Reactor Characteristic Evaluation and Analysis Technologies of JFE Steel†

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Abstract:

Reactor characteristic evaluation and analysis technique was constructed by JFE Steel including the design optimization simulation for the purpose of performance improvement of high frequency reactor. Based on the simulation, reactors which satisfy a given specifcation were designed with different core materials and core size. The validity of the simulation result was proved by physically fabricating these reactors and estimating the performance under the actual use conditions. Moreover reactor noise visualization was achieved by using a sound energy fux density system. It is possible to promote a solution suggestion of reactor to a customer by utilizing these tools.

1. Introduction

In power electronics circuits, high frequency reactors are one key component which plays the roles of voltage transformer and filter by accumulation/discharge of magnetic energy. As a typical example of reactor applications, **Fig. 1** shows the circuit of a power conditioner for solar power and the reactor current waveform. Reactors are used under direct current or alternating current on which a high frequency ripple is superimposed[1)]. In order to reduce the size of reactors, a ferromagnetic core material is usually inserted in the coil. In this type of reactor, it is necessary to pay special attention to the point that magnetic saturation exists in the core material and the point that heat generation increases remarkably due to eddy currents in the core at higher frequencies. Coil heat generation also has a large influence on the design of reactors. In order to obtain an appropriate reactor, not only evaluation of the magnetic properties of the core material, simulation techniques for predicting the reactor characteristics reflecting the desired conditions, and technology for performing characteristic evaluation and analysis by actual excitation waveform is also essential. This paper explains the outline of reactor simulation and the reactor evaluation equipment of JFE Steel, then, introduces the comparative evaluation examples of loss and noise between the same specification reactors which are fabricated with different core materials respectively.

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Eq. (5), which considers fringing effect of the magnetic flux, and the magnetic data for the core material (either μ_r-I or μ_r-B characteristics)[2].

2.2 Reactor Design Support

In reactor design, estimation of copper loss and core loss, which are causes of heat generation, is also important. Although various methods for calculating these types of loss have been studied[3], a simple rough calculation of loss is possible from the reactor rated current I_m, ripple amplitude $\Delta I_{p\text{-}p}$, direct current superimposition characteristics and iron loss characteristics of the core material. The core material, dimensions and gap length are selected so that the heat generation of the core does not exceed the allowable temperature. Similarly for the coil, the wire diameter and number of turns are adjusted considering heat generation. As shown in Eq. (5), the core sectional area and the number of turns of the coil also have a large influence on the inductance of a reactor. Moreover, even with the same number of turns, copper loss will differ depending on the coil geometry and winding method. The cooling conditions in the actual use environment, also is an important factor for the reactor design.

As described above, magnetic design, coil design and heat design are closely related. Therefore, mutually optimizing these factors so as to obtain the desired electrical specification under the given conditions can be considered the essence of a reactor design (**Fig. 4**).

The merits of reactor simulation include the fact that it is possible to respond flexibly, without limitations associated with evaluation equipment, for example, in predicting the characteristics of reactors which are to be used in the large current region of several hundred amperes and various control methods under excitation conditions corresponding to the power source. Moreover, simulations also make it possible to propose the most suitable use method quickly and flexibly, before manufacturing the reactor, to customers who have few opportunities to deal with electrical steel sheet.

Fig. 4 Important point with a reactor design

3. Reactor Evaluation Equipment and Examples of Its Application

3.1 Reactor Evaluation Equipment

JFE Steel has introduced reactor evaluation equipment which enables magnetic excitation of reactor test materials with the specified excitation current waveform by connecting the test material and adjusting the effective value of the commercial alternating current and the frequency and amplitude of ripple, respectively, and uses this system to perform evaluation tests under a variety of conditions. The basic configuration of the reactor evaluation equipment is shown in **Fig. 5**. In general evaluations, ripple corresponding to the carrier frequency is superimposed on an alternating current corresponding to the rated current of the reactor, the amplitude of the ripple is adjusted while checking the waveform monitor, and the reactor loss at the specified excitation current waveform is measured with the power meter. It is also possible to measure the core loss by applying a secondary winding to the reactor. In this case, the copper loss is calculated as the difference between the reactor loss and core loss.

3.2 Comparison of Loss of Alternating Current Reactors

This section presents the evaluation example of an alternating current reactor which satisfies the specification in **Fig. 6**. As the test reactor, two test reactors were

Fig. 5 Reactor evaluation equipment

Fig. 6 Specifications of the test reactor

built using 4-block cores with dimensions of 70 Ĭ 20 Ĭ 30 mm and a co. Mc. Mco. l ao. œ cdm cn l mdn. n nn l