ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 5, March 2016

Modelling and Simulation of a Differential Protection Relay against Internal and External Faults for a 3Ø Transformer

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ABSTRACT: This paper elaborates the development and fabrication of a cost–effective numerical relay without sacrificing accuracy and reliability. The notion proposes reduction in functionality instead of accuracy to reduce the overall cost. The project involves design of a Transformer Protection Relay against internal faults and external faults. The protection unit is implemented by differential current and over fluxing scheme using MATLAB simulation with instantaneous hardware monitoring and control using Proteus and dsPIC respectively.

KEYWORDS: Differential Protection, Differential Current, Bias Current, Restraining Region, Operating Region.

I.INTRODUCTION

Protective schemes are very much essential for Electrical Power Systems which are primarily used in the isolation of equipment faults and ensure swift protection of other equipment. In case of short-circuits or faults, the need for a Protective system is gravely felt. If not isolated, it would damage the power system. This necessitates the protection of every part of the power system. The protective system implements differential current along with over fluxing scheme against internal faults and over fluxing of transformers. However, the differential current can sometimes be substantial even without an internal fault. This is due to certain characteristics of current transformers (different saturation levels, nonlinearities) measuring the input and output currents, and of the power transformer being protected. With the exception of the inrush and over excitation currents, most of the other problems, can be solved by means of the percent differential relay [1].

Certain phenomena can cause a substantial differential current to flow, when there is no fault, and these differential currents are generally sufficient to cause a percentage differential relay to trip. The following factors affect differential current in a transformer and should be taken into consideration while using differential protection scheme to protect a transformer [3].

Inrush current, input surge current or switch-on surge is the maximum, instantaneous input current drawn by an electrical device when first turned on. Alternating current electric motors and transformers may draw several times their normal full-load current when first energized, for a few cycles of the input waveform [4].

Overexcitation of a transformer could cause unnecessary operation of transformer differential relays. This situation may occur in generating plants when a unit-connected generator is separated while exporting VARs [5]. When the primary winding of a transformer is overexcited and driven into saturation, more power appears to be flowing into the primary of the transformer than is flowing out of the secondary [6].

The effect of CT saturation on transformer differential protection is double-edged. Although, the percentage restraint reduce the effect of the unbalanced differential current, in the case of an external faults, the resulting differential current which may be of very high magnitude can lead to a relay male-operation. For internal faults, the harmonics resulting from CT saturation could delay the operation of differential relays having harmonic restraint [7].

II.MODELLING OF 3ϕ DIFFERENTIAL PROTECTION SCHEME

This relay model can be operated as an over fluxing relay, a percentage differential protection relay or both in unison. Percentage differential protective relays have been in service for many years [2]. Fig. 1 shows a typical

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differential relay connection diagram. In differential protection, operating current and restraining current is compared. The operating current (also called differential current)I_d, can be obtained from the phasor sum of the currents entering the protected element.

$$I_d = \left| \vec{I}_{W1} + \vec{I}_{W2} \right|$$

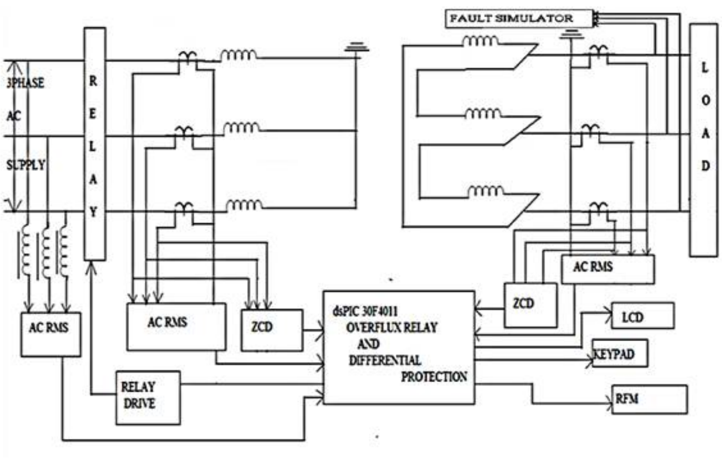

Fig.1. Differential power transformer protection diagram

Differential relays perform well for external faults, as long as the CTs reproduce the primary currents correctly. When one of the CTs saturates, or if both CTs saturate at different levels, false operating current appears in the differential relay and could cause relay male-operation.

III.MICROCONTROLLER BASED RELAY

A microprocessor based transformer relay scheme consists of several subsystems, such as, analog processing, analog to digital (A/D) conversion, digital processor, relay output, and power supply subsystems [6]. Fig. 2 shows a block diagram representing these subsystems.

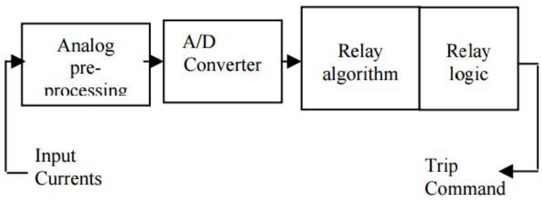

Fig. 2. Block diagram of a microcontroller-based transformer relay.

This scheme receives low level currents from each of the transformer phases via CTs [1]. From the block diagram we can see that the input analog signal is converted into digital signal so that the microcontroller will be able to detect the input and supply the trip command.

IV.RELAY CHARACTERISTICS [8]

A percentage differential element operates when the differential signal is above a constant pickup value:

$$I_{DIF} > P$$

And above a percentage of the restraining signal:

$$I_{DIF} > K \cdot I_{RST}$$

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Some relays may combine numerically, rather than logically, the pickup and restraining conditions:

$$I_{DIF} > \text{P} + \text{K} \bullet I_{RST}$$

The logic of the above equations yields a characteristic on the differential-restraining plane in the form of a straight line with slope K (Fig. 3a). This characteristic handles errors that are proportional to the restraining signal, such as CT errors or Current alignment errors.

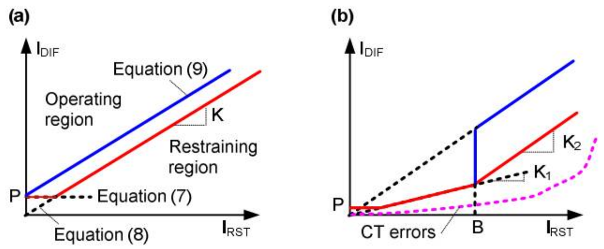

Fig. 3. Single-slope percentage differential characteristics (a); fictitiousdifferential signal due to CT errors and dual-slope percentage differentialcharacteristics (b).

Fig. 3b shows that the second slope (K_2) line can either cross the origin or connect to the first slope (K_1) line at the break point (B). The former implementation creates a true percentage differential characteristic, meaning the amount of restraint is a constant percentage of the restraining signal, but adds discontinuity at the break point between the lower and higher slope lines. The latter implementation avoids discontinuity at the break point but constitutes a variable percentage restraint. Both approaches are valid as long as the fictitious differential signal is kept within the restraining region of the characteristic.

V. RESULTS AND DISCUSSION

In the Fig 4, it shows the graph of Differential Current(I_d) Vs Bias Current(I_{bias})of the relay characteristics.

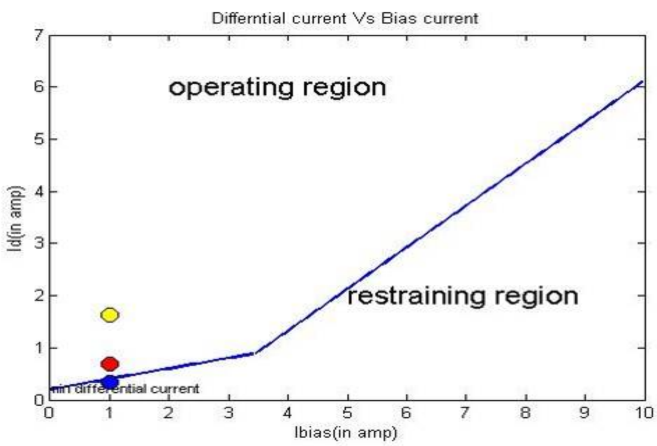

Fig. 4 Simulation ofI_d Vs I_{bias}

A system with an external fault in the red and yellow phases was considered for the purpose of analysis. It is seen from the Matlab simulation (in Fig. 4), that the position of phases R and Y are in the operating region depicting they are faulted. While the B phase in the restraining region is healthy.

The instantaneous hardware monitoring of the relay controlled by the dsPIC is shown below.

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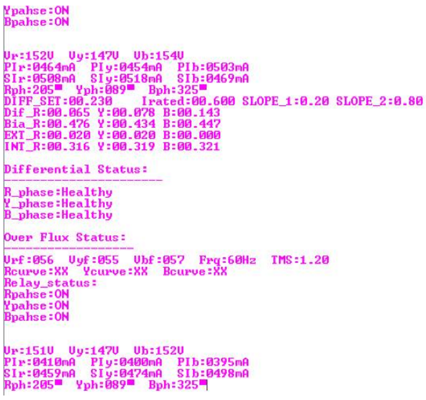

Fig. 5 Hardware monitoring when system is healthy.

Fig. 5 depicts the status of the three phase system which is healthy in all three phases, i.e., before the actuation of the fault.

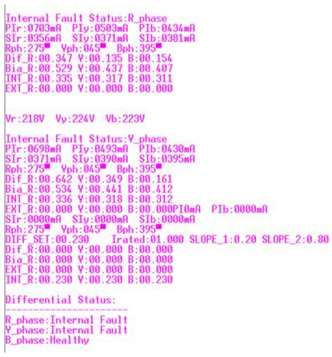

Fig. 6 Hardware monitoring when phased Y and R are faulted.

Fig. 6 shows the status shown while monitoring the hardwarewith an internal fault in the phases yellow and red with the blue phase being healthy.

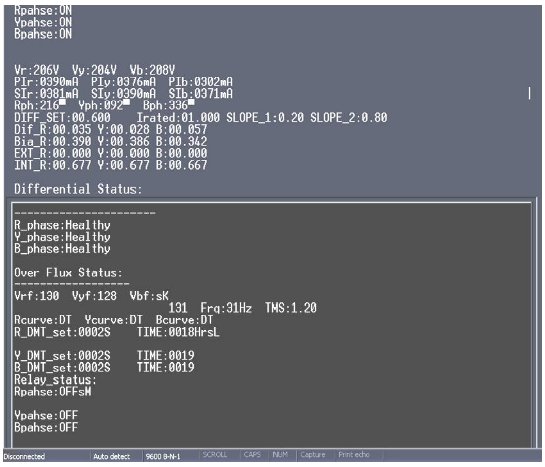

Fig. 7 Hardware monitoring showing the Overfluxing of the system.

Fig. 7 illustrates the Overfluxing statusat all phases. It is seen from the Fig. 7 that the system is healthy.

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VI.CONCLUSION

The designed relay is restraint to minimal currents developed from CT Saturation, Vector Group Compensation. It protects the power transformer from the effects of over fluxing and differential currents (Differential Protection). The relay is designed to operate at a high speed. It also has the advantage of instantaneous digital monitoring of faults that has occurred in the system.The three phase relay thus designed can be extended to be realized and installed at remote areas where a profound GSM technology could be integrated to achieve efficient power transformer protection with lessened manual monitoring, along with a backup protection.

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