Winding Fault Detection of Transformer using Symmetrical Components Theory

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***Abstract*— Transformers are amongst the most costly equipment in power systems. A large research is done focusing on detecting failures of transformers before unexpected machine outage. Majority of the transformer faults are due to winding insulation failure. Several methods have been employed to detect winding faults like DGA, FRA, wavelet theory etc. This paper will mainly focus on detection of faults through symmetrical components theory especially use of negative sequence components. The differential protection is used to detect winding faults but it fails to detect below 10% of turns short. For detection of such low level of turn to turn faults, a sensitive method is needed. This method of using negative components theory is very sensitive. Negative sequence components are sensitive to unbalanced condition and this feature is used for fault detection.**

Keywords— Transformer differential protection, winding faults, negative sequence components

I. INTRODUCTION

Transformers are essential in any power system and their unexpected outage can cause total disruption of electrical supply which could result in major economic loss. For this reason, online evaluation of transformer is very important. The majority of faults on transformers are due to internal winding insulation failure. If not quickly detected, these turn-to-turn faults gradually result into more serious and costly to repair faults. Hence internal faults of transformer are one of the biggest topics of concern due to its low magnitude but high injures effect on transformers. According to IEEE standard it is nearly impossible to generate a protection scheme which provides protection against internal fault with required standard of sensitivity and time of response with exact position [1].

These winding faults are mostly a result of the degradation of the insulation system due to thermal, electrical, and mechanical stress, ageing, moisture, and so on [2]. Degradation means reduction in insulation quality, which will eventually lead to breakdown in the insulation which either leads to adjacent winding turns being shorted, or directly to a winding being shorted to the ground. A short circuit between turns can be due to mechanical forces, ageing, and deterioration of insulation due to overload conditions, loose connection or breakdown by impulse voltage [3].

The basic purpose of traditional transformer differential protection is to detect and limit damage caused by internal faults as early as possible. The main disadvantages of traditional differential protection are CT saturation, unwanted operation during external faults and inrush currents and bad sensitivity for low level internal faults. The first two faults can be handled with introduction of numerical technology [5]. But sensitivity for internal winding turn-to-turn faults did not improve much. This paper introduces the new protection principle, which will improve differential relay sensitivity for minor internal turn-to-turn faults.

II. DIAGNOSTIC METHOD FOR DETECTION OF INTERNAL FAULT OF TRANSFORMER

The new protection principle is based on the theory of symmetrical components, or more exact, on the negative-sequence currents. The existence of high negative-sequence currents is in itself an indication of a disturbance. The negative-sequence quantities are particularly suitable for different kinds of directional tests.

The new protection principle yields a very sensitive protection for low-level turn-to-turn faults. All such faults, which involve around 1% short-circuited turns, can be detected. The new negative-sequence-current-based sensitive protection is better than the traditional power transformer differential protection, which is based on the well-known bias–differential characteristic. The paper presents the principle of this new protection, and concludes with simulation results.

The concept that the secondary line current of transformer does not show much variation even if the fault is on primary or secondary side but primary current shows increase in magnitude of current in affected phase [5]. Secondary side line currents are not affected whether the fault is on primary or secondary side. This forms the basis for further calculations and hence secondary current if remains same can be compared with primary current and any difference in them will detect the fault. But for that secondary current has to be brought to level of primary current.

III. MATLAB SIMULATION

A. Simulation Model

A three phase, 100KVA, 400/200V, Y-Y is simulated in MATLAB Simulink. This transformer is initially tested for low level winding faults using differential relay. Then it is compared with the transformer using negative sequence component fault detection. The fault is made on R phase on secondary side of transformer. sThese two results are compared and better one is found out in next section.

B. Simulation Results

When turn-to-turn faults occur on primary side of transformer, there is an increase in magnitude of current in affected winding as compared to healthy condition. Fig 1(a) and 1(b) shows transformer healthy primary and secondary currents. This results in unbalanced system of primary currents. But the secondary side currents do not have much change as compared to transformer healthy condition. Fig 2(a) and 2(b) shows transformer primary and secondary currents when fault is on primary side.

In case of secondary side winding faults, the additional load produced by shorted turns results increase in magnitude of primary side winding current as compared to healthy condition. Again the secondary line currents do not show significant change in magnitude [4]. This can be seen from fig. 3(a) and 3(b) which shows primary and secondary currents of transformer when fault is on secondary side.

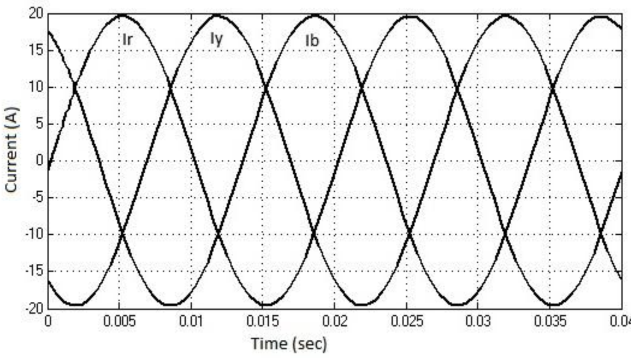

Fig. 1(a). Healthy transformer primary currents

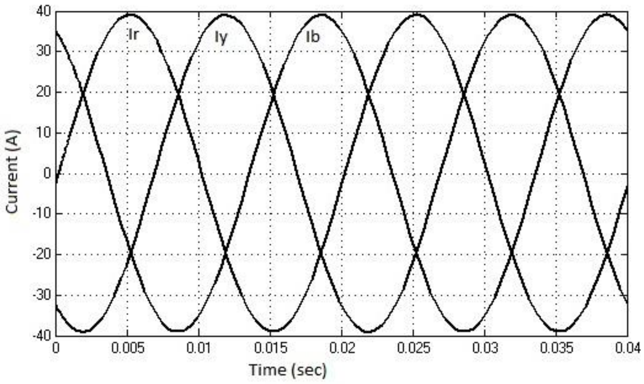

Fig. 1(b). Healthy transformer secondary currents

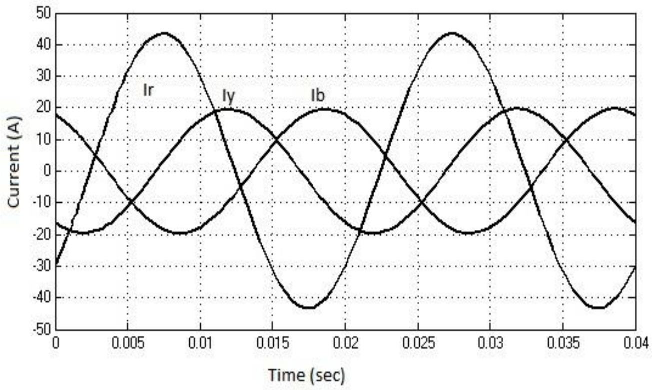

Fig. 2(a). Primary currents when fault on primary side

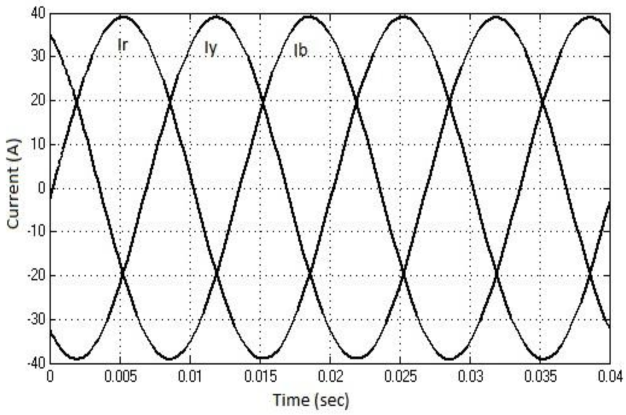

Fig. 2(b). Secondary currents when fault on primary side

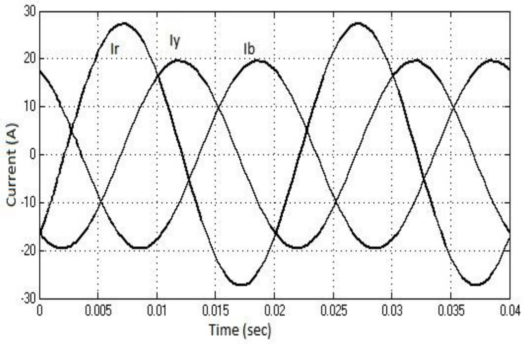

Fig. 3(a). Primary currents when fault on secondary side

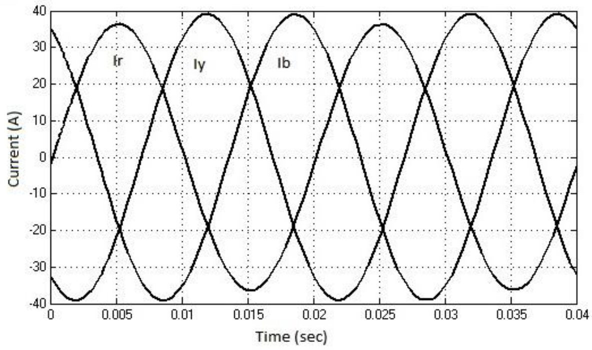

Fig. 3(b). Secondary currents when fault on secondary side

The traditional differential protection is unable to detect faults at 5% of shorted turns. This can be seen from Fig 4(a) and 4(b) which shows that restraining current is higher than the operating current.

So the new principle of negative sequence components is applied to detect inter turn faults. Negative sequence currents are present in unbalanced load conditions even if there are no faults. Fig 5 shows that if negative sequence components of primary and secondary currents are compared the result is very small.

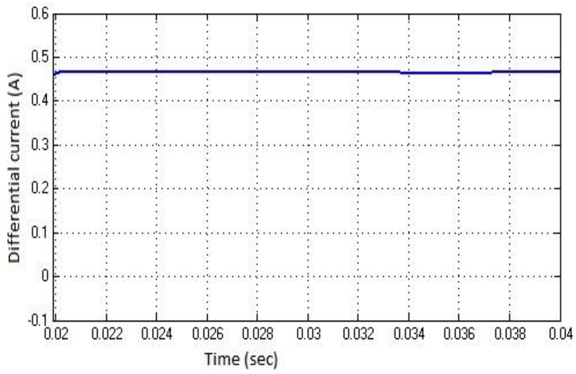

Fig. 4(a). Differential current in differential relay

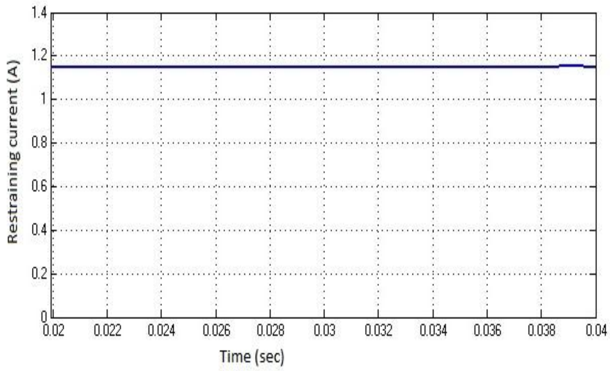

Fig. 4(b). Restraining current in differential relay

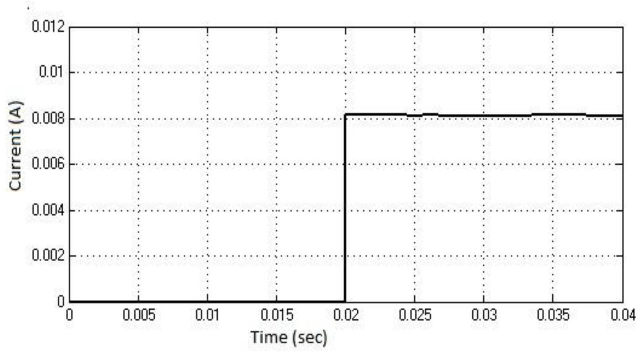

Fig. 5. Comparison of negative sequence components of primary and secondary components during unbalanced load condition

During fault conditions, the comparison of negative sequence components of primary and secondary currents show a large change as seen in fig 6.

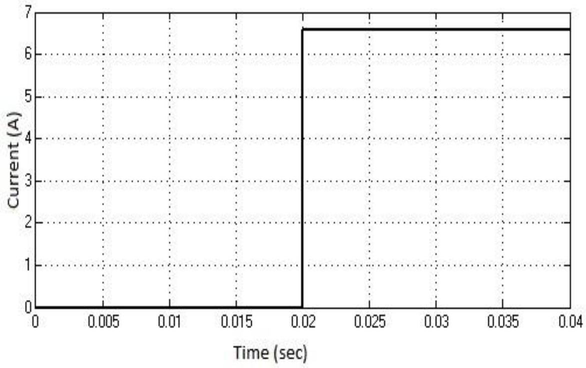

Fig.6. Comparison of negative sequence components of primary and secondary components during fault condition

IV.CONCLUSION

This paper presents the application of negative sequence components theory for detecting the occurrence of inter turn windings fault on three phase transformers. The proposed diagnostic method proves beneficial and sensitive over traditional differential relay. Simulation test results were presented which demonstrates the effectiveness of the above technique. This technique can also be used to apply to avoid the effect of CT saturation, for discriminating between internal and external faults and to avoid unwanted operation of differential reay due to inrush currents for future work.

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