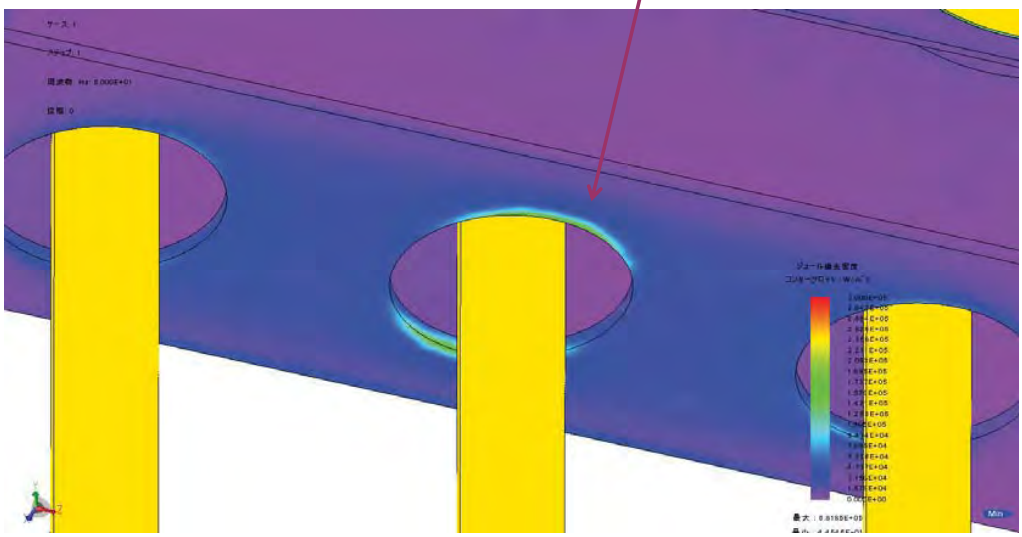
Magnetic Field Analyses Around IPB Connection Boxes

Analysis results (loss distribution)

1.61×10^5 W/m^3



The loss caused by eddy currents is reduced because the lower plate of the IPB connection box is thicker than the other plates

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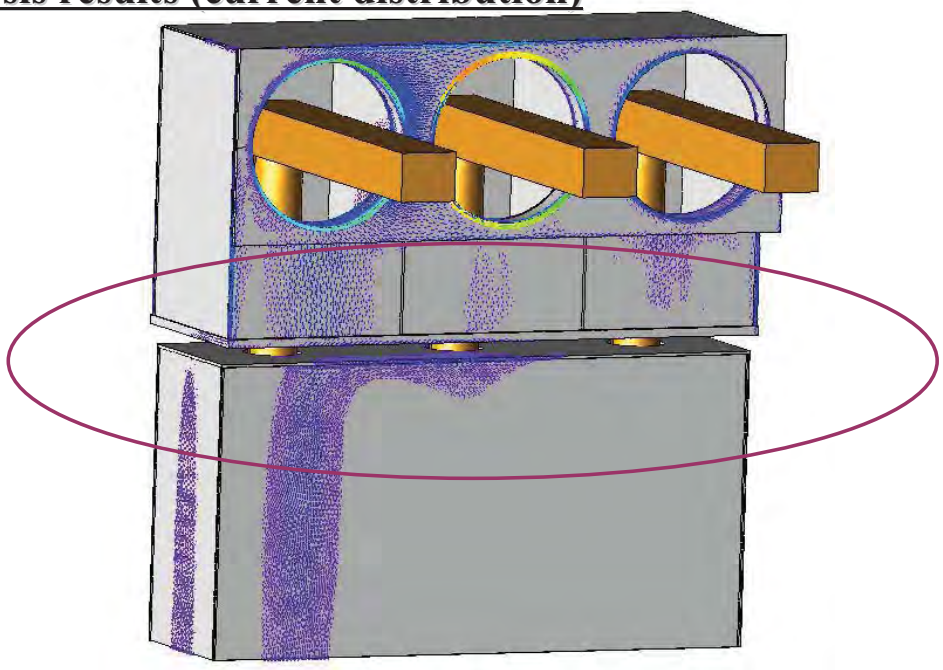
Magnetic Field Analyses Around IPB Connection Boxes

Analysis results (current distribution)



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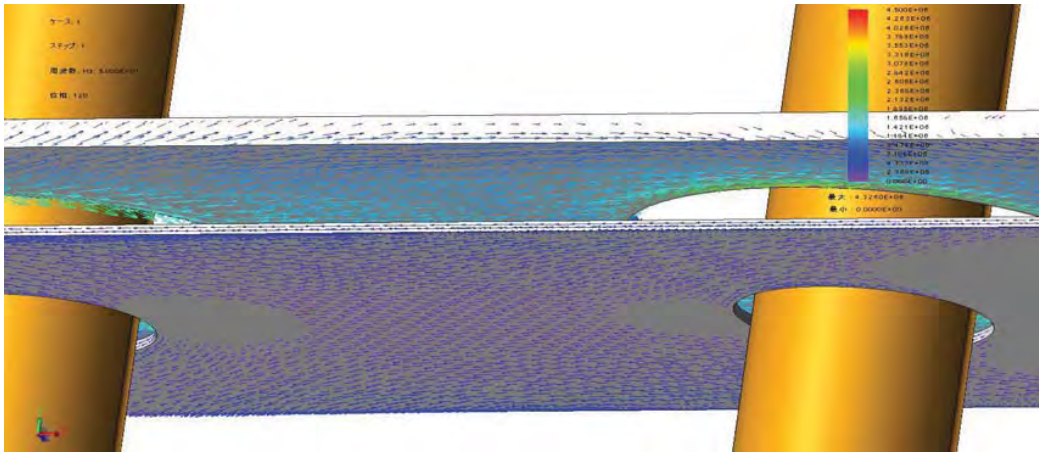
Magnetic Field Analyses Around IPB Connection Boxes

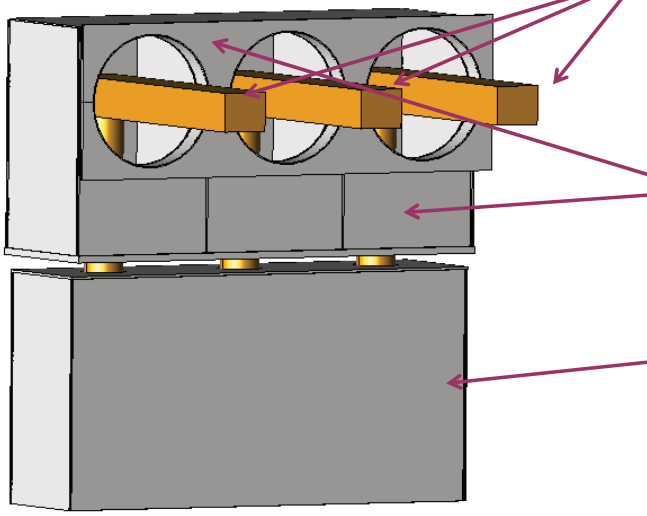
Analysis results (current distribution)



The top of the low voltage pocket is across from the IPB connection box and the eddy currents produced in the low voltage pocket eliminate eddy currents flowing in the IPB connection box.

Coupled Analysis [Temperature]

Material properties



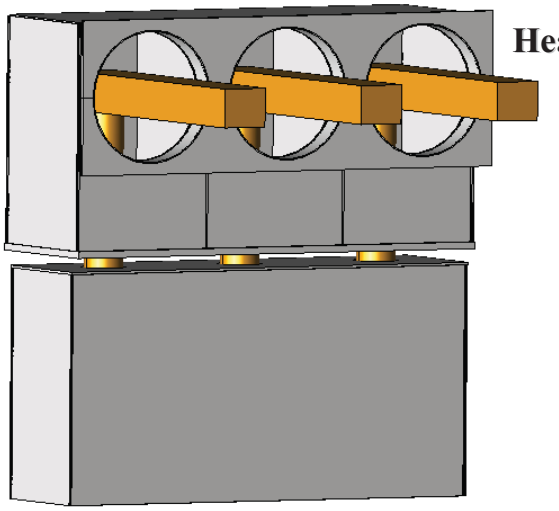
Part name	Primary busbar
Thermal conductivity	395 W/m/deg C
Specific heat	380 J/kg/deg C

Part name	IPB connection box/ short-circuit plate
Thermal conductivity	240 W/m/deg C
Specific heat	877 J/kg/deg C

Part name	Low voltage pocket
Thermal conductivity	16.3 W/m/deg C
Specific heat	120 J/kg/deg C

Coupled Analysis [Temperature]

Boundary condition



Surrounding temperature: 0℃ (air)
: 41 K (oil)
Heat transfer coefficient :10 W/m^2/deg C (air)
:100 W/m^2/deg C (oil)

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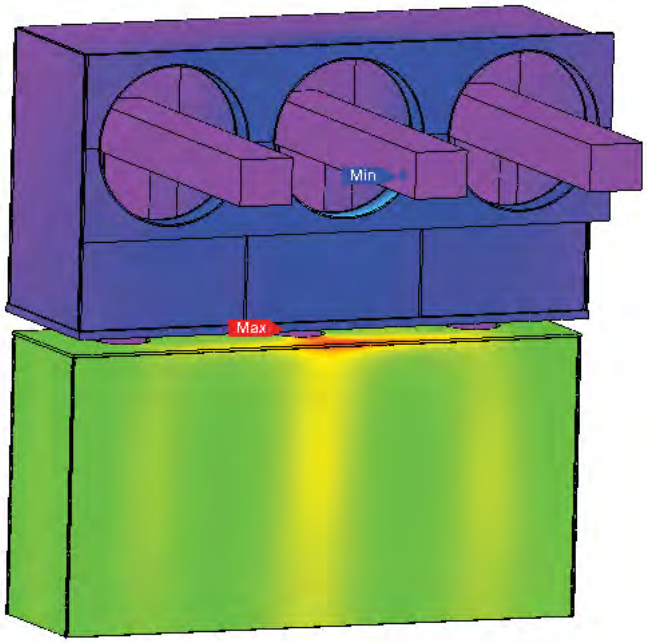
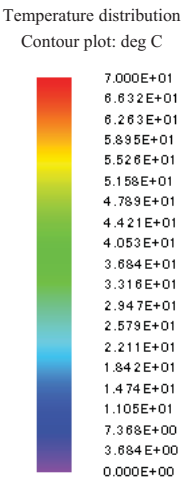
Coupled Analysis [Temperature]

Analysis results





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Considerations

- The loss is concentrated on the center phase in the low voltage pocket
  → The loss is concentrated on the middle phase because it is the pathways the eddy currents flow for the other currents even when the middle phase is 0 degrees Celsius.
- The temperature rises around the IPB connection box
  → The values for the analysis results and actual results as well as distributions are almost the same.

Conclusion

The analysis results obtained in JMAG have been proven to be sufficiently accurate to evaluate the phenomena proposed in this presentation.

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Future Ventures

- Analysis of the central structure of transformers (eddy current analysis)
- Loss analysis of reactors (air/gap cores)
- Improve analysis accuracy by accumulating data

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