Approach of a transformer analysis using JMAG

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Approach of a transformer analysis using JMAG

-Introduction of the latest transformer analysis techniques focusing on a power transformer-

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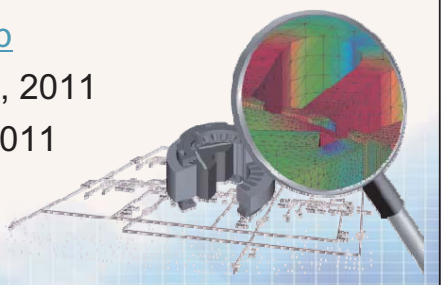

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Today's topics

- Introduction
- Technological challenges and analysis examples in large size transformers
- The latest transformer analysis technique
- Conclusion

Introduction

Introduction

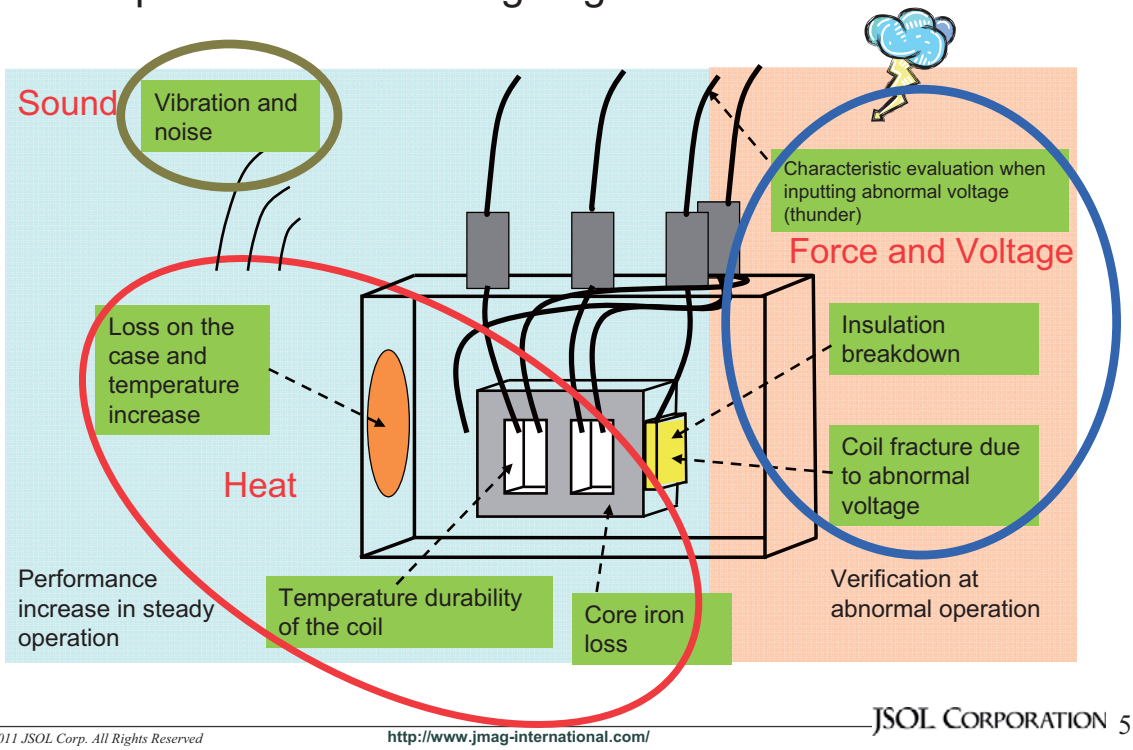
- Electromagnetic field analysis seems not to be fully utilized for middle or large size power transformers due to the particularities of their technological challenges.
- One of the possible particularities is in addition to a basic performance evaluation of the transformer, a durability evaluation of heat and vibrations is required.
- In this session, I will introduce the analysis techniques that can be applied to power transformers and the case of a durability evaluation using JMAG.
- I will also introduce the latest transformer analysis techniques that enables you to perform a highly precise analysis in a short period of time. These techniques can be applied to small size transformers and reactors as well.

- The above mentioned “technological challenges” suggests the difficulties in the product developments. “Analysis techniques” does both the concept (know-how) of analysis modeling and analysis features that is included in the software.

Technological challenges and analysis examples in large size transformers

Technological challenges and analysis examples in large size transformers

- Various problems concerning large size transformers



Technological challenges and analysis examples in large size transformers

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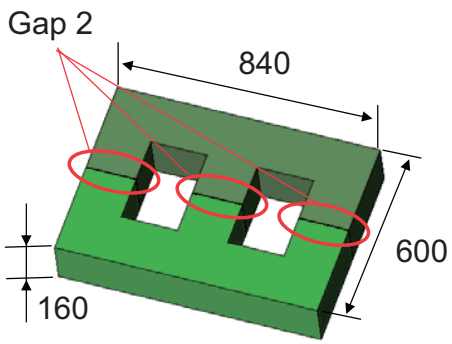
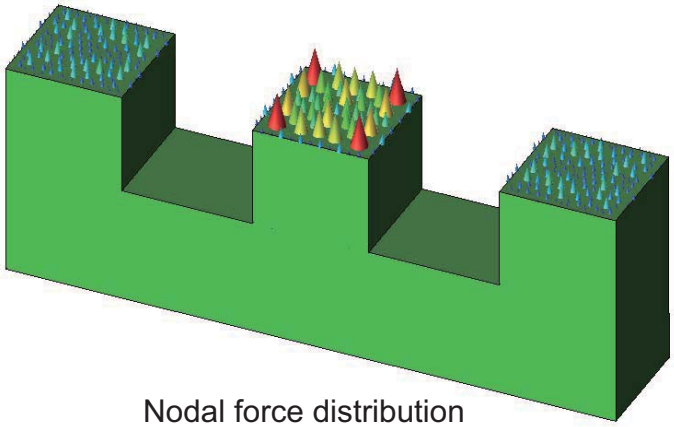
- Consideration of vibrations and noises

Electromagnetic field analysis → Vibration analysis → Sound pressure analysis



Three-phase transformer (EE core)

Unit : mm



Nodal force distribution (360 Hz)

Technological challenges and analysis examples in large size transformers

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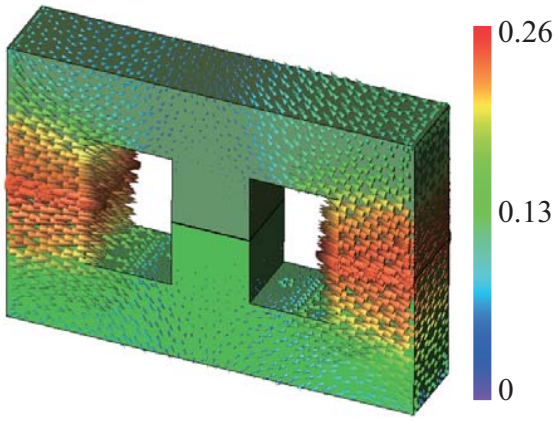
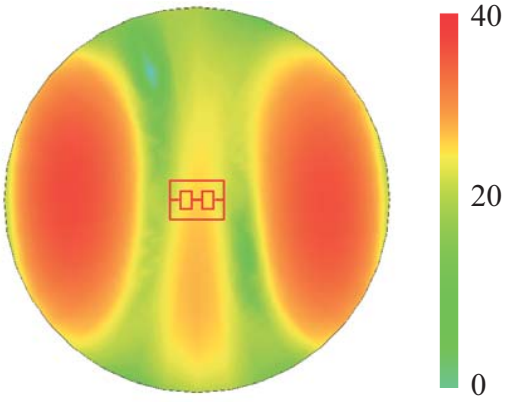
- Consideration of vibrations and noises

Electromagnetic field analysis → Vibration analysis → Sound pressure analysis



Acceleration Distribution (360(Hz))

(Unit: m/s^2)

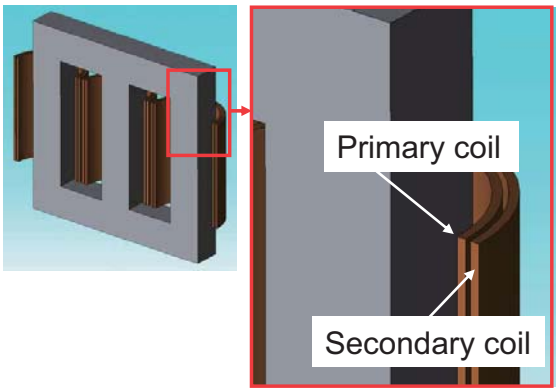


Sound pressure distribution (360(Hz))

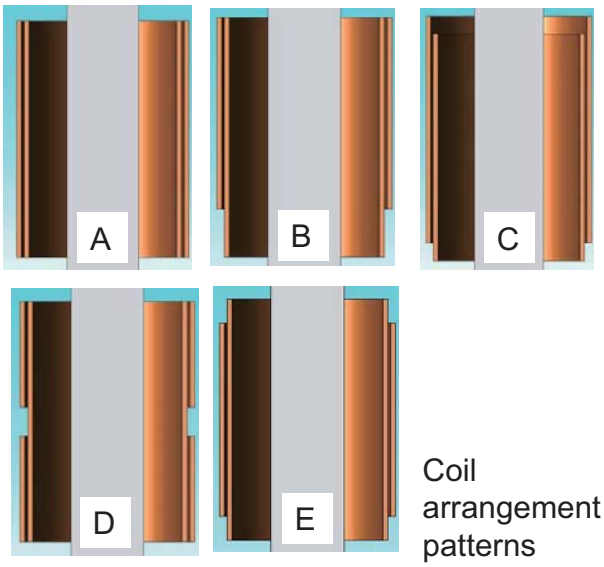
(Unit: dB)

Technological challenges and analysis examples in large size transformers

- Coil fracture evaluation due to the abnormal voltage
  - Change the coil geometry to evaluate the Lorentz force produced in the coil.



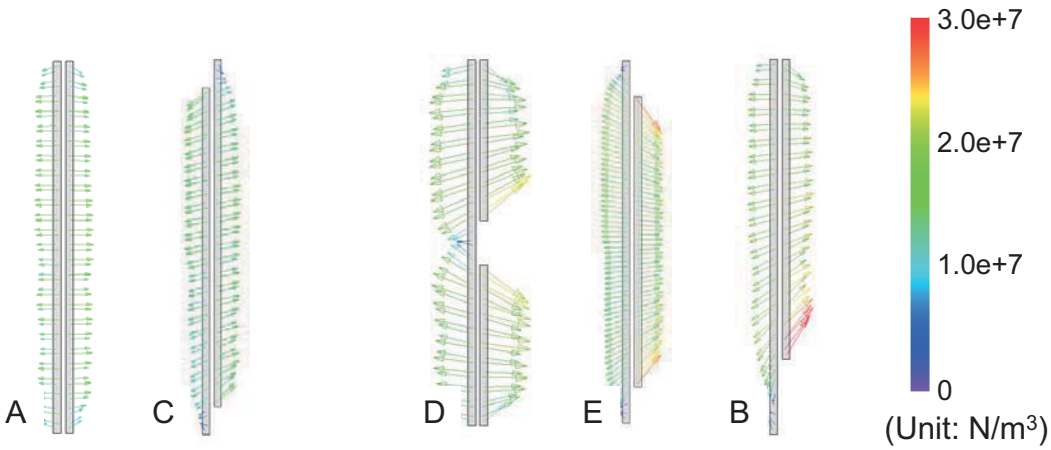
Model diagram



Coil arrangement patterns

Technological challenges and analysis examples in large size transformers

- Evaluation with the uniformity degree of the force acting on the coil



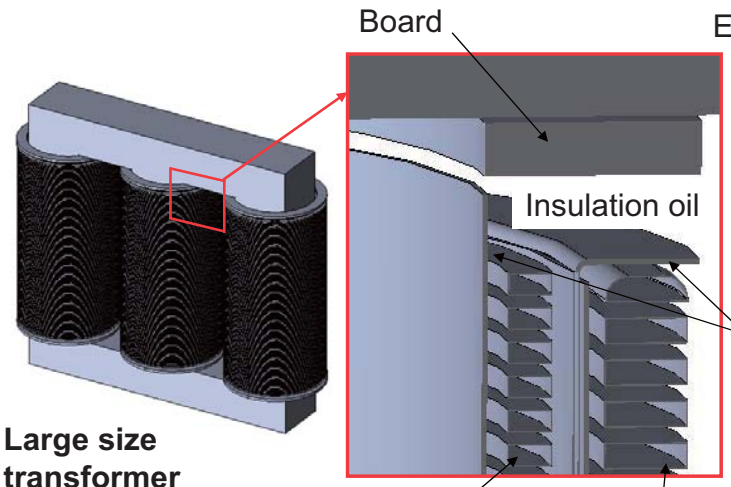
Uniform force distribution

→Different heights of primary and secondary coils result in the large un-uniform force distribution.

Local strong force distribution

Technological challenges and analysis examples in large size transformers

- Evaluation of the insulation breakdown



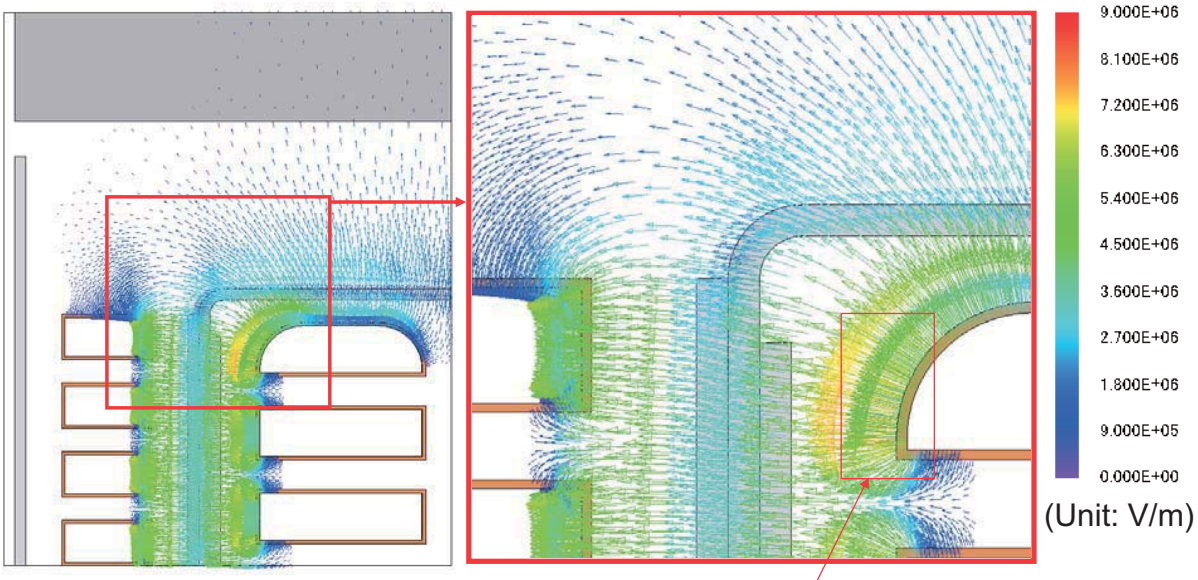
Large size transformer analysis model

Estimated each insulation strength

Parts	Insulation strength (kV/mm)
Coil insulation, pressboard, and board	10
Insulation oil	12

Technological challenges and analysis examples in large size transformers

- Evaluation of the insulation breakdown



Electric field distribution

Max. 9.05(kV/mm) is lower than the estimated insulation strength

Technological challenges and analysis examples in large size transformers

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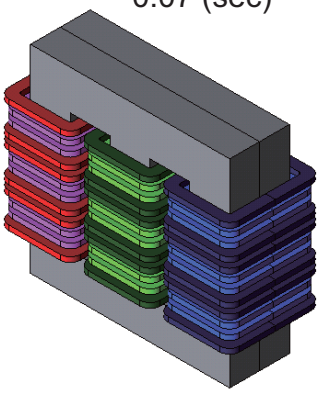
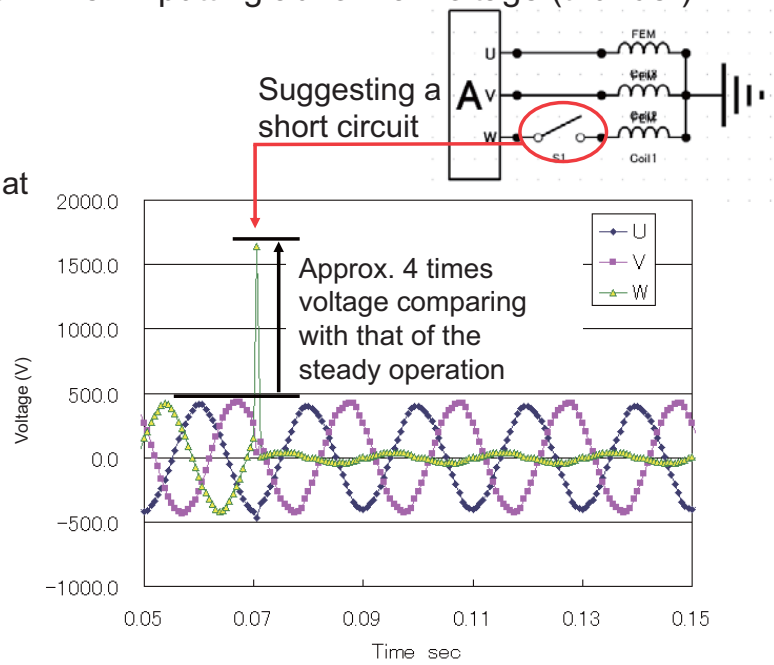
- Characteristic evaluation when inputting abnormal voltage (thunder)

W-phase short circuit occurred at 0.07 (sec)



Three-phase transformer



Voltage when an abnormal incident occurred

Technological challenges and analysis examples in large size transformers

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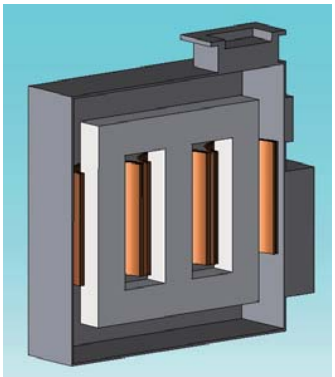
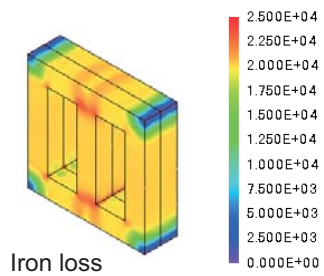
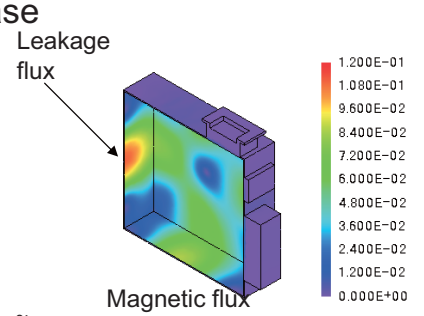
- Loss on the case and temperature increase



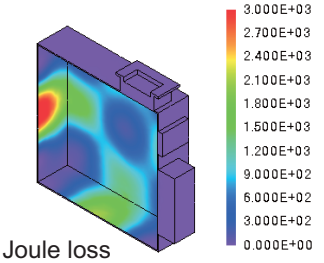
Analysis model



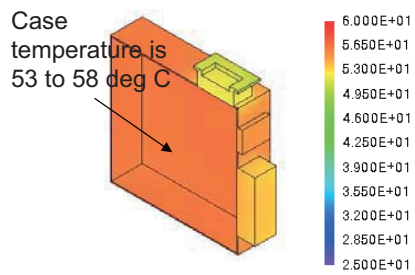
Iron loss Density distribution (Unit: W/m³)



Magnetic flux density distribution (Unit: T)



Joule loss density distribution (Unit: W/m³)



Case temperature (Unit : deg C)

Technological challenges and analysis examples in large size transformers

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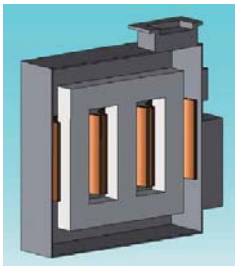
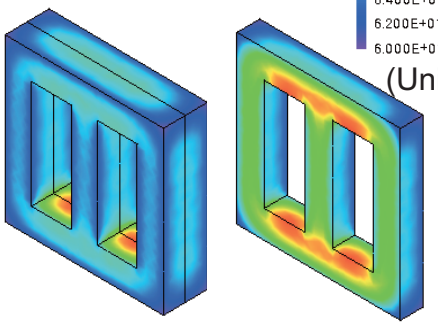
- Temperature durability of the coil

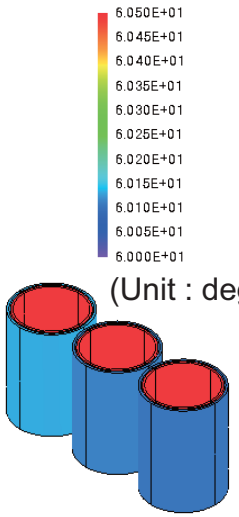


Analysis model



(Unit : deg C)

Temperature distribution of the core



(Unit : deg C)

Temperature distribution of the coil

Technological challenges and analysis examples in large size transformers

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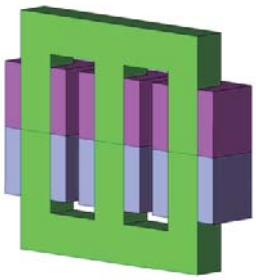
- Core iron loss



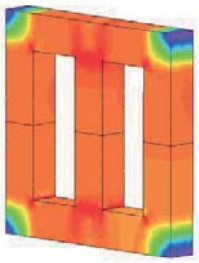
Core material:

JFE Steel 50JN270

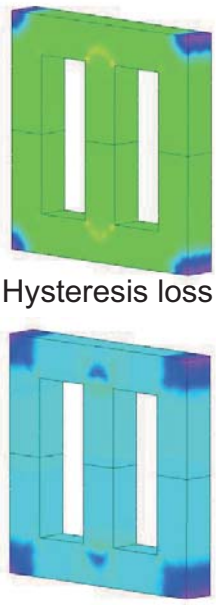
Laminated material (Laminating ratio 98(%))

Power supply :

141.42(V), 60(Hz) Sine wave



Iron loss



Hysteresis loss

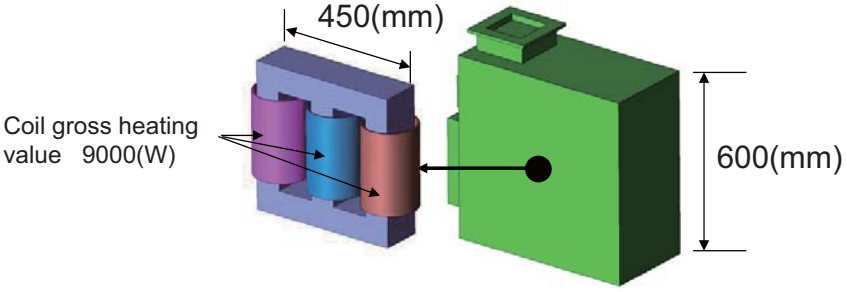
Joule loss

Loss distribution (60(Hz))

(Unit: W/m^3)

Technological challenges and analysis examples in large size transformers

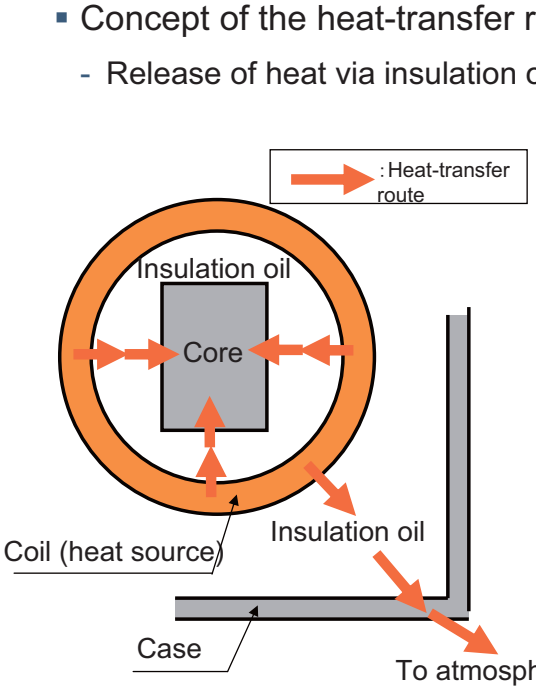
- Loss on the large size transformers and temperature increases due to high current
  - Estimating the temperature increase due to the coil loss using thermal analysis
  - Due to the existence of the insulation oil or the case etc., the heat-transfer route differs from that of the small size one.



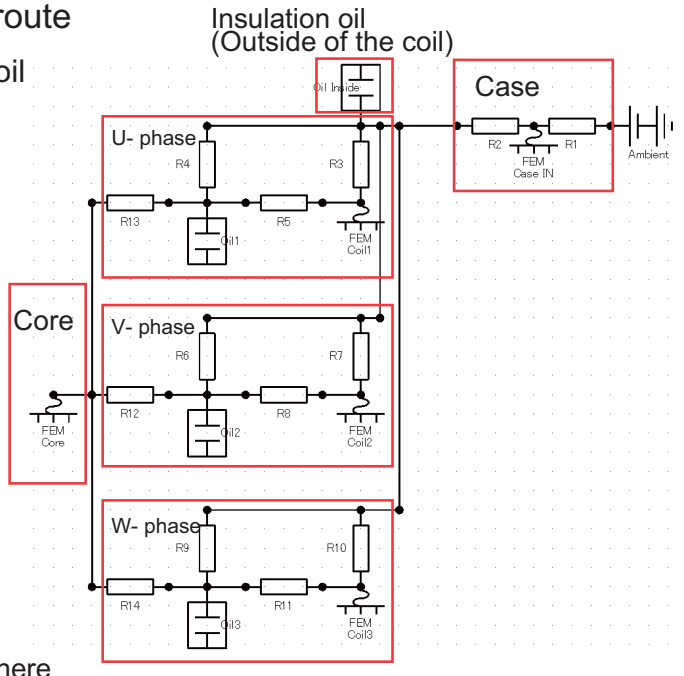
Large size three-phase transformer thermal analysis model

Technological challenges and analysis examples in large size transformers

- Concept of the heat-transfer route
  - Release of heat via insulation oil



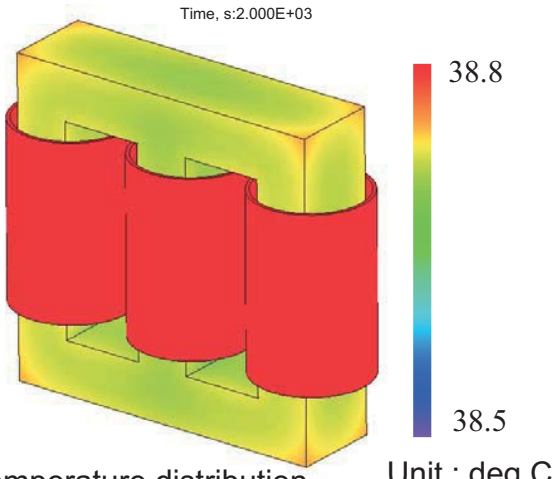
Conceptual diagram of heat-transfer route



Thermal circuit (JMAG-Designer)

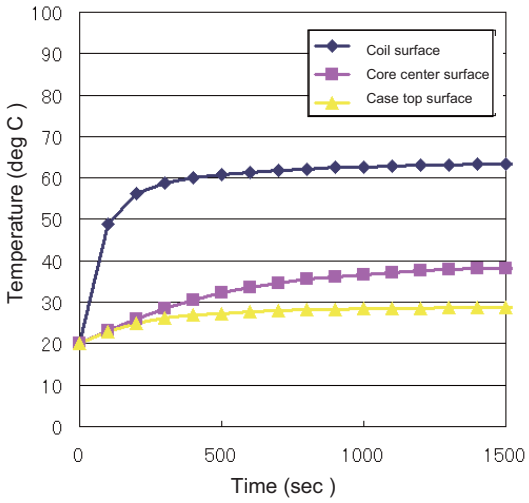
Technological challenges and analysis examples in large size transformers

- Analysis results



Temperature distribution

Unit : deg C



Temperature history

The latest transformer analysis techniques

The latest transformer analysis techniques

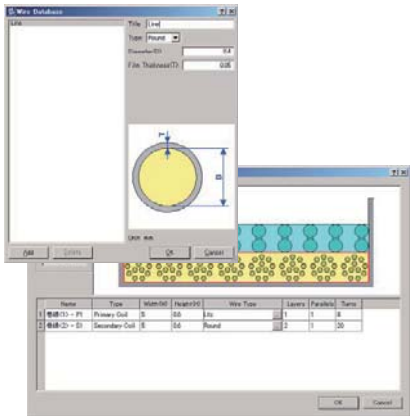
- Taking the current distribution in the wires easily and at high speed into account
- High-speed processing of a large scale simulation. Auto mesh generation for high-precision output
- Shifting the transient state to the steady state in a short period of time
- High-speed calculation of superimposed direct current inductance

The latest transformer analysis technique #1

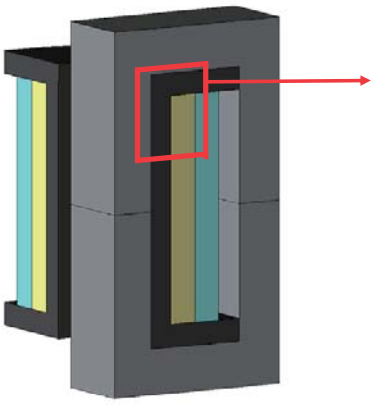
- Existing technological challenges and problematic points:
  - In the case of high-frequency transformers and power transformers, when considering frequencies higher than industrial frequencies, accuracy improvements of losses and AC resistances are required.
  - On another front, it takes long time to model the wires.
  - It takes a long time for analysis because of the large scale of the model.
- The latest analysis technique:
  - Technique to take the current distribution in the wires easily and at high speed into account

The latest transformer analysis technique #1

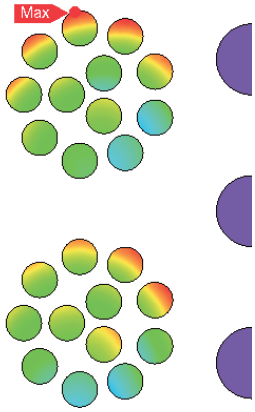
- Simplifying the wire creation (the setting is 3 minutes)
- High-speed cross-section calculation processing (analysis will be finished in a few minutes as well)



Cross-section wire geometry creation



3D solid model (EEcore ¼ model)



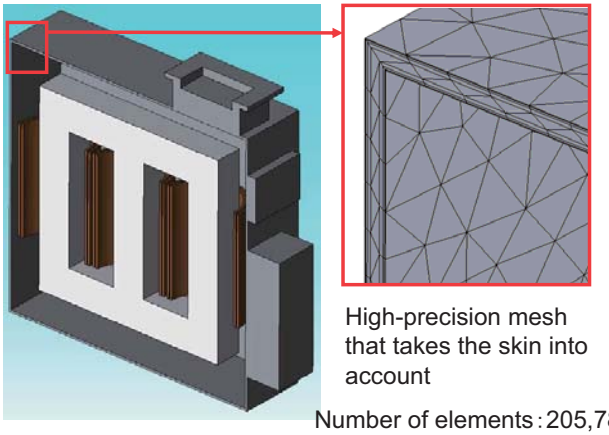
Wire current density distribution

The latest transformer analysis technique #2

- Existing technological challenges and problematic points:
  - An accurate loss calculation is required for the stray loss analysis.
  - In some cases, 3D large-scale model analysis may be vital.
  - Mesh accuracy and analysis time will be concerned in such cases.
- The latest analysis technique:
  - High-precision automatic mesh generation technique that takes the skin effect into account.
  - Speeding up using the SMP parallel operation
  - New solution method (Aφ2 method) suitable to eddy current issues.

The latest transformer analysis technique #2

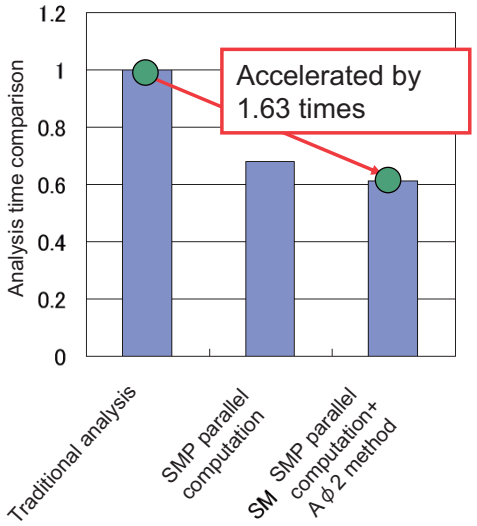
- Analyze the large-scale model with high precision and at high speed.



High-precision mesh that takes the skin into account

Number of elements : 205,780

Number of nodes : 57,339



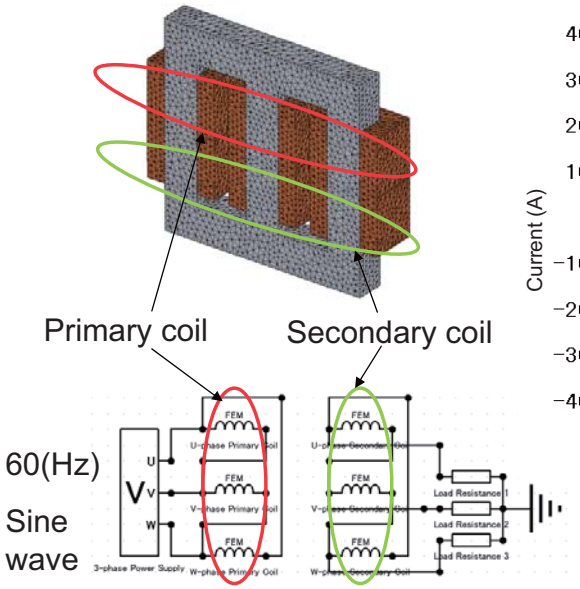
Time comparison with the traditional analysis

The latest transformer analysis technique #3

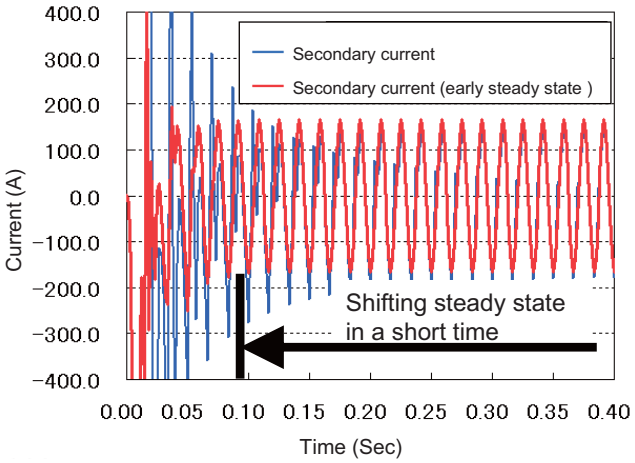
- Existing technological challenges and problematic points:
  - In case of the large size transformer, the inductance becomes larger due to the increased turns, and the time constant increases.
  - When a supply voltage component is used, the transient state lasts longer.
- The latest analysis technique:
  - Technique to shift the transient state to the steady state in a short period of time.

The latest transformer analysis technique #3

- Resolve transient state in a short period of time



Three-phase transformer model



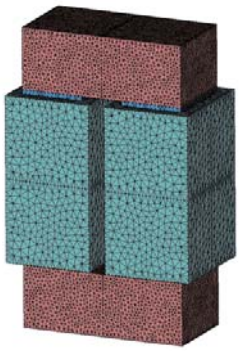
Secondary current waveform

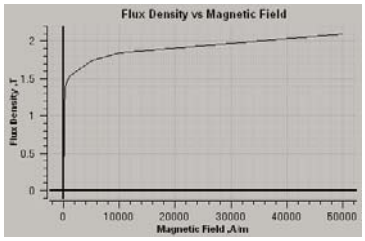
The latest transformer analysis technique #4

- Existing technological challenges and problematic points:
  - Current that includes high-frequency components conducts due to the carrier influence.
  - Inductance calculation close to the operational state, that is to say accounting the superimposed direct current, is required.
- The latest analysis technique:
  - High-speed superimposed direct current inductance calculation

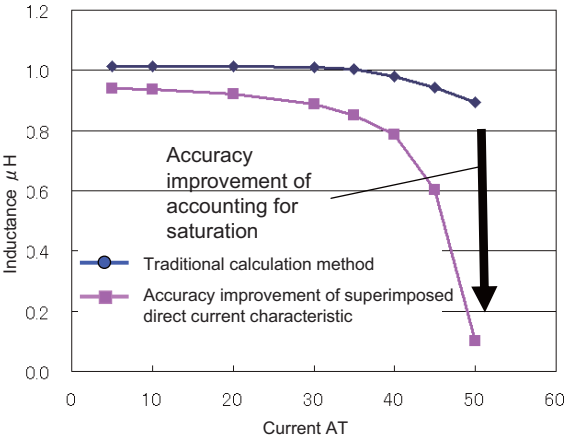
The latest transformer analysis technique #4

- High-speed superimposed direct current inductance calculation
  - High-precision and high-speed calculation method that accounts for magnetic saturation more accurately.





A reactor model and a BH curve (50A470)



Inductance as a function of current.

An analysis using DC magnetizing properties → An analysis using differential permeability

Technological challenges of future transformer analysis

- Accuracy improvement in coupled thermal analysis
  - Accuracy improvement of the magnetic field analysis loss
  - Appropriate thermal analysis modeling
- Accuracy improvement in coupled vibration analysis
  - Appropriate vibration analysis modeling

Conclusion

- There are various technological challenges for power transformers.
- It is possible to extrapolate physical phenomena with a creative modeling and using the JMAG's features.
- I introduced the concept of analysis techniques such as modeling and analysis features especially concerning thermal and sound estimation techniques.
- We will continue to work on the technical development of JMAG for performing highly-accurate transformer analysis in a small amount of time.
- Your indications or frank opinions would be appreciated.

Contact us

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