Differential Protection for Power Transformer Using Relay
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Abstract: In this paper, differential protection for power transformer using relay is presented. MATLAB / SIMULINK platform were used to analyze differential protection relay for a large power transformer. The basic approach is to protect the power transformer against internal faults and prevent interruption due to other operating conditions. The trip time for power transformer relay was seen at 0.05 sec. The obtained result illustrate that the proposed differential relay represents an appropriate action. The proposed relay was able to discriminate between inrush, fault and no-fault conditions.

Keywords: Differential Protection, Power Transformer, Matlab / Simulink, Inrush, Fault Conditions

I. INTRODUCTION

Power transformers are subject to different natures of transient disturbances including internal fault, magnetizing inrush, and external fault and through-fault currents. Harmonic-restrained differential relay is centred on the fact that the magnetizing inrush current has a large second harmonic component, and nowadays the above technique is widely applied. But this technique must be customized because harmonics occur in an ordinary state of power system and the magnitude of second frequency component in inrush state has been decreased because of the advancement in core steel.

Transformer protection methods that use its terminal behaviors are based on differential protection and the studies for improvement of transformer protection have focused on discrimination between internal short circuit faults and inrush currents in transformers [1]. If a power transformer experiences a fault, it is necessary to take the transformer out of service as soon as possible so that the damage is minimized. The costs associated with repairing a damaged transformer may be very high. The unplanned outage of a power transformer can also cost electric utilities millions of dollars. Accordingly, high demands are imposed on power transformer protective relays. The requirements include dependability (no missing operations), security (no false tripping), and speed of operation (short fault clearing time) [2].

There are cases in which the presence of differential currents cannot make a clear perception between fault and inrush. New relaying technique with high reliability is required for flexibility in spite of change of condition in power system.

Among the phenomena most likely to upset the current balance and cause the relay to malfunction are inrush magnetizing currents, stationary over excitation of a core, external faults in the presence of current transformer (CT) saturation, and/or CT and power transformer ratio mismatch.

Most of these approaches are liable in the case of magnetizing inrush with low second harmonic component and internal faults with high second harmonic component.

One of the most effective methods of protection to protect Power transformers is the Differential protection method by using differential relay circuits. This scheme is based on the principle of that the power input to the transformer under normal conditions is equal to the power output. By proper connection of the secondaries of current transformers (CT), under normal conditions, no current will flow into the relay coil. Whenever a fault occurs the current balance will no longer exist and relay contacts will close and release a trip signal to cause a certain Circuit Breakers (CB) to operate in order to disconnect the faulty equipment [3].

Digital differential protection is a developed idea of the old system of conventional differential protection which had made quite satisfactory solutions to the above mentioned problems.

II. DESIGN CONSIDERATION

A number of factors have to be taken into account in designing a scheme to meet these objectives. These include:

i. The matching of CT ratios
ii. Current imbalance produced by tap changing
iii. Dealing with zero sequence currents
iv. Phase shift through the transformer
v. Magnetizing inrush current

A. The Matching of CT Ratios

The CTS used for the Protection Scheme will normally be selected from a range of current transformers with standard ratios such as 1600/1, 1200/1, 600/1, 300/1, 200/1, etc. This could mean that the currents fed into the relay from the two sides of the power transformer may not balance perfectly. Any imbalance must be compensated for and methods used include the application of biased relays and/or the use of the interposing CTS [4].
B. Current Imbalance Produced by Tap Changing

A transformer equipped with an on-load tap changer (OLTC) will by definition experience a change in voltage ratio as it moves its tapping range. This in turn changes the ratios of primary to secondary current and produces out-of-balance (or spill) current in the relay. As the transformer taps further from the balance position, so the magnitude of the spill current increases. To make the situation worse, as the load on the transformer increases the magnitude of the spill current also increases. Consequently through faults could produce spill currents that exceed the setting of the relay [5].

C. Dealing with Zero Sequence Currents

Earth faults downstream of the transformer may give rise to zero sequence current, depending upon winding connections and earthing arrangements. Since zero sequence current does not pass through a transformer, it will be seen on one side only producing spill current and possible relay operation for an out-of-zone fault. To prevent such occurrence, zero sequence current must be eliminated from the differential scheme [6].

This is achieved by using delta connections on the secondary side of CTs that are associated with main transformer windings connected in star.

Where CT secondaries are connected in star on one side of a transformer and delta on the other, allowance must be made for the fact that the secondary currents outside the delta will only be 13 of the star equivalent.

D. Phase Shift through the Transformer

Having eliminated the problem of zero sequence currents through faults will still produce positive and negative sequence currents that will be seen by the protection CTs. These currents may experience a phase shift as they pass through the transformer depending upon the transformer vector group. CT secondary connections must be compensated to avoid imbalance and a possible malfunction [7].

E. Magnetising Inrush Current

When a transformer is first energized, magnetising inrush has the effect of producing a high magnitude current for a short period of time. This will be seen by the supply side CTs only and could be interpreted as an internal fault. Precautions must therefore be taken to prevent a protection operation. Solutions include building a time delay feature into the relay and the use of harmonic restraint driven, typically, by the high level of second harmonic associated with inrush current.

III. MATERIALS AND METHODS

A. Materials

Data for this research was collected from the Transmission Company of Nigeria (TCN), New Haven Area Transmissions Work Centre, Enugu. Their TR3 150MVA 132/33kV Power Transformer Differential Protection Scheme is the main case study. Transformer protection manuals from TCN library were also used during this research.

The transformer data is as shown below:

- Sub Station: New Haven T/S
- Manufacturer: ABB Transformer
- Rating: 60MVA, 132/33kV
- Frequency: 50Hz
- Cooling: ONAN / ONAF 75/100%
- Vector Group: YNd11
- % impedance at nominal Tap: 10%

Power system is a set of interactive components of generation, transmission, distribution and utilization. These work as a unit system to supply electricity to the consumer end from generation side. To have practical aspects of power system, SIMULINK toolbar of MATLAB is used. This provides variety of built-in components that could be easily connected with each other to form a complete system. The set of monitoring blocks provide ease to visualize the behavior of system at any time of simulation.

Before the design of transformer protective relay system, a model of the power transformer is required to generate the fault data required to calibrate the fault detector.

The Simulink Power system library browser in the Matlab / Simulink environment is used to model the power transformer protection system. The following components make up the fault simulation model:

a. Three-Phase Breaker
b. Three-Phase Source
c. Three-Phase Transformer
d. Three-Phase Fault
e. Three-Phase V-I Measurement
f. Subsystem
g. Three-Phase Series RLC Load
i. Scope
h. Current Measurement

B. Methods

This implementation is done using Matlab/Simulink environment. Figure 3.1 shows the simulated Conventional relay system built in Matlab / Simulink environment. In which a three phase, 150 MVA, 60Hz, 132/33kV, Δ/Δ power transformer were used.

The designed Conventional differential relay consists of two input portals Id1 and Id2, where, Id1 and Id2 are the output currents of the CT1 and CT2 respectively. These two input signals would be divided into three parallel paths in order to be analyzed. The first one will lead the
signal to enter a block named (Amplitude comparator). The second one will make the signal to be impressed in the harmonic test and send the result to a block named (Harmonic comparator).

Amplitude comparator block will compare the amplitudes of both input current $I_{d1}$ and $I_{d2}$. Then it will send an indicating signal to the comparator block showing the difference between the two signals. Harmonic comparator block will receive two signals from two blocks named (subsystem) and send the result to the comparator also as mentioned above. The subsystem block will analyze the input signal to investigate if harmonics exist in this signal. Figure 3.2 illustrates the contents of the subsystem block. In this block the signal will be analyzed to determine the percentage value of the second harmonic with respect to the fundamental frequency. This process will be carried out in the harmonic analyzer block. The harmonic analyzer block will make a percentage ratio comparison of the second harmonic with the fundamental. The decision of the harmonic comparator is designed to be taken only at the instant of transients.

Figure 1: Matlab/Simulink Model of Conventional Differential Relay

Figure 2: Differential Relay Subsystem
IV. RESULTS AND DISCUSSION

A. Results

The normal conventional relay was simulated in MATLAB using the Simpower system toolbox of SIMULINK. The external and internal fault cases are simulated. These currents are generated when the circuit breaker is closed to connect the transformer and external fault appears. The currents are measured by current transformers and then introduced to the relay.

Figure 3: The plot of the differential of conventional differential protection scheme when there is no fault

Figure 4: The plot of the Conventional Differential Protection when fault occur

B. Discussion

The tests are conducted with two situations, external faults and internal faults. Each test is with different harmonic components, including the 1st harmonic components, the 3rd harmonic components, and etc, and summations of different harmonic components.

In Figure 4.1 the differential current as well the restrain current are shown for switching on the transformer at t=0 and then applying and external fault at t=0.1 sec. The output and response time of the relay are shown in figure 4.1. However, the trip times that have been found include the waiting time of one cycle of the power frequency. The trip time was seen at 0.1sec, and cleared at 0.22 sec. It was also seen that the differential currents cannot make a clear perception between fault and inrush.

Also, after the switching of the transformer at t=0 sec, as shown in Figure 4.2, fault is created at 0.05 sec, the relay detected this increase using the harmonic and amplitude comparators and realized it as an internal fault. Consequently the transformer is isolated from the grid.

CONCLUSION

In this paper, an attempt has been made through the use of MATLAB/SIMULINK to analyze differential protection relay for a large power transformer. The basic approach is to protect the power transformer against internal faults and prevent interruption due to other operating conditions. The obtained result illustrate that the proposed differential relay represents an appropriate action. The proposed relay was able to discriminate between inrush, fault and no-fault conditions.

References

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