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Non centered minor hysteresis loops evaluation based on exponential parameters transforms of the modified inverse Jiles–Atherton model

M. Hamimid [a,b,*], S.M. Mimoune [a], M. Feliachi [c], K. Atallah [d]

[a] Université de Bordj Bou Arréridj, 34265 Bordj Bou Arréridj, Algérie
[b] Laboratoire de Modélisation des Systèmes Energétiques LMSE, Université de Biskra, BP 145, 07000 Biskra, Algérie
[c] IREENA-IUT, CRTT, 37 Boulevard de l'Université, BP 406, 44602 Saint Nazaire Cedex, France
[d] Department of Electrical Engineering, University of Sheffield, Mappin Street, Sheffield, S1 3JD, United Kingdom

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ABSTRACT

In this present work, a non centered minor hysteresis loops evaluation is performed using the exponential transforms (ET) of the modified inverse Jiles–Atherton model parameters. This model improves the non centered minor hysteresis loops representation. The parameters of the non centered minor hysteresis loops are obtained from exponential expressions related to the major ones. The parameters of minor loops are obtained by identification using the stochastic optimization method "simulated annealing". The four parameters of JA model (a,α, k and c) obtained by this transformation are applied only in both ascending and descending branches of the non centered minor hysteresis loops while the major ones are applied to the rest of the cycle. This proposal greatly improves both branches and consequently the minor loops. To validate this model, calculated non-centered minor hysteresis loops are compared with measured ones and good agreements are obtained.

1. Introduction

The accurate evaluation of iron losses in electromagnetic devices such as rotating machines and transformers plays an important role in the design procedure. In order, to achieve an optimal design, it is necessary to determine the iron losses in these devices regardless of the kind of power supply. The waveform of the magnetic flux in almost of these devices is non-sinusoidal and contains harmonics. Depending on the amplitude and phase of theses harmonics, the waveform of the magnetic flux may be distorted and causes a non centered minor hysteresis loops inside the main loop. Many empirical models are used to evaluate minor hysteresis loops losses and they give appropriate results only under certain conditions [1–3]. More precise models are used in the literature to represent the hysteresis phenomenon characteristic. The Jiles–Atherton model (JA) is the widely used one and it has proved its efficiency in many applications [4]. However, it cannot be used to predict the iron loss in a wide variety of waveforms of magnetic flux density encountered in electromagnetic devices. When the flux density is distorted, the JA model has a non-physical behavior [5]. To overcome this unphysical behavior, Benabou et al. in Ref. [5] proposed a modification of the parameters c and k depending on the variation of the magnetic field to improve the non centered minor loops at non-sinusoidal waveforms. These researchers have applied this modification only during the return branch of the non centered minor loop and acceptable results are obtained. A precise determination of non centered minor hysteresis loops characteristics is required for the determination of losses. In our previously works, we have used the JA model based on exponential and Langevin transforms of JA parameters [6,7]. These models demonstrate a good effectiveness for the evaluation of the centered minor hysteresis loops.

In this work, we propose the use of the exponential transforms model for the non centered minor hysteresis loops. In this model, only the three parameters of J–A model a,α and k are evaluated with keeping c as constant but for the non centered minor hysteresis loops case we need also the modification of the parameter c. This model is applied to both ascending and descending branches of the non centered minor hysteresis loops. This proposal greatly improves both branches and consequently the minor loops.

2. Modified inverse Jiles–Atherton model

The modified inverse Jiles–Atherton model (MJA) [8] which considers the magnetic flux density B as an independent variable

* Corresponding author.
E-mail addresses: Hamimid_mourad@hotmail.com (M. Hamimid), s.m.mimoune@mselab.org (S.M. Mimoune), mouloud.feliachi@univ-nantes.fr (M. Feliachi), k.atallah@sheffield.ac.uk (K. Atallah).

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