

# Magnetizing Current, Harmonic Content and Power Factor as the Indicators of Transformer Core Saturation

Ismail Daut, Syafruddin Hasan, and Soib Taib

**Abstract**—The paper proposes a measurement method for obtaining the parameters needed to calculate a reliable indicator of the state of transformer core saturation. The major nonlinear effects in transformer core are saturation, eddy current and hysteresis. Saturation is the predominant effect in power transformers, followed by eddy current and hysteresis effects. In saturation, a transformer core act as a source of current generating harmonics, some of which will flow directly toward the primary and secondary windings. The method is based on magnetization current, harmonic content and power factor evaluated of the transformer no-load current with high magnetic flux density subjected. The investigation is done on single phase model core type transformer. The transformer is connected to variable voltage variable frequency (VVVF) source and the investigation is done on various flux densities. The results show that the magnetization current and harmonic content increase significantly when high magnetic flux densities are injected and vice versa with power factor that decrease sharply. These phenomena can be used as the indication of transformer core saturation.

**Index Terms**—Harmonic content, no-load current, power factor, saturation, transformer

## I. NOMENCLATURES

$B$  magnetic flux density  
 $B_r$  remanence magnetic flux density  
 $B_s$  saturation magnetic flux density  
*CRGO* Cold-Rolled Grain Oriented  
 $H$  magnetic field intensity  
 $H_c$  coercivity magnetic field intensity  
 $H_{pk}$  peak value of magnetic field intensity  
 $H_s$  saturation magnetic field intensity  
*IEC* International Electrotechnical Commission  
*IEEE* Institute of Electrical and Electronic Engineers  
 $I_m$  magnetizing current  
 $I_{rms}$  rms value of all the current harmonic component  
 $I_{1,rms}$  rms value of fundamental current  
 $I_{h,rms}$  rms value of current harmonic component of order  $h$   
*M4* commercial name for grain oriented silicon steel sheet's grade

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$P$  power  
 $PF$  total (true) power factor  
 $PF_{disp}$  displacement power factor  
 $PF_{dist}$  distribution power factor  
THDn percent total current harmonic distortion  
 $V_{1,rms}$  rms value of fundamental voltage  
 $\mu$  permeability of core material

## II. INTRODUCTION

The magnetic circuit is one of the most important active parts of transformer. It consists of laminated iron core and carries flux linked to windings. Energy is transferred from one electrical circuit to another through the magnetic field carried by the core. The iron core provides a low reluctance path to the magnetic flux thereby reducing magnetizing current.

The performances of transformers are also constrained by the magnetic flux limitations of the core. For ferromagnetic core transformers, we must be mindful of the saturation limits of the core. Remember that ferromagnetic materials cannot support infinite magnetic flux densities; they tend to "saturate" at a certain level (dictated by the material and core dimensions), meaning that further increases in magnetic field force (mmf) do not result in proportional increases in magnetic field flux.

Choosing the right lamination material for a particular application is an important power transformer design step, since lamination properties have a direct link to the losses power or efficiency of the transformer. Currently, important lamination properties (core loss and permeability) to be used for assessment are presented at 50 or 60 Hz, 1.0/1.5 T sinusoidal. Electromagnetic designers have to decide on the material based on this single operating point, although under practical working conditions, some transformers operate at flux density levels and frequencies beyond this point. It has been shown that choosing the lamination material that based on the lamination performance at one operating point only is not enough [1]. Designers of transformers have, however, never had data available on the specific iron losses of the materials they use for alternating flux densities higher than of the saturation value. The usual methods of measurement, applied to specimens of the material, fail completely at higher flux densities than because the power factor becomes very small and the magnetizing current very high [2]. The major nonlinear effects in transformer iron core are saturation, eddy current and hysteresis. Saturation is the predominant effect in power transformers, followed by eddy current and hysteresis effects [3]. The iron core of transformers and other electromagnetic devices is laminated so that at 50 Hz or 60 Hz (or, in general, at power frequency) skin effect is

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