Geomagnetically Induced Current Effects on Transformers

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Abstract: Geomagnetically induced currents (GIC) can cause saturation of the magnetic circuit of transformers in a power system. This saturation can increase the Mvar absorption of the transformers leading to voltage control problems, generate significant harmonic currents and cause heating of the internal components of the transformer itself, leading to gas relay alarm/operation as well as possible damage. This paper sets out the methods used to examine these effects using a mathematical model explicitly incorporating both the electric and magnetic circuits, including the shunting effect of the tank to predict the current and flux waveforms. The model has been used to predict GIC effects for a variety of winding connections for single-, three-, and five-limb core type transformers connected to the National Grid Company plc transmission system in England and Wales. The size and form of the return limbs together with the tank shunting effect determine the magnitude and the often complex shape of the waveforms resulting from GIC. Field and factory dc injection tests on various types of transformers have been conducted to validate the model and gain an insight into the magnetic behavior of transformers. With the aid of finite element analysis techniques and a consideration of the various constructional arrangements of the core and coils in the tank, it is possible to evaluate the power losses and accompanying temperature rises of the core, structural components, windings and tank. Some guidance on the acceptable GIC current levels for various transformer types is given.

Keywords: DC saturation, finite element analysis (FEA), geomagnetically induced currents (GIC), simulation, transformers, transformer heating, transformer tests.

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Calculation of Core Hot-Spot Temperature in Power and Distribution Transformers

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Abstract: Accurate calculation of the value of the core hot-spot temperature at the design stage is becoming very critical in order to ensure that hydrogen generation that can be caused by oil-film degradation at core hot-spot temperatures as low as 110-120 ºC is limited. Presented are two calculation methods developed for this purpose. Results of the FEM calculation of the location and value of the hot-spot temperature in cores of three-phase, three-limb cores of power and distribution transformers show excellent agreement with tested values on a number of transformers. Insight learned from this analysis was used to enhance a previously available empirical method. This simplified calculation method is appropriate for everyday use and, hence, is suitable for design calculations. This method was shown to have very good accuracy in the range of 2 ºC for most of the cases. The simplified calculation method was also shown to provide a much greater accuracy than the original empirical method.

Keywords: Transformer, transformer cores, core temperature.

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A Wavelet-Based Technique for Discrimination Between Faults and Magnetising Inrush Currents in Transformers

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Abstract: This paper presents the development of a wavelet-based scheme for distinguishing between transformer inrush currents and power system fault currents, which proved to provide a reliable, fast, and computationally efficient tool. The operating time of the scheme is less than half power frequency cycle (based on a 5 kHz sampling rate). In this work, the wavelet transform concept is presented. Feature extraction and method of discrimination between transformer inrush and fault currents are derived. A 132/11 kV, transformer connected to a 132 kV power system were simulated using EMTP. The generated data was used by MATLAB to test the performance of the technique as to its speed of response, computational burden, and reliability. The proposed scheme proved to be reliable, accurate, and fast.

Keywords: Wavelet transforms, protective relaying, digital signal processors, protective relaying, transforms, transient analysis, transformers.

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Transmission and Distribution

High Temperature Ampacity Model for Overhead Conductors

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Abstract: A computer-based ampacity model that can predict the temperature of overhead conductors for temperatures as high as 250 °C has been developed. The model is a revision of a program that has been reliably used for nearly 20 years to calculate the transient ampacity of a wide variety of conductor designs. The accuracy of the program has been determined by comparing the program predictions with temperatures that are measured on a full-scale energized outdoor test span. The accuracy of the program decreases as the average conductor temperature increases. As the conductor temperature increases, the spatial variations, both azimuthal and radial, are magnified, and the task of calculating a single average conductor temperature becomes more challenging. Typical variations in the conductor temperature were as high as 65 °C in a single span when the conductor temperature approached 250 °C. These temperature variations create difficulties when trying to either measure the conductor temperature with hardware attached to the line or predict the temperature with a computer-based ampacity model.

Keywords: Ampacity, overhead lines, heat transfer, high temperature operation.

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A New Method for Real-Time Monitoring of High-Voltage Transmission Line Conductor Sag

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Abstract: The amount of power flowing through a high-voltage transmission line is proportional to its voltage and the current flowing through it. To increase power flow without modifying the line to allow increased voltage, the current must be increased. There is a limit to this, however, since increasing the current causes the conductor temperature to increase and hence the conductors to elongate and sag. In this paper, a method to simply and inexpensively measure the amount of conductor sag and, by simple calculation, the average conductor core temperature is described and the results of a field test are summarized. The method involves attaching two ends of a grounded wire of high electrical resistance to an appropriate location on each of two transmission line towers and measuring the current induced on the wire by the nearby transmission line conductors. Information from this measurement is a critical input to any method for dynamically rating transmission lines.