Introduction for the utilization techniques of JMAG for transformer design

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Abstract :
It is necessary to adopt suitable simulation and its utilization techniques for evaluating transformer design, because argument points are not the same for a large-scale electric power transformer and for a small switching transformer.
In this presentation, some utilization techniques for transformer analysis and the capability of transformer analysis with JMAG will be shown through some analysis examples.
The Transformer study has been renewed since this July and it will be also shown through the demonstration in the latter half of the presentation.

JMAG
Simulation Technology for Electromechanical Design

Introduction for the Utilization Techniques of JMAG for Transformer Design

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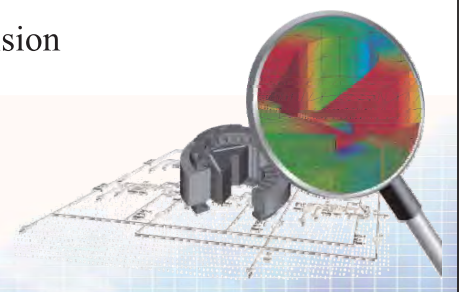

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0. Preface

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- There are many products with various configurations for power transformers from large scale electric power transformers to small frequency transformers. Therefore, the points that need to be addressed when designing transformers differs for each product.
- Selecting the application suitable for the problem and understanding the techniques to use are indispensable to effectively utilize simulations when designing transformers.
- This seminar introduces the techniques used in JMAG for the analysis of transformers through analysis examples by product application in JMAG.
- In addition, this presentation demonstrates the transformer study which has been enhanced as of the end of July.

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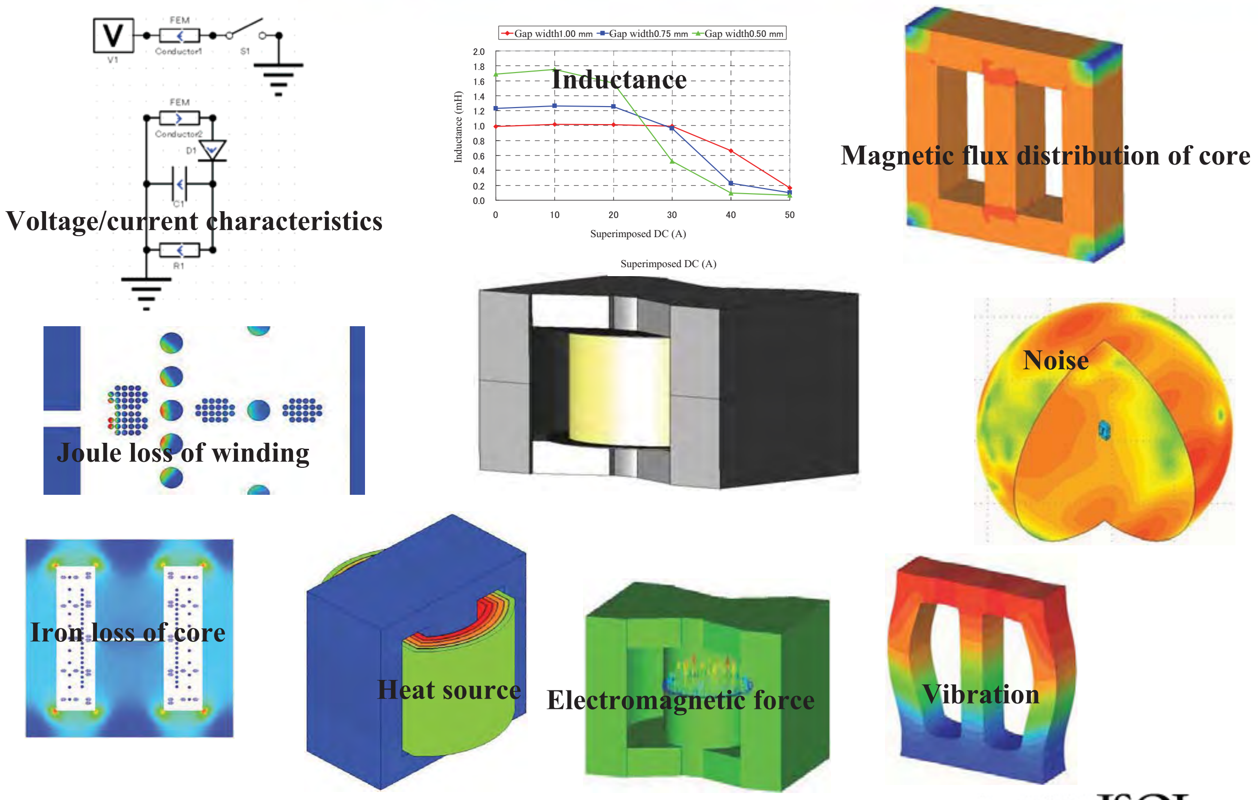
1. Evaluating Transformers/Reactors



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2. Points of Simulation

■2-1. Large and Mid Size Transformers/Reactors for Electric Power

■Problems and Points of Evaluation

- Problems related to the transient phenomena when power is supplied

→Transient response analyses, evaluation of input currents, Lorentz force analysis of coils during inrush currents are required

- Problems related to heat generated by core and copper losses.

→Iron loss analysis and thermal analyses are necessary to evaluate rising temperatures of cores

- Problems related to stray loss produced in cases, etc.

→Modeling including case and eddy current analyses to evaluate stray loss and thermal analyses are required

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2. Points of Simulation

2-2. Transformers/Reactors for Small Scale Power Supplies

Problems and Points of Evaluation

- Increased AC resistance caused by the frequency that is used

→ Modeling individual wires is indispensable to account for the skin effect and proximity effect in and between wires.

- Transient phenomena is necessary to handle switching

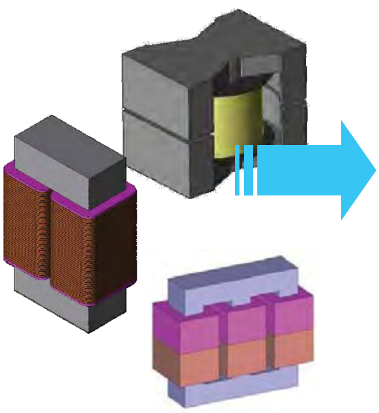
→Transient response analyses are required

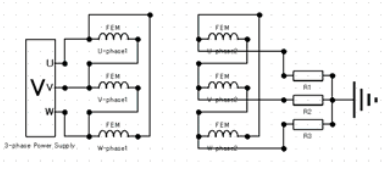
- The heat generation density is large even though the heat generation is small because the physical size is small.

→ Iron loss analyses and thermal analysis to evaluate rising temperatures of cores are necessary

3. Characteristic Analysis Flow of Transformers/Reactors

Input
- Current rating
- Power supply frequency
- Input voltage or current (amplitude)
- Environmental temperature





Magnetic field analysis based on input power supply (amplitude/frequency) (Frequency response analysis)

↓

Magnetic flux density of magnetic field analyses to iron loss analyses

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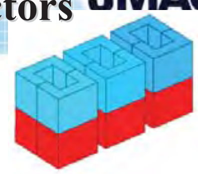
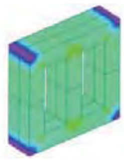
Copper loss from the magnetic field analysis and iron loss from the iron loss analysis to the thermal analysis (steady state analysis)

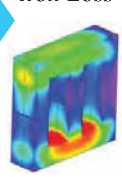
Calculate inductance at each point by generating current point sequences from rated current values



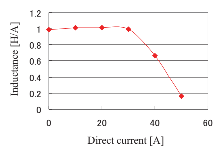
Copper Loss



Iron Loss



Temperature



Inductance table
Equivalent circuit models

4. Evaluating Transient Phenomena of Large Scale Transformers

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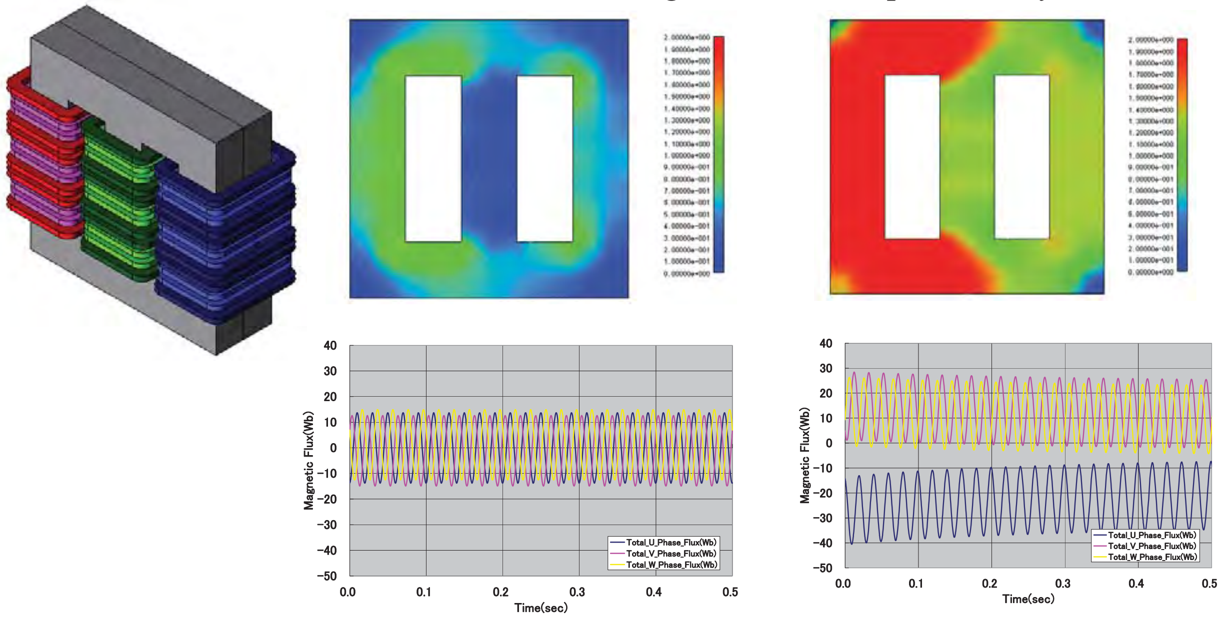
- The inductance is reduced and an inrush current occurs when power is supplied because of the magnetic saturation in large scale transformers. The dynamic characteristics of currents are confirmed using a transient response analysis.



Magnetic flux density distribution (top left) and magnetic flux (bottom left) of each coil during normal operation
Magnetic flux density (top right) and magnetic flux (bottom right) of coil when an inrush current is produced

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4. Evaluating Transient Phenomena of Large Scale Transformers

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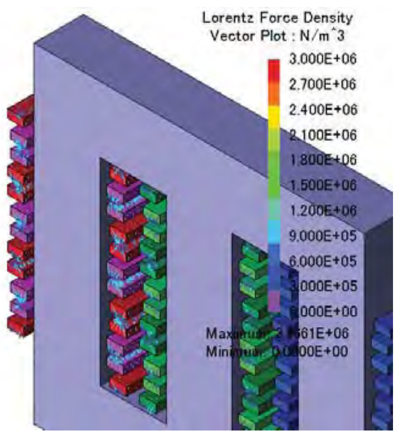
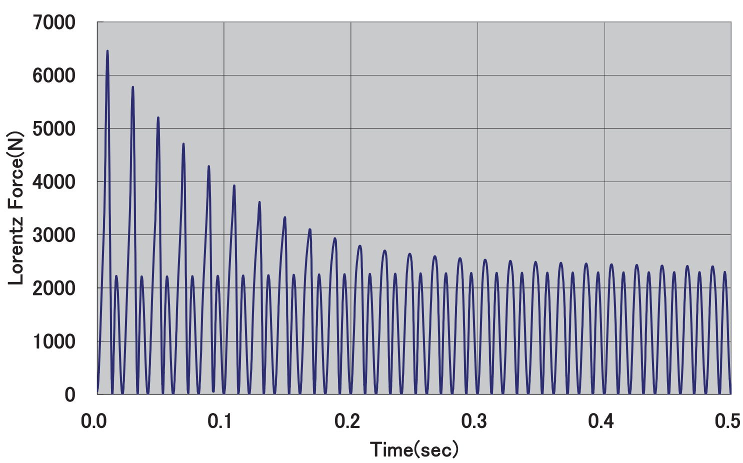
- The inrush current when power is supplied produces transient Lorentz force in the coil.



Lorentz force distribution in coil wire



Electromagnetic force produced in the coil winding when an inrush current occurs (N)

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5. Evaluating Loss of a Large Scale Transformer

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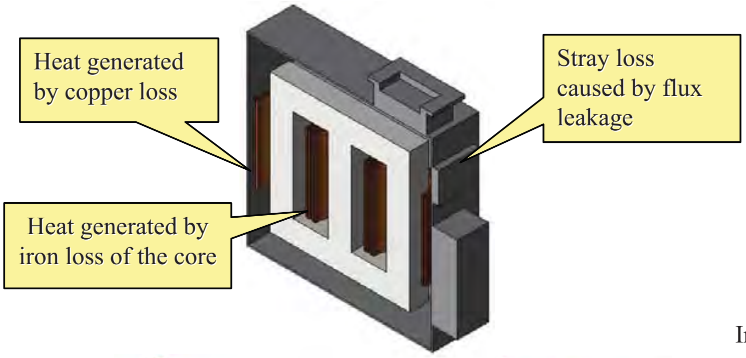
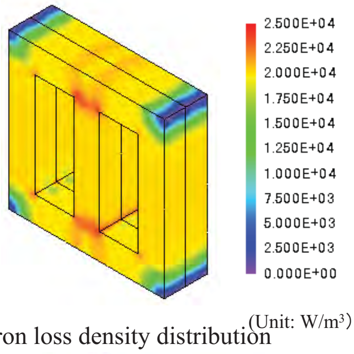
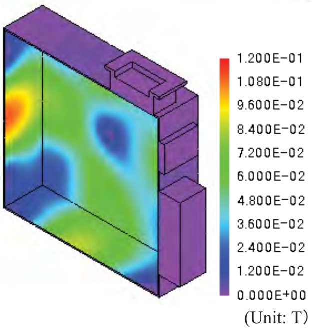
- The absolute value of loss is large even though the ratio of loss contributing to the electromagnetic force is small because of the physical size of large scale transformers.

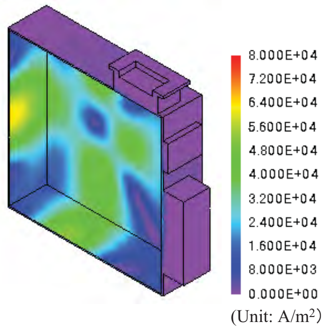




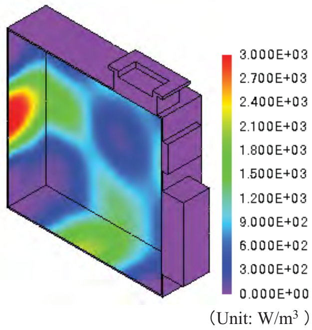
Iron loss density distribution



Magnetic Flux Density Distribution



Current density distribution



Joule Loss Density Distribution

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6. Evaluating Rising Temperatures of Large Scale Transformers

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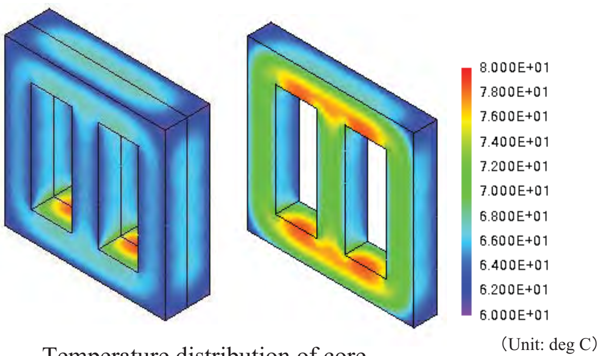
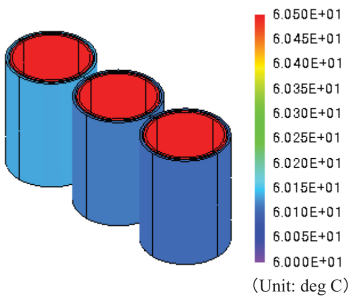
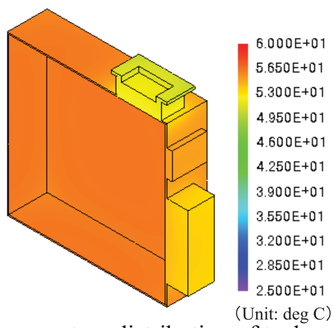
- The rising temperatures in the core are related to the deterioration of the magnetization properties. Evaluating the temperature for the winding insulation is vital to safe designs.



Temperature distribution of core



Temperature distribution winding



Temperature distribution of tank

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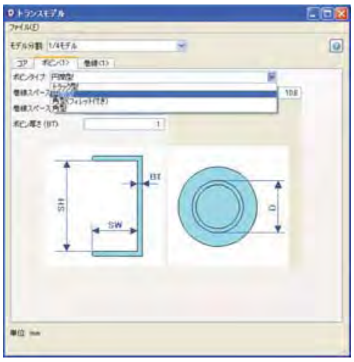
7. Analysis of a Frequency Transformer Using the Transformer Study

- Transformer Study (TS) is:
  - A magnetic field analysis tool specialized for analyzing transformers.
  - Geometry can be defined simply by selecting a template and specifying settings in the transformer modeling tool.
  - The effects of the loss distribution caused by the skin effect of wires, the proximity effects between wires, AC resistance, winding arrangement, and flux leakage can be evaluated.

Selecting the core

Multiple core geometries are built-in, such as the core template provided by TDK



Selecting the bobbin

The bobbin with the appropriate core geometry, such as a track type bobbin, can be selected.

Determining the coil arragement

The winding region and insulation region can be specified

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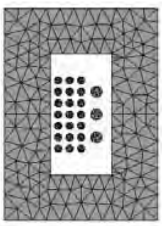
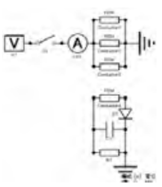
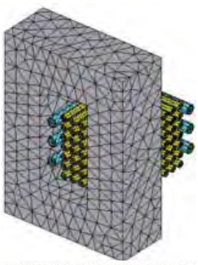
7. Analysis of a Frequency Transformer Using the Transformer Study

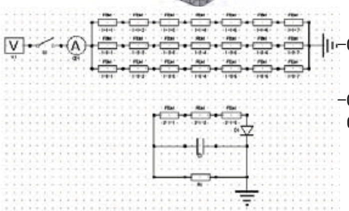
- Modeling each wire of the winding is very simple
- The time required for analysis is much faster when compared to a 3D transient response analysis (TR)
- The accuracy is almost the same as a detailed model using TR if the winding axis geometry of the coil is stack geometry (EE, EI, etc.) or cylindrical geometry (PQ core, etc.).



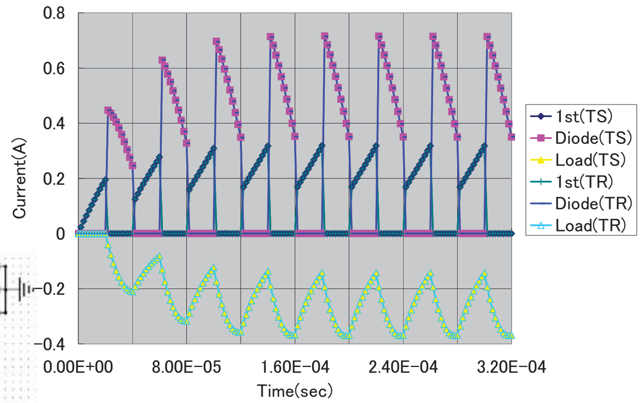


Analysis model used for TS





Analysis model used for TR for comparison



Comparing the Analysis results of the models on the left

Compare the current values for the primary current, secondary diode, and load resistance.

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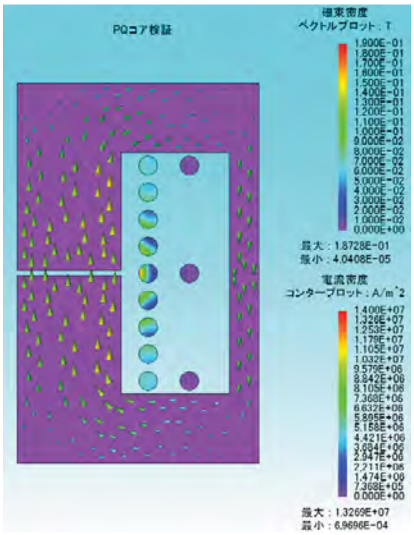
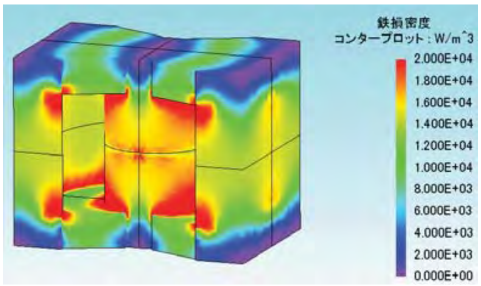
8. Loss and Rising Temperature Analysis of a High-frequency Transformer

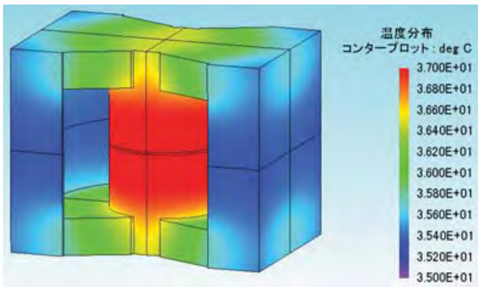
- An analysis can be expanded to a thermal analysis by utilizing analysis results and geometry templates from the transformer study. The rising temperature of the core caused by loss is evaluated.



Magnetic flux density distribution of the PQ core cross-section (vector) and the current density distribution (contour)



Iron loss density distribution of PQ core



Temperature distribution of PQ core

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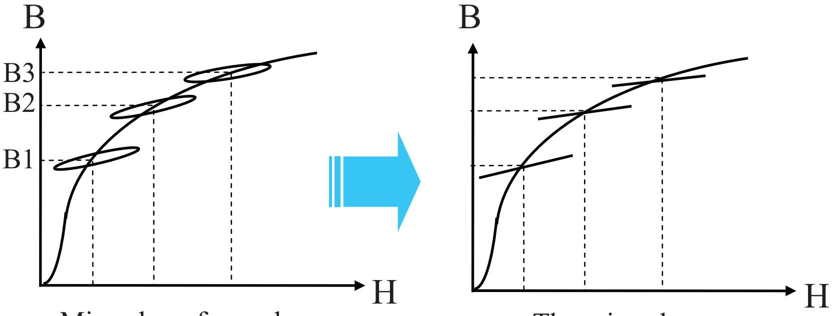
9. Expanding New Analysis Technology

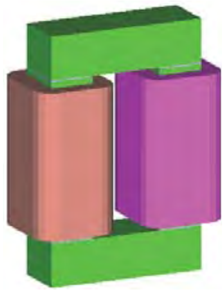
- New technology to evaluate dynamic inductance highly accurately
  - The direct superimposed characteristics of the transformer has inductance smaller than the values estimated from the direct magnetization characteristics in the saturation region because of the effects of magnetic hysteresis.
  - The inductance in the saturation region is obtained highly accurately by accounting for the artificial hysteresis characteristics of the DC magnetization characteristics. (From JMAG-Designer 10.4)



Minor loop for each operating point

The minor loops are generally a line

The loss cannot be expressed, but the dynamic characteristics such as current are vastly improved.



	Inductance
Conventional method	0.547mH
New method	0.282mH

Reactor model for analysis (provided by Tabuchi Electric Co., Ltd.) and comparison of the inductance calculation

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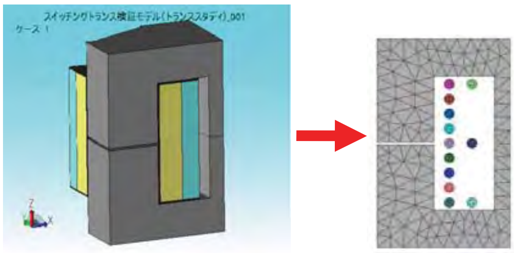
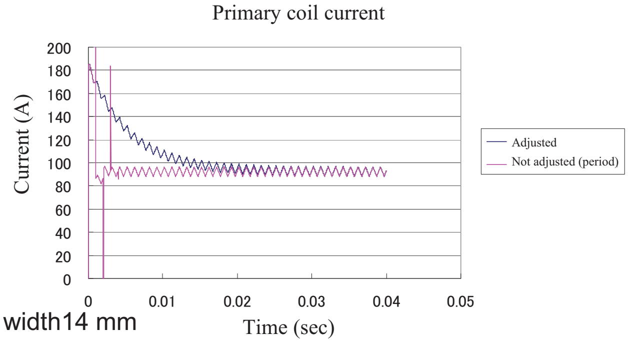
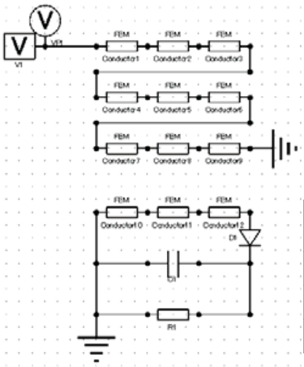
9. Expanding New Analysis Technology

- Examining steady state acceleration methods for transient analysis (TPEEC)

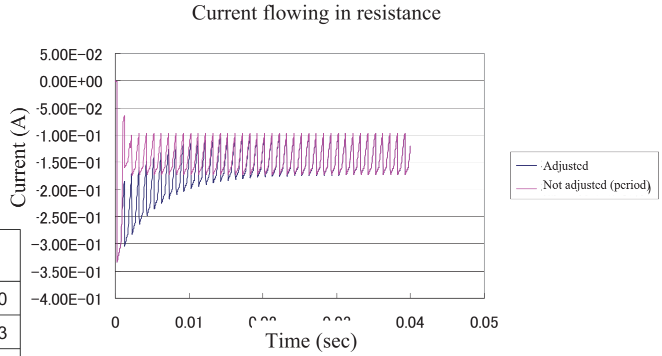




Model dimensions Height 16.2 mm、length 20.5 mm、width14 mm



Pulse table (maximum 1 V)	
FrequencyHz	1000
Capacitor F	1.00E-03
Resistanceohm	1.00E+00



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