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A REVIEW ON INEQUITY BETWEEN INRUSH CURRENTS AND INTERNAL FAULT CURRENTS OF TRANSFORMER

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Abstract

The most important problem for transformer protection is to distinguish the inrush from fault currents. Abundant academic studies and many achievements have been reported to solve this equality but still some issues are comes for the research. The discrimination of inrush currents and internal fault currents in transformers is a significant aspect of a transformer protection method. Power transformers are at the heart of power scheme and it plays a key role in present power systems. Hence its protection is of huge significance to promise steady and consistent function of the power system. The inrush current fact is one of the major causes formal-operation of the protection system. Hence precise and rapid discrimination of inrush current and fault current is necessary in research point of view.

Keywords- *Inrush and Fault Currents, Transformer Protection, Electrical Machine, Inequity, Power System.*

Introduction:

Transformer is an extremely competent fixed electrical machine that plays a significant job in the power system. It is an important element of power system, so it is essential to have a speedy and correct operating protection system for the protection and proper execution. Protection scheme of transformer depends upon the transformer rating, working condition, tap changing scheme and loading condition of the transformer. In small rating distribution transformers high voltage fuses are used for the protection. Similarly Buchholz relay protection over current protection with restricted earth fault protection and differential protection scheme also have a solution for the same.

Discrimination between inrush current and internal faults has been acknowledged as an extremely challenging power transformer protection problem. The inrush current contains a huge second harmonic constituent in association to a fault. Sometimes also the second harmonic may be generated in case of internal faults in power transformer. This may be due to current transformer (CT) saturation and distributive capacitance in extended transmission line to which the power transformer is connected. Also sometimes the magnitude of second harmonic in internal fault current can be close to that present in the inrush current. Also the inrush current magnitude is comparatively fewer in contemporary power transformer due to design improvements. Therefore the traditionally provided protection system with harmonic restraint will not solve the problem and continuously taken into account by the researchers.

Inrush Current in transformer often gets not as much of weight compared to other faults/effects. It may happen whenever the transformer is energized. Though the magnitude of inrush current may be fewer compared to short circuit current, the frequency and duration of inrush current is more frequent, important to more undesirable effects compared to other faults. Inrush Current, Input Surge Current or Switch– on Surge Current is the greatest, instantaneous input current drawn by an electrical device when it is first turned on. It can last for few cycles of the input waveform. When electrical power transformer operates usually, the flux developed in the core is quadrature with the applied voltage. Inrush current occurs in a transformer whenever the remaining flux does not match the instantaneous value of the steady-state flux

The inrush current observable fact occurs due to provisional over fluxing of the transformer core. This may depend upon:

- Switching instant on the voltage waveform at which the transformer is energized.
- The magnitude and polarity of the residual flux present in the transformer during re- energisation.
- Rating of the transformer.
- Total resistance of the primary winding.

When a transformer is energized from a standard power source it takes huge magnetizing current which can be about 7 to 10 times the rated current. This huge current can results in deterioration of the transformers life.

For successful transformer differential protection service, accurate discrimination between inrush current and fault current is necessary. It is one of the main focuses of our study and one of the major challenges for transformer protection. As per the power system protection idea, every scheme elements are main, and nothing may be missing without any protection. However, the particulars and strength of the protection point depend on the significance, price, function, and place of the confined aspect. Transformer protection is considered one of the central priorities of scheme protection, regardless of its location, due to the direful result of losing it.

The fault current and magnetization inrush current both of have an ordinary high magnitude. A differential relay recognizes the diversity in both conditions, in various fault scenarios as is also the result due to inrush current. Due to this a decision to remove the healthy section that does not necessary to be removed and ignoring it may direct to the loss of the transformer. It may even result in successive failures that make threats the whole power system.

Hence, it is required to construct or design a scheme for accurately differentiating in between the two currents conditions. The operation of relay or restricting is depends on choices of results taken by such a scheme. Generally adopted methods for solving and representing such problems are depending on use of harmonics. Distinction of inrush current from internal fault is very important in order to improve the consistency and safety of differential protection.

Literature Review:

The classification of internal fault currents and magnetic inrush currents in the transformer is performed by using an extended Kalman filter (EKF) algorithm in [1]. The detection time of internal faults decreases with the severity of the fault and this scheme provides fast protection of the transformer for severe faults.

A discrimination method based on utilizing chromatic monitoring of the box dimension algorithm outcome curve for transformer differential current in time-domain analysis is proposed in [2] in which the x-L chromatic mapping is employed for general detection of fault cases, while the x-y chromatic mapping result is used for distinguishing inrush current from the fault current cycles. The proposed method can effectively provide correct discrimination of the current type within quite a short time and thus help in providing efficient decision-making supportive protection tool.

A new approach to distinguish between inrush current and internal faults of power transformer using a recursive Gauss Newton method in [3] in which The HS-transform (Hyperbolic S-transform) is used to extract patterns of inrush current and internal faults from the captured transformer current. Also the spectral energy and standard deviation are calculated and Fuzzy C-means clustering is used to distinguish the inrush current from internal faults.

Different methods which can also be used for proper distinction between inrush current and internal fault current are highlighted in [4] and some conclusion has been drawn. All the techniques can be used in real life situation but instantaneous inductance and wavelet based technique are relatively faster as compared to other techniques. Also, Instantaneous inductance technique and morphological technique are better than other techniques because they work even when CT is saturated.

The basic principles, fundamental theory of inrush current and its effects and the various mitigation techniques for addressing the problem of Stability and security of transformer protection, inrush current faults/effects, short circuit current and the frequency and duration of inrush current are also discussed in [5]. When a transformer is energized from a standard power source it draws high charging current which can be as high as 10 times the rate current. This high current can lead to deterioration of the transformers life. The various factors affecting this inrush current are studied. Various mitigation techniques based on this study are also dealt with. Of those strategies, the controlled 0switching technique is found to be more accurate and reliable.

An analytical and extensive review of various techniques used for discrimination between inrush current & internal fault current of transformer with their advantages & limitations is presented in [6] while the approach adopted is mainly depends on the rating of transformer, application and detection time. It has been found that most of the researchers are inclined towards the use of signal processing and soft computing techniques for the discrimination of inrush current and internal fault current of transformer.

An inrush current discrimination algorithm based on MMFE is proposed in [7]. The ratio of entropy area to the given braking zone area is designated as the entropy area ratio. Inrush currents and internal fault currents are identified according to the numerical value comparison between Kset and 1. The proposed algorithm is verified through a simulation and dynamic simulation experiment. The following conclusions are drawn: (1) The hard boundary of the Heaviside function in the MMSE is softened by using the fuzzy membership function, which relieves the dependence of MMSE on similarity tolerance. (2) In comparison with other discrimination methods, the proposed algorithm based on MMFE can discriminate inrush current under different conditions, including internal fault, energisation with internal fault, over excitation condition, magnetizing inrush, magnetizing inrush with CT saturation and sympathetic inrush. Moreover, the maloperation of differential relay can be avoided.

Fault discrimination scheme for power transformer protection based on RF classifier is presented in [8]. The proposed scheme effectively discriminates between internal fault (including special types of fault such as turn-to-turn and primary-to-secondary windings) and various disturbances such as different types of magnetising inrush and over-excitation conditions on power transformer using one cycle differential currents. Various simulation cases consisting of internal faults and disturbances have been generated by modelling an existing power transformer using PSCAD/EMTDC software package. The proposed scheme offers more than 98% overall fault discrimination accuracy, in which 5244 simulation cases have been tested for validating the suggested scheme from the total dataset consisting of 10,884 cases, and hence it is superior than the existing schemes. Moreover, it gives promising results for different connection types and ratings of the power transformer, even though dataset of power transformer is trained only one time for a single rating and connection of a transformer. In addition, the proposed scheme gives robust performance and remains stable under CT saturation condition.

The impact of SFCL installed in the transformer neutral point on the performance of the inrush current discrimination algorithms is investigated thoroughly in [9]. It is confirmed that the neutral-line SFCL would impose significant harmonic content in signals used for discrimination purposes. The results confirm that the SFCL has negative effects on the performance of the discrimination methods. Many scenarios are considered to examine the robustness of the algorithms in the presence of the SFCLs. The SFCL limiting impedance and the fault distance from the neutral point are two factors which have the most impact on the detection algorithms. The results demonstrate that the performance of the method which only utilizes the dead angle zone samples is more accurate at the expense of a relatively long decision time. However, the percentage of mal-operation of the other algorithms could be reduced by increasing the response time as a compromise.

By analyzing the amplitude and phase characteristics of zero-sequence currents on both sides of zero-sequence deferential current protection, combined with correlation analysis that can magnify the deference between signals, the new criterion for zero-sequence deferential current protection of the converter transformer based on correlation analysis is proposed [10]. The simulation results are verified based on the HVDC transmission model. The results show that the traditional zero-sequence deferential current protection may mis-operate under external fault persistence and removal accompanied by CT saturation. The proposed new criterion for zero-sequence deferential current protection based on waveform correlation can be locked reliably. It can operate sensitively in all kinds of internal fault conditions. It has strong CT anti-saturation ability, as well as the reliable ability of identification even when external fault removal causes recovery inrush current with CT saturation.

Inrush Currents and Internal Fault Currents of Transformer:

When transformer is energized, the core flux and the corresponding exciting current undergo a transient before reaching steady state values. The severity of the switching transient is related to the instant of switching. Under steady state condition if the applied voltage is sinusoidal, the instantaneous value of common flux in the core (with no residual flux) changes from –φmaximum to +φmaximum in half cycle to balance the applied voltage and lag its voltage by 90 degree. If the transformer is switched on at the instant of its positive peak then the flux rises from zero and transformer is switched on with normal magnetizing current, the same would happen if the applied voltage is at its negative peak at the switching instant. However if at the instant of switching, the applied voltage is at zero and say going toward positive then the flux must change from zero to 2φmaximum in half cycle for a flux less core and if the flux contains residual flux then this value will increase because of the effect of residual flux.

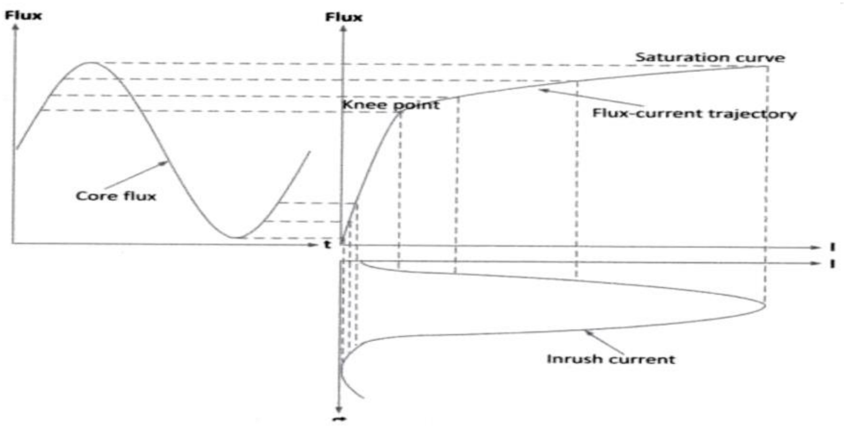

Fig 1: Inrush current generation in transformer

This gives a rise to almost double the flux and is known as doubling effect and further causes a huge magnetizing inrush in the primary current. An analogous situation would arise when applied voltage is going toward negative. The value of inrush current can reach five times the full load current in the transformer and is therefore nearly 100 times the normal no load current. [4]

Before energisation the flux is zero in the core of transformer. The flux will not reach the steady-state instantly. The flux in the transformer core will increase from its zero value at the time of energisation and as per Faraday's law of electromagnetic induction the rate of change of flux is responsible for induction of voltage in the windings which is given by the equation e = dφ/dt. The total flux will be integral of the voltage wave which is given by

$$e = E.\sin\omega t = \frac{d\varphi}{dt} \ , \ \ \varphi = \int e.dt = E \int \sin\omega t.dt$$

If the transformer is energized at the voltage zero instant then the flux wave will also start from the same origin as voltage waveform, the value of flux after first half cycle of the voltage waveform is given by

$$\varphi_m = {}^{E}/_{\omega} \int_0^{\pi} \omega.\sin\omega t \ dt = \ \varphi_m \int_0^{\pi} \omega.\sin\omega t.d(\omega t) = 2\varphi_m$$

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Where φ_m is the maximum flux. The core of transformer generally gets saturated when the flux is above the maximum steady-state flux. During the energisation of transformer, the maximum value of flux will rise to twice the steady-state maximum value.

The core of transformer gets saturated when the flux exceeds the steady-state maximum value, hence the transformer draws a heavy current to produce the rest of flux. This heavy current drawn by the transformer during energisation is called as the magnetizing inrush current. The magnitude of this current may be up to ten times the rated current of the transformer.

The operation of differential relay is affected by the interference of inrush current in a power transformer.

High magnetizing inrush current affect the rating of fuses or breakers, it also introduces noise and distortion back into the supply mains. Hence it is very much essential to discriminate inrush current from the internal fault current to improve the protective system of transformer. Figure 2 shows the magnetizing inrush current of transformer along with the applied voltage. [6]

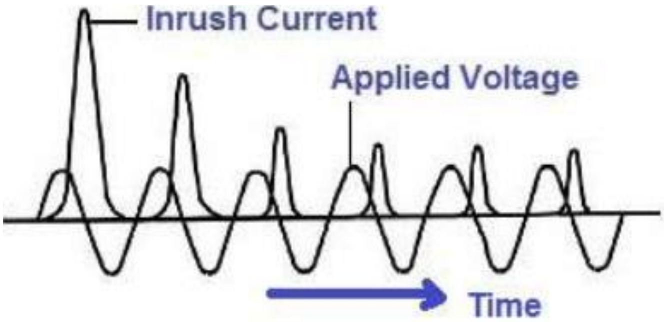

Fig 2: Magnetizing Inrush Current of Transformer

Conclusion:

A power transformer is at the backbone of power scheme and it acting a vital role in recent power systems. Hence its protection is of enormous significance to guarantee steady and consistent function of the power system. The inrush current concept is one of the key causes for mal-function of the differential protection method. Hence precise and quick discrimination of inrush current and fault current is necessary. In this paper, a general review of different method used for discrimination between inrush current and internal fault current of transformer with their advantages and limitations is presented. The selection of the approach adopted is primarily depends on the rating of transformer, application and detection time. It has been found that most of the researchers are inclined towards the use of signal processing and soft computing techniques for the discrimination of inrush current and internal fault current of transformer.

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