Advanced techniques for transformer protection

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ABSTRACT

The power transformer can be expensive and are an incredibly valuable component in the power system. Faults can lead to repairing or replacement, therefore, it is necessary to minimize it thereby reducing the damage. Currently, the protection by electromagnetic relay makes use of the individual relay and monitoring equipment for identification. This paper firstly summarizes all available protection methods then suggests a certain method to implement advanced relay with high performance, flexibility monitoring capability and advanced programmable.

Keywords— Advanced relay, Fuzzy logic, Artificial neural networks, Protection, Advanced numerical method

1. INTRODUCTION

Power transformer experiences various faults while they are in operation. In this phase, the parameters change to different values which are undesirable till the fault is cleared. The common practice to clear these faults is by using a fuse, circuit breaker, protective relays. Present systems use an electromagnetic relay. Individual relay and monitor equipment are used for the identification and isolation of each fault. Therefore control of fault is difficult and costly. Accurate value is also not monitored, therefore we implement Power transformer protection using an advanced relay.

2. ISSUES

These abnormal conditions cause electrical failures in the power transformer(s). Short circuit and open circuit of conductor takes place due to failure of insulation or conducting path. Broken conductor or circuit breaker in one or more phases results in open circuit fault. Breakdown or deterioration of insulation in various equipment causes short circuit failure.

2.1 Various faults

- **Earth faults:** A fault on a transformer winding will result in currents that depend on the source, neutral grounding impedance, leakage reactance of the transformer, and the position of the fault in the windings. The winding connections also influence the magnitude of fault current. In the case of a Y-connected winding with a neutral point connected to ground through an impedance Zg, the fault current depends on Zg and is proportional to the distance of the fault from the neutral point.
- **Core faults:** Core faults due to insulation breakdown can permit sufficient eddy-current to flow to cause overheating, which may reach a magnitude sufficient to damage the winding.
- **Interturn faults:** Interturn faults occur due to winding flashovers caused by line surges. A short circuit of a few turns of the winding will give rise to high currents in the short-circuited loops, but the terminal currents will be low.
- **Phase-to-phase faults:** Phase-to-phase faults are rare in occurrence but will result in substantial currents of magnitudes similar to earth faults.
- **Tank faults:** Tank faults resulting in loss of oil reduce winding insulation as well as producing abnormal temperature rises.

In addition to fault conditions within the transformer, abnormal conditions due to external factors result in stresses on the transformer. These conditions include:

- Overloading,
- System faults,
- Overvoltage,
- Under-frequency operation

The differential relaying principle is taken into consideration for protection of medium and large power transformers. This superior approach compares the currents at all the terminals of the protected transformer by computing and monitoring a differential (unbalance) current. The non-zero value of the differential signal indicates an internal fault.

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The relaying methods applied in today’s products basically use the current signals and limit the analysis to the fundamental frequency components and higher harmonics of those signals. The advanced numerical principles use more information including voltage signals as well as signal features other than just harmonics. AI methods tend to utilize all the available information. The numerical complexity of an algorithm is the price to pay for processing more information.

2.2 Global approaches
By the global approach, we mean a relaying algorithm that recognizes internal faults versus all the other phenomena in a power transformer without specifically classifying the later into magnetizing inrush, over-excitation and external faults.

3. MODEL METHODS
This family of approaches solves on-line a mathematical model of a fault-free transformer. Either certain parameters of the model are computed assuming the measured signals, or a certain fraction of the terminal variables are computed based on all the remaining signals, and next compared to their measured counterparts. In the first case, the values of the calculated parameters differentiate internal faults from other disturbances. In the second case, the difference between the calculated and measured signals enables the relay to perform the classification. These approaches call for voltages and currents at all the terminals to be measured.

3.1 Differential power method
Another relaying principle uses the differential active power to discriminate between internal faults and other conditions. Instead of the differential currents, the differential power is computed and monitored. The operating signal is a difference between the instantaneous powers at all the transformer’s terminals. This approach calls for measuring the voltages at all the terminals but pays back by enabling avoiding the vector group (angular displacement between the current and voltages at different windings) and ratio compensation. The dependability of this method may be further enhanced by compensating for the internal active power losses — both in copper and in iron.

In addition, having the active power available, the method enables one to compute the energy released in the tank and to emulate the back-up protection both the accumulated and sudden pressure gas relays.

3.2 Multi-setting over-current principle
Severe internal faults may be recognized by the differential relay based only on the amplitude of the differential current without checking any extra conditions (unrestrained tripping). If the amplitude of the current is higher than the highest possible value under no-internal fault conditions (the inrush current, as a rule), then the relay trips without further analysis.

The classical unrestrained differential over current element must apply the threshold set above the maximum non-internal fault current. If so, internal faults denoted as class A is tripped by the over current element while all other faults of the classes B to D must wait to be detected by the restrained element. However, the internal faults of class B may be distinguished from external fault and over-excitation phenomena by the over current element working with the second lower threshold. If so, the internal faults of the category A are detected by the over current principle with the threshold. The internal faults of the category B are detected by the over a current element with the threshold if the inrush hypothesis is rejected by the other relaying principle such as the second harmonic restraint. The external fault and over-excitation conditions may not be checked at all since they are ruled-out be the over the current element. Similar reasoning applies to the faults of the categories C and D.

The principle of the multi-setting over a current element is implemented and represents a solution that can be placed between the traditional restrained and unrestrained differential functions. This approach enables reduction of the operating time particularly for the internal faults with medium levels of the fault current. This approach enhances dependability by speeding-up the operation and covering the low-current internal faults.

3.3 Phenomena specific approaches
By the phenomenon specific approach, we mean a relaying algorithm that restraints the relay from tripping only in one particular non-internal fault related situation (such as inrush) although some of the restraining algorithms occasionally deliver an extra blocking during other conditions as well. Flux based inrush restraint this relaying algorithm differentiates internal faults from the inrush and over-excitation conditions based on the calculated flux in the core. As its advantage, this approach tides together the cause of the problem (saturating of the core as a source of the current unbalance) with the phenomenon used for recognition (flux in the core). When invented more than fifteen years ago, the method displayed a disadvantage due to the lack of ability to measure the voltage signals. Nowadays, the voltages are easily available for digital transformer protection terminals which make this kind of relaying principles attractive.

3.4 Detection of external faults
In order to overcome dependability limitations inherent in the biased characteristic and enhance the performance of the differential relay, three approaches that modify the standard principle may be applied. Protective relaying is, however, to distinguish between internal faults and other conditions (pattern recognition), and consequently, to initiate or deny tripping (decision making). This brings the application of Artificial Intelligence methods as an alternative or improvement to the existing protective relaying functions.

3.5 Artificial Intelligence methods
Regardless of their digital implementation, numerical relays basically emulate their analog predecessors: they extract specified features of the signals such as magnitudes, active/reactive powers, impedance components, and compare the signals with appropriate pre-set or adaptable thresholds. Based on such comparisons they generate the tripping signal. The task of protective relaying is, however, to distinguish between internal faults and other conditions (pattern recognition), and consequently, to initiate or deny tripping (decision making). This brings the application of Artificial Intelligence methods as an alternative or improvement to the existing protective relaying functions.

4. OPTICAL CTS AND OTHER SENSORS
The optical CTS have many essential advantages over the classical CTS. Lack of saturation effect, which They are The DELTA-differential criterion which compares the increase of the differential current (with respect to its pre-fault value) with
the adequate increase of the restraining current. The modified single slope bias characteristic is applied for such incremental signals. The sequence of events principle that enables distinguishing between internal and external fault currents under saturation of the CTs. This criterion acts as the trip suppressor and blocks the relay when the external fault hypothesis gets confirmed. The saturation detector that detects considerable saturation of the CTs. The result of detection is used to control on-the-fly the slope of the biased characteristic, which is increasing the dependability of the differential relay.

5. FUZZY LOGIC APPROACH
The criteria signals such as amplitudes, harmonic contents, etc. are fuzzified in order to account for dynamic errors of the measuring algorithms. Thus, instead of real numbers, the signals are represented by fuzzy numbers. Advances in the area of measuring sensors will certainly contribute to the quality of power system protection. Since the fuzzification process provides a special kind of flexible filtering, faster measuring algorithms will help to avoid many problems with differential relaying, is the primary benefit apart from excellent electric isolation and absence of any flammable materials such as oil. Present-day optical CTs are of two types: a bulk optical CT which uses a ring-like glass sensor and an optical fibre CT which uses optical fibre as a sensor. The later kind displaying higher accuracy is of particular interest. The efforts in this area focus on overcoming the problems associated with the linear birefringence inside the fibres in order to prevent the decrease of sensitivity of the optical CT. The Rogowski’s coil, a current measuring device that produces a low power output but offers many advantages over the classical CTs, is another option for improving the operating conditions for transformer protection. Also, completely new measuring devices are under research. The integrated measuring unit for both voltage and current is a good example. The operating principle of it is based on Poynting’s theorem which defines how the electromagnetic energy in terms of the electric and magnetic field intensities at a point in space. The current is measured by sensing the tangential component of the magnetic field. The voltage is measured by sensing the radial component of the electric field in a well-defined region around the high voltage conductor.

6. CONCLUSION
Transformer experiences various faults in its working period like earth faults, over voltage, transient states. These faults can, therefore, because some damages to the internal elements of the power transformer which can then lead to improper functions and cause damages to the power system. This paper summarizes various protection schemes which help in preventing and importantly detect such faults that will be occurring in the power transformer. These techniques essentially help the transformer to differentiate the various faults that can occur and help to provide a remedy to it.

Artificial networks are the next in line to replace the old relaying techniques which are based upon the analog signals. These artificial intelligence methods help get the time to detect and clear the fault to reduce. The fuzzy logic approach is the very essential part of the protection which helps in the faster processing of signals and helps speed up the relaying process.

The fuzzy signals are compared with the fuzzy settings. The comparison result is a fuzzy logic variable between the Boolean absolute levels of truth and false.

Several relaying criteria are used in parallel. The criteria are aggregated by means of formal multi criteria decision making algorithms that allow the criteria to be assigned a weight according to the reasoning ability. The tripping decision depends on the multi-criteria evaluation of the status of a protected element (sound vs. faulty). Additional decision factors may include the amount of available information or the expected costs of relay disoperation.

7. REFERENCES
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