A REVIEW STUDY ON TRADITIONAL AND ADVANCED PROTECTION SCHEMES OF POWER TRANSFORMER

Dr. Pavan kumar Singh*

*Faculty of Engineering,
Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, INDIA
Email id: pavan.engineering@tmu.ac.in

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ABSTRACT

Power transformers play a critical function in providing a stable power supply to energy users in a power system network. This article provides the idea of many kinds of transformer protection, which will be more useful in analyzing the transformer's protective system. The goal of this paper is to bring together recent advances in transformer protection. To that aim, efforts have been made to cover all of the methods and ideas utilized. The article discusses both the most current and classic transformer methods. Many essential components are placed in the transformer, and they are extremely expensive, therefore they must be safe in an abnormal state. Transformers play a vital role in the power system, changing voltage and current levels, thus adequate transformer protection is critical for system dependability. In most cases, a well-designed transformer protection system will last a long time even if the power supply is stopped. Reduces stress on the transformer is the only way to improve life, efficiency, and overall performance, therefore this protective system helps in correctly observing those things.

KEYWORDS: *Fault statistics, Fuzzy, Over current protection, Power Transformer, Relay.*

1. INTRODUCTION

Protective relaying's purpose is to start the early removal of a defective part from service in order to limit system damage. The role of digital computers for the first time. With the introduction of the microprocessor in the early 1970s, its use in digital protective relays became a highly appealing alternative. Among the many components of the power system, the power transformer is an essential component. Because of its significance, it requires quick and dependable security. As a result, a lot of work has been done in this area(1–3).

Because the transformer is a component of the electricity system, it requires appropriate protection. In general, backup protection should be needed for protected transformers since if the relay or circuit breaker fails, the whole transformer may be destroyed, which is not cost effective. The following are the several types of transformer operations: Normal operation, magnetizing inrush, over-excitation, and a fault state are all examples of normal operation. The relay should not function under the first three operational circumstances, but it must operate in the event of a fault. Because the transformer's cost and weight are considerable, and we can't transfer it to the maintenance department for fault clearing, the protective system plays a critical role in avoiding this situation(4–6).

1.1. Fault Statistics:

IEEE guidance in Protective relay system for Power Transformer provides failure data for six types of failures. Winding and tap changer failures account for almost 70% of transformer problems, and other faults are rare, thus winding and tap changer are the most common causes of transformer defects(7,8). As a result, transformer protection under unusual circumstances is a difficult component to design. As well as insulation failures, loose connections are implicated as the starting event. CT failure, external defects, overloads, and shipping damage are among the many categories. Advanced online monitoring equipment (such as a gas-in-oil analyzer) may detect these problems before a major event occurs. Because of high failure rates, appropriate transformer protection gear is required to keep the power supply running. As a result, the different kinds of transformer protection systems are represented in this article(9–11).

1.2. Classification of Transformer Protection Relay:

n most cases, the failures in the transformer were caused by insulation failure or deterioration. As a result of the insulation breakdown, the temperature of the transformer oil rises, resulting in poor transformer performance. As a result, a temperature monitoring system for transformer oil is supplied. Overvoltage and over current may arise as a result of a transitory condition, therefore an over current relay and differential protection mechanism are employed. Many faults have occurred, although certain atypical defects, such as magnetic inrush current, excessive fluxing, and low oil level, do not pose a serious threat to the transformer (Figure 1).

These aberrant circumstances are not caused by a transformer failure. As a result, no protective gear is used to address these flaws. But one thing to remember is that if the abnormal fault persists for a long period, it will cause a major issue in the transformer. Below is a diagram of the most essential protective systems. This protective gear must always be operational; otherwise, when a fault occurs, it will cause a major issue in the transformer(12–14).

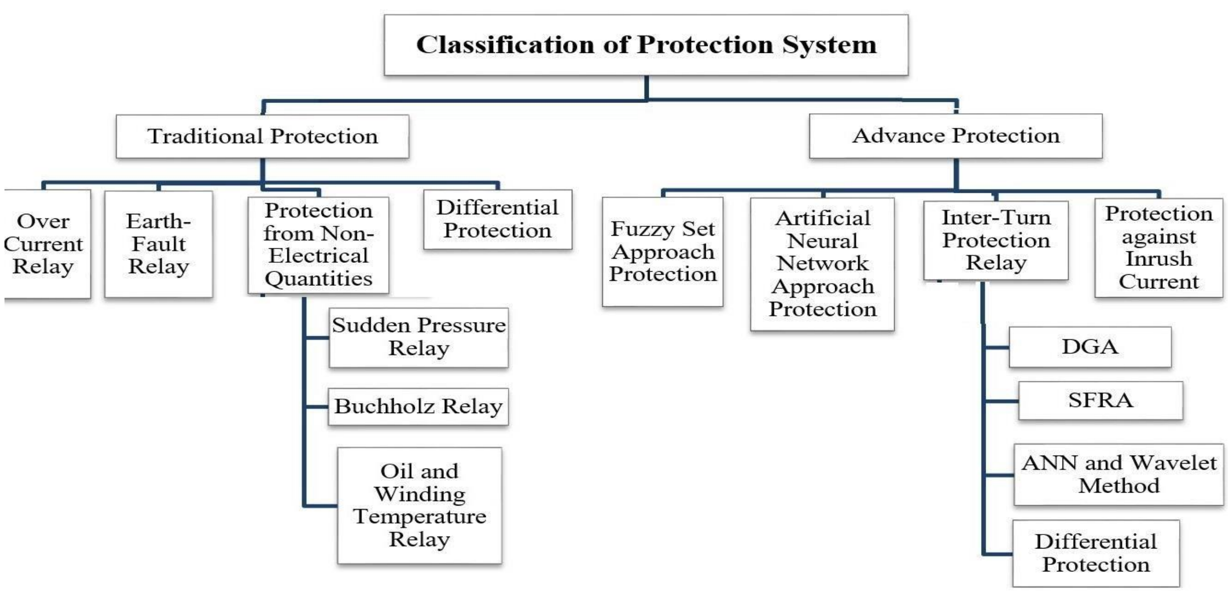

Figure 1: The Above Figure Shows the Fuzzy Set Approach for Transformer Protection.

The idea of fuzzy set theory was originally proposed by Zadeh in 1965 to deal with unclear and ambiguous characteristics of occurrences. The fuzzy set idea was originally utilized in 1979 for power system safety. As a result, fuzzy set theory may be considered a broadening of conventional set theory. In fuzzy set theory, the element's association may be modified at any time. Fuzzy logic is a highly useful mathematical medium for solving decision-making problems because it combines heuristic knowledge, expert knowledge, and experience. As a result, it is a highly effective tool for expressing quantitatively ambiguous values and their relationships.

The transformer is an important component of any electrical power supply. Fuzzy logic methods are utilized to improve the fault detection sensitivity of the conventional percentage differential current relaying methodology. Fuzzy inference is a decision-making technique that works in parallel. Because of this feature, no data is destroyed throughout the process, resulting in much more accurate final fault detection than conventional relaying methods. Rather of using numerical variables, fuzzy logic employs language variables. Fuzzification is the process of turning a numerical variable (crisp variables or real numbers) into a linguistic variable (fuzzy number). Fuzzification is a powerful tool for dealing with ambiguous data, whether objective or subjective.

1.2.1. The following advantages shows the fuzzy logic based approach:

- In the case of a magnetizing inrush with a low second harmonic component and internal faults with a high second harmonic component, the fuzzy based relaying algorithm is not permitted to run the relay needlessly. As a consequence, our findings improve accuracy and resilience in the face of changing power system conditions.
- This fuzzy algorithm allows the relay to identify faults with great sensitivity and function with an average tripping time of approximately 3/4 cycles. As a result, the technique is both dependable and quick.

1.3. Artificial Neural Network Approach Protection:

The artificial neural network (ANN) is the second most popular mathematical technique in recent years, attracting researchers to solve the transformer protection problem. The ANN's distinguishing feature is that it takes into account the accumulated information obtained during training and reacts to new occurrences in the best appropriate way possible based on the experiences gathered during training. The network design, transfer function, and learning rule are all used to create the ANN model. Weights and a connecting system are used to complete the design. The goal of the training procedure is to modify all ANN weights such that the target and computed ANN outputs are as close as possible to the mean value of all input samples.

According to the conventional gradient method, the criteria function for the sum square error is minimizing. The quality of the training process determines the efficacy of ANN. The waveform analysis technique is used to train neural networks in ANN. The following three challenges arise when implementing the neural network: defining a set of training examples, ensuring that the multilayer perceptron is small enough to allow weight convergence, and ensuring that the input is defined and coded with the core so that it is representative of the events to be identified.

1.4. Protection against Inrush current:

The transformer is an important component of any electrical power supply. Differential protection transformers are often used to safeguard transformers. However, when a transformer is turned on, inrush current may cause the differential protection to fail. To degrade the defect, various methods are employed. Per-phase method, cross blocking method, percent average blocking method, and harmonic sharing method are examples of these methods. The internal fault was then separated from the magnetizing inrush current using a fuzzy logic method. Following that, differential protection based on the wavelet packet transform was implemented. The inrush blocking method was then based on mathematical morphology. The per-phase approach, cross-blocking method, % average blocking method, harmonic sharing method, fuzzy logic, wavelet packet transform based methodology, and finally Mathematical morphology based inrush blocking scheme are all compared in this article. The following techniques demonstrate several magnetic inrush current prevention schemes.

1.4.1. Per-Phase Method:

The per-phase method is a simple and conventional way to keep harmonics under check. The restraint algorithm is simultaneous and independent in each step. This criteria applies to each step individually in the Per – Phase Method. The residual flux is variable in each phase. As a result, the amplitude of the second harmonic will vary depending on the phase. The threshold value is used in this technique. The differential protection may trip if the 2nd harmonic content in a phase is low when energizing. As a result, although this method is highly dependable, it is not particularly secure.

1.4.2. Cross-Blocking Method:

The only difference between this method and the Per–Phase Method is that the signal that restrains differential operation for one phase also restrains differential operation for all other phases. Differential protection will also trigger if the second harmonic value exceeds the pre-set value for other phases. This method works well in the case of symmetrical faults. The differential protection, on the other hand, will trigger if there is a single unsymmetrical fault.

This approach improves security by allowing a phase with a low harmonic ratio to be cross-blocked by a phase with a greater ratio, preventing the risk of erroneous tripping. At the moment of energization, the insulation is subjected to a significant deal of mechanical stress, and the inrush current is typically several times higher than the rated current. This cross-blocking method is secure, although it isn't entirely reliable. A cross-blocking technique is comparable to the two-out-of-three restraint method. To identify the appropriate amount of harmonics, blocking differential operation requires at least two phases in this technique. However, this approach suffers from the same fundamental flaw as the simple cross-blocking technique.

1.4.3. SFRA Scheme:

Sweep Frequency Response Analysis (SFRA) is a reliable and sensitive technique for determining the mechanical integrity of a power transformer's core, windings, and clamping structures by calibrating their electrical transfer functions across a wide frequency range. For frequency measurements, SFRA is an approved technique. SFRA is one of the most reliable and precise techniques available. In this technique, we apply a pulse wave on one side of the winding and examine the frequency response for the provided input on the other side of the winding. There are three ways for analyzing the results.

1.5. Buchholz Relay:

With the assistance of thermal monitoring, a Buchholz relay is utilized to identify a transformer failure. Low-energy arcs, insulation breakdown, and overheating are used to identify tiny generated gas in oil. This relay may also detect heating from greater power transmission, higher ambient temperature, and high eddy current between laminations, arcing, and overloading. Between the conservator and the transformer tank is a Buchholz relay.

When a problem occurs in the transformer, the temperature of the oil rises, and the Buchholz relay operates on this premise. The relay is positioned such that the arrow points towards the conservator and is at a 5-degree angle. There are many methods for analyzing a transformer problem. However, among the various methods, the technique of monitoring oil temperature is one of the most reliable.

1.6. Sudden Pressure Relay:

When used in combination with a basic differential relay, the gas pressure relay may safeguard a transformer. The main benefit of this relay is that it will operate in a steady manner even when there is an inrush current. This relay may be utilized as a backup to the Buchholz relay's protected relay. When there is a significant amount of gas in the transformer tank, this relay activates instantly. The rate of increase of the gas in the transformer is the operating concept for this kind of relay.

Heat is produced whenever a strong current passes through a winding. Introduce arcing in the oil such that winding heat is responsible for raising the temperature. As a consequence, the pressure in the transformer oil would rise. A sudden pressure relay may detect a rapid rise in gas pressure. This kind of relay is mounted on the oil-filled transformer's top. It has two functions: one is to detect the gradual buildup of gases and the other is to sound an alert when a certain quantity of gas has been gathered.

A standard transformer gas relay is made up of two chambers, each of which serves a unique purpose. It responds to a rapid pressure shift that occurs when gas output is high. Figure 4 depicts a simple sudden pressure relay(15,16). A gas accumulation chamber is placed immediately above a pressure chamber in the relay configuration. Slowly generated gases are accumulated in the accumulation chamber. As the gas volume rises, a float in this partly oil-filled cylinder slides. When the quantity of gas collected reaches a certain threshold, it activates an alert switch. The only disadvantage of a pressure relay is that it can function when there is a lot of current flowing through the winding. As a result of this flaw, some users only set it up for alarm purposes.

1.7. Over current Protection:

For lower rated transformers, an over current relay is the best option for protection. This over current relay is suited for transformers ranging from 100 to 500 KVA. This relay may also be used as a backup safeguard for high rating transformers. In general, this relay is configured to an above-normal rated current so that it can handle a short time rating(17,18). When the pick-up over current value is not exceeded during a low-level fault, the instantaneous over current relay will allow the fault to continue forever. In typically, this relay is set at 2-3 times the transformer's rated voltage. One thing to note is that this relay's pickup value is always greater than the magnetic inrush current. An instantaneous over current relay is used to provide main protection against severe internal faults.

When a transformer is overloaded, the rating size of the transformer increases, and mechanical force is produced. These mechanical forces will attempt to raise the transformer's winding hot spot temperature and movement. This movement causes mechanical damage to the insulation, resulting in a temperature hotspot. As a result, the transformer should not be operated in an overloaded condition for an extended period of time(18,19).

1.8. Earth-fault Protection:

The current taken from the source terminates its course without adding to the load in an earth fault. The primary goal of this protection is to keep ground fault current to a minimum. Short-circuit currents travel through the system when the fault occurs, and this current is returned via the earth or any electrical equipment. This fault current causes damage to the power system's equipment and disrupts the supply's continuity. Using the limited earth fault (REF) protection design, the earth fault may be distributed.

When a star side external fault occurs, current flows in the afflicted phase's line current transformer while a balancing current flows in the neutral current transformer, resulting in a zero resultant current in the relay. As a result, this REF relay will not function in the event of an external earth fault. During an internal fault, however, the neutral current transformer only provides unbalanced fault current, requiring the use of a Restricted Earth Fault Relay. The internal earth fault of the electrical power transformer is very sensitive to this system of limited earth fault prevention. The protection plan is less expensive than the differential protection plan. Only one residual current is accessible at the output since three CTs are linked together. The secondary side of CTs balances the residual current.

2. DISCUSSION

Medium and large-scale power transformers are important and essential components of power systems. Its protection must be properly handled due to its importance and expense. Transformer protection has to be quick and dependable(8,20). Appropriate monitoring of the power transformer should be chosen to give early warning of electrical faults and avoid catastrophic losses. The primary purpose of the protective system is to rapidly identify and isolate any failed or faulty components, minimizing the impact on the rest of the electric system. As a result, the protective system must be reliable (act only when needed), secure (not operate needlessly), selective (just the bare minimum of devices should function), and quick. Without this fundamental need, the protective system would be useless and even dangerous.

3. CONCLUSION

The most essential thing to remember is that the effects of thermal stress and electrodynamic forces must be minimized, which can only be done with properly chosen transformer protection that reduces the time it takes to disconnect in the case of a failure. This article offers an overview of the many types and methods of transformer protection, as well as basic and higher level information. This article contributes to the development of sophisticated and conventional transformer protection relays. Many problems may arise in the transformer, therefore appropriate protective gear must be in place to safeguard the transformer. The protective systems that have been devised so far are capable of effectively protecting the transformer and reducing the danger of massive damage. The advantage of this technique is that it is an automated protection solution that does not need any human effort. In reality, this notion is very easy to manipulate.

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