One transformer inrush current calculation method based on field-circuit-network coupled co-simulation

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Abstract. In this paper, one calculation method based on field-circuit-network coupled co-simulation is presented. Compared with the traditional simplified transformer model, this transformer model takes the nonlinear factors into account, and the accuracy of the simulation results will be improved. The transformer is build with the finite element method by using the software of Maxwell, and circuit of transformer is build by using the software of Simplorer, and the network model is build under Matlab/Simulation's environment. At last, this field-circuit-network coupled model is used to calculate the inrush current of transformer.

Introduction

The power transformer is one kind of basic and important equipment in power system, and its running state directly affects the reliability of the power supply. So, it is very necessary to work on the modeling method of power transformer.

The practical power transformer model is widely used in power system simulation. This modeling method of physical meaning is clear, and is easy to implement the requirements of power system dynamic analysis and calculation. However, this model is obtained by simplified processing, and many nonlinear factors are not taken into account [1-2]. So this model can not accurately reflect many nonlinear factors, it will affect the accuracy of the simulation results, and it even causes serious errors of the analysis. So, it has the significance to study the transformer model with nonlinear factors [3-4]. In this paper, the field-circuit-network coupled modeling method is presented. The transformer is build with the finite element method by using the software of Maxwell. In this field transformer model, the nonlinear factors such as the nonlinear hysteresis curve is considered, and circuit of transformer is build by using the software of Simplorer, and the network model is build under Matlab/Simulation's environment.

The construction of Transformer field-circuit-network coupled model

Time step finite element model of the transformer

The two-dimensional finite element model of single-phase transformer is shown in Figure 1, in which the establishment of the "field model" is completed. The modeling parameters of single-phase transformer are shown in table 1.

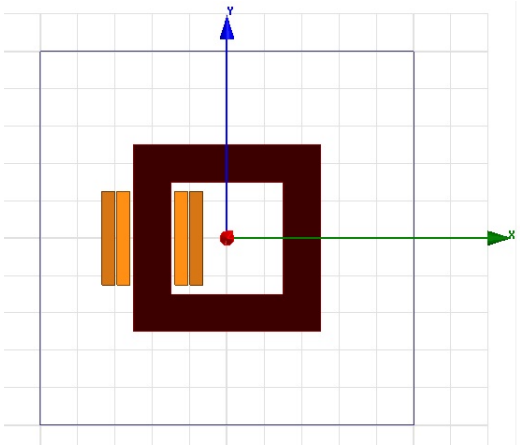


Fig.1 The 2D finite element model of transformer

Table 1. Model parameters of transformer

Parameter	Value	Parameter	Value
Voltage class	35kV	Rated capacity	1000 kVA
Transformation ratio	3.33	Height of coil	500 mm
Inside length of iron core	1000 mm	Length of coil	70 mm
Outside length of iron core	600mm	Size of solve field	2000 mm

The establishment of the transformer excitation model

For the preliminary model, the single-phase transformer excitation source is established in Matlab/Simulink, and only a voltage source is added. So, the establishment of the "network" is completed. The model is shown in figure 2.

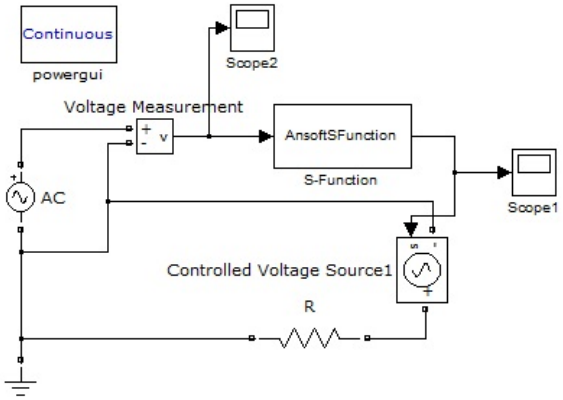
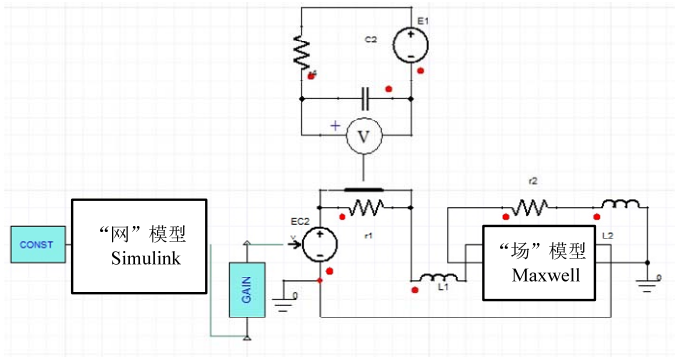


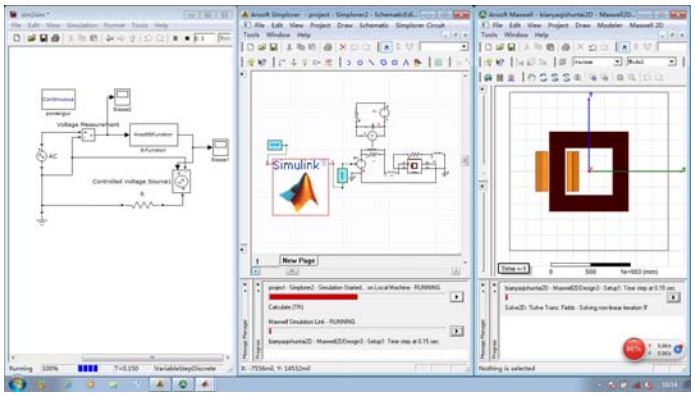
Fig.2 The excitation model of transformer

The connection between the coupled models

After the completion of the above "field" and "network" models, it needs to establish the connection relationship between the two models, which requires the establishment of the "circuit". The circuit model is finished by Ansoft/Simplorer software, and the established "circuit" model is shown in figure 3.



(a) Circuit connection between field model and network model



(b) The operation interface of co-simulation

Fig.3 The field-circuit-network coupled model of transformer

Simulation result of the transformer field-circuit-network coupled stepping finite element model

The simulation result of transformer inrush current

The high voltage side of transformer is added with load voltage, and it can cause excitation inrush current. The simulation result of coupling model is shown in figure 4.

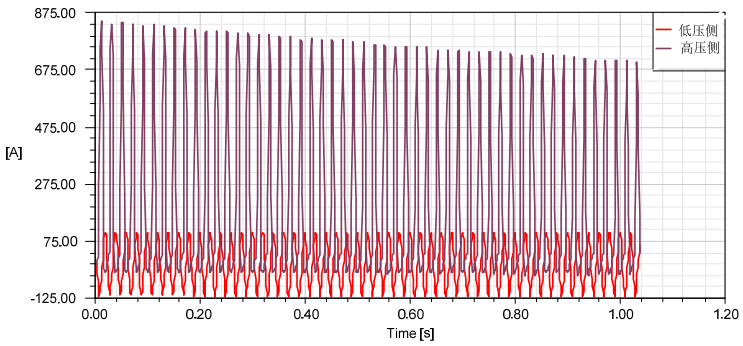


Fig.4 The simulation results of transform's inrush current by two different models

Transformer inrush current Suppression

In order to eliminate this part of the energy as soon as possible and make high-voltage side current settle down as soon as possible, one 100 ohm resistance is connected to the high side circuit, and it will be removed in 0.2 seconds. The current waveform is shown in figure 5. It can be found that, the inrush current is suppressed obviously.

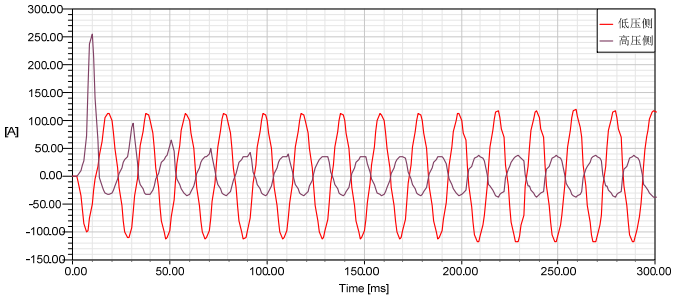


Fig.5 The current of transformer when closing resistor is connected in short-time

The induced voltage waveform is presented in Figure 6, and the flux in transformer's iron core is presented in Figure 7.

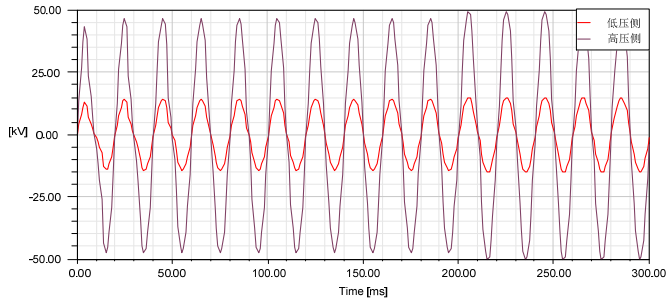


Fig.6 The induced voltage of transformer

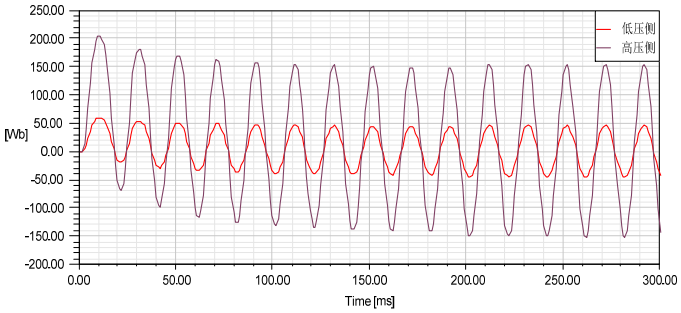


Fig.7 The flux-linkage of transformer

At this time, after the transformer is stable, the magnetic distribution in the iron core is shown in figure 8. Obviously, the maximum flux density in core don't passed knee point of B-H curve (about 1.6 T), which means that the transformer operates in unsaturated state.

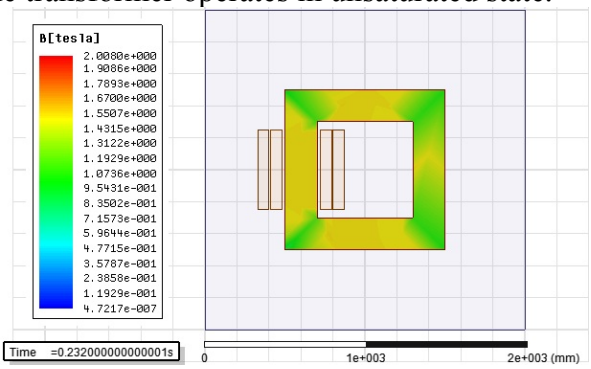


Fig.8 The flux density in the iron core of transformer

Conclusion

This paper introduced one field-circuit-network coupled model of transformer. The transformer is build with the finite element method by using the software of Maxwell. In this field transformer model, the nonlinear factors such as the nonlinear hysteresis curve is considered, and circuit of transformer is build by using the software of Simplorer, and the network model is build under Matlab/Simulation's environment.

The transformer field-circuit-network coupled time step model can give play to the advantages of different software, and it provides a very meaningful tool for the transformer simulation analysis.

References

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