International Journal of Research in Advent Technology, Vol.4, No.3, March 2016
E-ISSN: 2321-9637
Available online at www.ijrat.org

Different Reverse Designing Methods for Analysis of the Transformer

Rajendra Muhare [1], Alka Thakur [2]
Department of Electrical Engineering[1, 2], SSSIST, Sehore[1, 2]
Email: rajmuhare@gmail.com[1] , alkathakuree@gmail.com[2]

Abstract- A design process is not merely engineering calculations but involves careful considerations of the design base, specifications, design transfer and information updating. This paper deals with the importance of various reverse transformer design methods. For that purpose different methods which were presented in the last few years are discussed and a review has been made on the modem development in transformer design of this practical technology.

Index Terms- Transformer; Reverse design Method, Simulation; MATLAB.

1. INTRODUCTION

Electrical energy transfer between two circuits takes place through a transformer without the use of moving parts; the transformer therefore has higher efficiency and low maintenance cost as compared to rotating electrical machines[1]. There are continuous developments and introductions towards betterment of its design considerations. As the transmission voltages are increased to higher levels in some part of the power system, transformers again play a key role in interconnection of systems at different voltage levels[2][3]. Transformers occupy prominent positions in the power system, being the vital links between generating stations and points of utilization [1][2][3][4][5]. With the rapid development of digital computers, the designers are freed from the drudgery of routine calculations. Computers are widely used for optimization of transformer design[3]. Within a matter of a few minutes, today's computers can work out a number of designs (by varying flux density, core diameter, current density, etc.) and come up with an optimum design[2]. The real benefit due to computers is in the area of analysis. Using commercial 2-D/3-D field computation software, any kind of engineering analysis (electrostatic, electromagnetic, structural, thermal, etc.) can be performed for optimization and reliability enhancement of transformers.

In the reverse design approach, the physical characteristics and dimensions of the windings and core are the specifications. By manipulating the amount and type of material actually to be used in the transformer construction, its performance can be determined. This is essentially the opposite of the conventional transformer design method. It allows for customized design, as there is considerable flexibility in meeting the performance required for a particular application. This paper summarizes the different reverse methods of transformer design and also gives a comparative analysis.

2. REVERSE TRANSFORMER DESIGN

In the reverse design method, the transformer is built up from the core outwards. The core cross-section dimensions (diameter for a circular core and side lengths for a rectangular core) are selected from catalogues of available materials([5] A core length is chosen. Laminations that are available can be specified in thickness. A core stacking factor can be estimated from the ratio of iron to total volume. Given the core length, c l , and diameter, DC (or core b and core w for a rectangular core), the inside winding (usually the low voltage winding) is wound on layer by layer. The wire size can be selected from catalogues. They also specify insulation thickness. The designer can then specify how many layers of each winding are wound. Insulation is placed between the core and the inside winding (former) and between each layer for high voltage applications. Insulation can also be placed between each winding. The outer winding (usually the HV winding) is wound over the inside winding, with insulation between layers according to the voltage between them. Winding current densities and volts per turn become a consequence of the design, rather than a design specification. The only rating requirements are the primary voltage and frequency. The secondary voltage and transformer VA rating are a consequence of the construction of the transformer.

3. LITERATURE SURVEY

Survey Transformer design is a complex task in which engineers have to ensure that compatibility with the imposed specifications is met, while keeping manufacturing costs low. Moreover, the de- sign methodology may vary significantly according to the trans-former type(distribution, power or instrument transformer) and its operating frequency (ranging between 50/60 Hz and a few megahertz), while many alterations according to the core constructional characteristics, the cooling method, or the type of the magnetic material may be encountered This paper pro-vides an overview of research, development, and the application of various computational methods for transformer design, base in today's competitive environment; 2) utility engineers who would like to enrich their educational background about the system interaction aspects of transformers in a power system; and undergraduate and postgraduate students who wish to integrate traditional transformer theory with modern computing practice.

3.1 . Simulation, design and fabrication of an efficient single phase transformer by: Muhammad Shahzad Aziz Sohaib Ahmed ; Umair Saleem ; Majid Ali, 2015

Transformer is a vital component of electric power systems for transmission and distribution. Robust design for the efficiency enhancement is the main stress in the fabrication of a transformer. Efficiency of a practical transformer is limited by the losses which are accounted for the design and manufacturing imperfections[1]. This paper deals with the simulation, design and fabrication of a 0.30 KVA, Single phase, Shell type, tapped transformer. Design and fabrication of this transformer has been made possible by the special calculations and design procedure. Simulation has been performed in MATLAB. Open circuit test and short-circuit tests have been performed to investigate the losses and efficiency of the designed transformer. Simulation results and experimental results have been compared which are closely matching.[1]

Transformer is the most important component of a power system. A good design for efficiency boost is a challenge in the fabrication of a transformer[1],[2],[3][4][5]. Less efficient transformers are poorly designed because the losses occurring in a transformer are more likely considered the design flaw. Transformers can be made maximum efficient if fabricated using the precise dimensions. In the current work, a model transformer of the rating 0.30 KVA was fabricated by carefully using the exact dimensions calculated from the special design procedure to make the transformer efficient up-to maximum. The losses were minimized by the robust design and the efficiency of the transformer came to be 98.6 %. Same transformer was simulated in MATLAB and the resulted characteristics from the simulation were compared with the experimental characteristics. Experimental results closely match with simulation results. Thus the effective design, precisely implemented resulted in the maximum efficiency.

3.2.Finite Element Method for Designing and Analysis of the Transformer A Retrospective by G. H. Chitaliya, S. K. Joshi 2013.

The finite element method (FEM) rapidly grew as the most useful numerical analysis tool for engineers and applied mathematicians because of its natural benefits over prior approaches[2]. The main advantages of FEM are, it can be applied to arbitrary shapes in any number of dimensions, the material properties can be nonhomogeneous (depend on location) and or anisotropic (depend on direction). The way that the shape is Supported (also called fixtures or restraints) can be quite general, as can be the applied sources (forces, pressures, heat, flux, etc.).

. Application of FEA is being expanded to simulation in electrical engineering also to solve the complex design problems. The circuit theory models for designing transformers are not much accurate in determining the transformer parameters such as winding impedance, leakage inductance, hot spot temperature etc. The physical realization of these parameters is needed on a prototype unit. The finite element method can play a vital role in deriving these parameters without any physical verification. An effort has been made in this paper to show the effectiveness of finite element method in determining the above said parameters while designing the transformers - both oil cooled as well as dry type - for power and distribution sectors as well as to analyze and detect the internal faults in the transformer.

This paper discusses the use and effectiveness of finite element method in designing the power transformer as compared to magnetic circuit theory internal winding fault detection and analysis, a three dimensional finite element analysis of electric fields at winding ends of dry type transformer hot spot and life evaluation of power transformer leakage inductance calculations and transformer over heating under non linear load conditions

The discussion above reveals that the finite element method is an efficient tool for designing the transformer. Whereas the determination of impedance, winding hot spots temperature, insulation class and insulation level etc. are the major challenges while designing a transformer, the FEA can serve a vital role and may provide a cost effective and efficient solution to the problem. The preliminary results obtained from finite element model may be useful to develop cost effective and efficient design. However from all above discussions, it is evident that a three dimensional finite element model is predominant over a two dimensional model. While initiating the analysis a two dimensional model may be adopted but for the betterment of results the analysis must be completed by developing a three dimensional model only.

3.3. Power transformer design using magnetic circuit theoryand finite element analysis – a comparison of techniques b Simon C. Bell and Pat S. Bodger, 2007

This paper summarizes different reverse methods of transformer design where the construction details of the transformer are directly specified and are used to determine the device performance and ratings[3],[4]. Two magnetic models are presented for the inductive-reactance components of the Steinmetz 'exact' transformer equivalent circuit. The first model, based on magnetic circuit theory, is frequently taught in undergraduate power system courses at universities. The second model is based on magneto-static finite element analysis. The reverse design method is used to design two sample high voltage transformers. The performance of the two magnetic models is compared to the measured performance of the as-built transformers. The magnetic model based on finite element analysis is shown to be more accurate than the model based on magnetic circuit theory, though at the expense of complexity of programming.

A finite element magnetic model has been introduced into the reverse method of transformer design. The model was found to be more accurate than the existing model [4], which was based on magnetic circuit theory, though at the expense of complexity of programming[3]. This has strengthened the use of the reverse design method as an entry-level design tool, from which more accurate models can be developed

3.4. Partial-core transformer design using reverse modeling technique by M.C. Liew and P.S. Bodger 2001.

The reverse-design method is applied to partial-core transformers. The laminated core occupies the central space only .The windings are wrapped around the core, with the primary winding inside the secondary winding. The yoke and limbs which usually form the rest of the core in full-core transformer, partial core-transformers are being studied because of their potential use with superconducting windings where the size of the core can be dramatically reduced albeit by an increase in winding turns[4]. The combination gives a better magnetization than a coreless transformer and maintains the leakage flux at an acceptably low level. The partial-core units is significantly reduced, and the are easier to manufacture.

It is thus a goal of this paper to present the partial-core transformer concept for mains frequency and associate modelling, which is sufficiently accurate for practical performance assessment. Current methods of determining equivalent circuit components for full core transformers have had notable limitations when applied to partial-core transformers [4]. Consequently, improvements in some of these components are derived and presented using the reverse transformer design method [4][5]. The dimensions of the core and winding materials are entered, based on what is available. The overall size ratings and performance of the transformer can then be predicted. The modified components include the core loss resistance, magnetizing reactance and the winding leakage reactance.

3.5. Applying reverse design modelling technique to partial core transformer year by M.C. Liew and P.S. Bodger 2001.

There are limitations to the conventional approach to transformer design. The terminal voltages, VA rating and frequency are input specifications and determine the types and dimensions of materials to be used. Core and winding material characteristics are known from standard values or physical measurements [5]. The resultant design may not match what is actually available in materials and hence the predicted performance can be in error. A reverse design method has been presented whereby the physical characteristics and dimensions of the windings and core are the specifications. This article gives an overview of the process of designing partial core transformers using a reverse modeling technique. Modifications are made to full-core equivalent circuit components to accommodate partial core transformers[4]. The model is applied to 50Hz transformers under normal operating temperature applications and also to transformers immersed in liquid nitrogen. It is then used for harmonic frequency analysis of partial core transformers where capacitive components are included. In all cases, comparisons are made between the model calculations and test results of as-built devices.

A reverse design modeling technique has been applied to partial core transformers for 50Hz applications under normal operating temperature [4] and also at liquid nitrogen temperature. It has been used for harmonic frequency analysis of partial core units. Matching results were achieved between the model calculations and test results of as-built devices. This has strengthened the use of the reverse design partial core model developed as an entry-level design tool from which more accurate designs can be made.

4. CONCLUSION

Conventional transformer design starts from a consideration of required frequency, voltage and VA ratings. It estimates a number of factors for the core and winding arran-gement, using values that are generally only known to experienced design engineers. The resultant design may not match specified requirement. An alternative is to reverse the design procedure. The dimensions of core and winding materials are entered based on whatever is available. The overall size, ratings and performance of the transformer can then be predicted. Sample transformers have been designed. The results highlight the problems associated with the conventional design and show the usefulness of the reverse design approach. Such a design philosophy allows for the exploration in the design of transformers with alternative construction options, where flexibility in shape and size is required.

REFERENCES

[1] Simulation, design and fabrication of an efficient single phase transformer by:Muhammad Shahzad Aziz Sohaib Ahmed ; Umair Saleem ; Majid Ali, 2015.
[2] Finite Element Method for Designing and Analysis of the Transformer – A Retrospective by G. H. Chitaliya, S. K. Joshi 2013.
[3] Power transformer design using magnetic circuit theory and finite element analysis – a comparison of techniques b Simon C. Bell and Pat S. Bodger, 2007
[4] Partial-core transformer design using reverse modeling technique by M.C. Liew and P.S. Bodger 2001
[5] Applying reverse design modelling technique to partial core transformer by M.C.Liew and P.S. Bodger 2001

.
(A.1)