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Biased Differential Protection Scheme for Transformer Protection Through Micro-Controller Based Relay

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Abstract—The paper explains the traditional method used for protection of transformer and deals with the implementation of the microcontroller-based relay for protecting transformer. Transformer protective relay should block the tripping during external fault or magnetising inrush and speedily operate the tripping during internal faults. Differential protection scheme is applied, which protects transformer from internal faults. Time delay is provided for magnetizing inrush current. Programming and simulation is done with the help of RIDE and PROTEUS.

Keywords*- transformer, differencial protection, microcontroller.*

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I. INTRODUCTION

The power transformer is major and very important equipment in a power system. It requires highly reliable protective devices, to minimize the frequency and duration of unwanted outages. The faults which transformer experiences can be categorized as external faults (overload, over voltage, over current, external short circuits and reduced system frequency),internal fault(fault between line to ground, line to line, inter-turn fault), incipient fault(poor electrical connection, core fault, failure of coolant, regulator faults, bad load sharing between transformer). Proper protection is needed for economical and safe operation of electrical power system. Power transformer protective relay should block the tripping during external fault or magnetizing inrush and speedily operate the tripping during internal faults. The foremost objective of the paper is to simulate microcontroller based relay for protection of transformer and its merits over the traditional method of protection.

In 2002, A. Rafa, S. Mahmod, N. Mariun, W.Z. Wan Hassan, and N.F. Mailah presented Protection of Power Transformer Using Microcontroller-Based Relay [1]. In 2014, Harjit Singh Kainth, Gagandeep Sharma proposed A New method for differential protection in Power transformer [2]. In 2015, Nikhil Paliwal and Dr. A. trivedi analyzed digital differential protection for modern transformer [3].

In comparison with electromechanical and solid-state relays, microcontroller based relay perform real time computation which leads to enhancement in relay performance, facilitating faster, more secure protection for power transformer. This paper proposes a simple and effective technique for the protection of transformer, i.e. percent differential protection through microcontroller based relay.

The relaying function implemented includes a percentage differential protection with time delay, so that the relay does not operate in case of inrush current condition. Programming and simulation is done with the help of RIDE and PROTEUS.

II. DIFFERENTIAL PROTECTION SCHEME

Differential protection scheme provides protection to the transformer against internal fault; such as phase-to-phase, phase-to-ground and fault in tap changer.

Figure. 1 shows a simple differential protection scheme of a transformer (also known as merz-price scheme). The CTs are used on both the sides to step down the current entering and leaving the transformer.

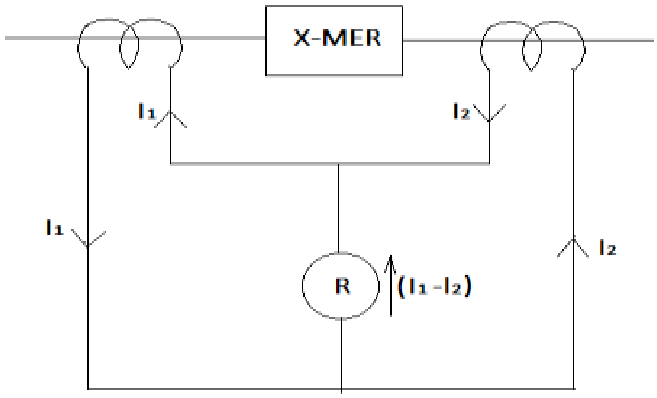

Figure 1. Simple differential protection

Under normal condition, the current I1 and I2 will be same. Thus spill current through relay will not operate. In case of an internal fault, I2 will become zero. Now, the sill current through relay will be equal o the internal fault current ($I_{f\,,\,int}$). And thus relay will operate to open CB, so as to isolate transformer from the system to avoid further damage.

Ideally, in case of external fault, I1 and I2 will be same, which will be equal to the external fault current ($I_{f\,,\,ext}$). Thus the spill current will be zero and relay will not operate.

So the zone of protection in case of differential scheme is only the equipment across which the CTs are placed.

III. ACTUAL BEHAVIOUR OF DIFFERENIAL PROTECTION SCHEME

So far we have discussed the performance of differential scheme assuming that the CTs are ideal. But practically there arises problem due to following reasons.

- CTs phase angle error
- Mismatch in the CT ratio on the primary and secondary side of the transformer and hence the characteristics vary.

Now, ideally for 'through fault' (external fault), the CT secondary on both the side of transformer will have the same value of current, but practically due to the above mentioned problems, the current will no longer be same. Rather, the CT error will aggravate as the primary current increases. And thus the spill current builds up as the external fault current goes on increasing. Figure. 2 shows rise in spill current with respect to though fault current.

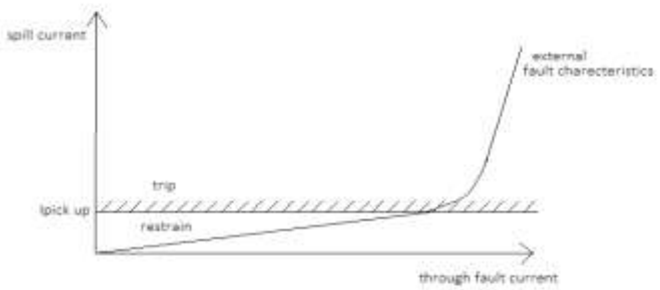

Figure 2. Charecteristics of simle differential relay

IV. TRADITIONAL METHOD FOR IMLIMENTATION OF PERCENTAGE DIFFERENTIAL SCHEME

Now, to overcome the above mentioned problem, restraining torque proportional to the 'through fault' current has to be applied. To achieve this, simple differential scheme was modified to percentage/biased differential protection scheme [4]. Figure. 3 shows the diagram of percentage differential relay.

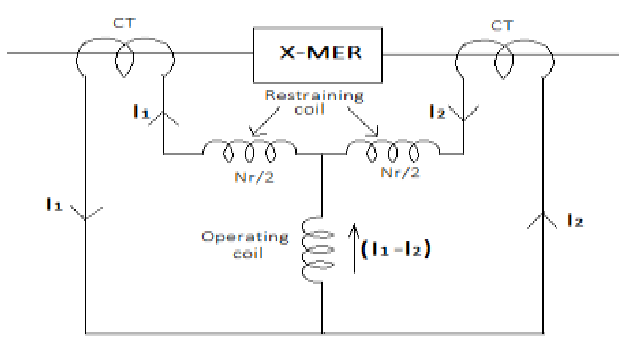

Figure 3. Percentage/biased differential relay

The implementation of restraining coil will be clearer by looking at Figure. 4.

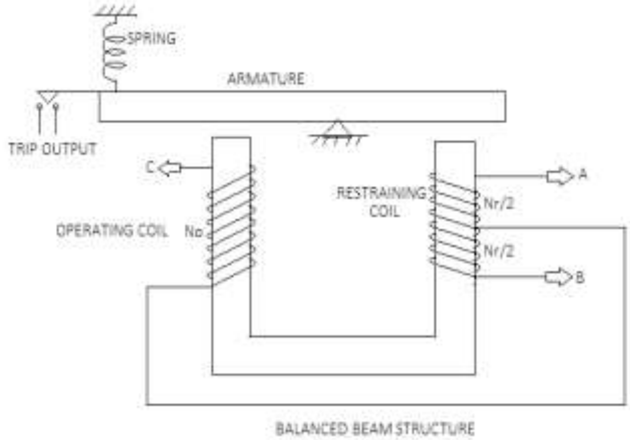

Figure 4. Balanced beam structure

Ampere-turn acting on left side of restraining coil = $\frac{N_r}{2} I_1$

Ampere-turn acting on right side of restraining coil = $\frac{N_r}{2} I_2$

Total = $\left[\frac{N_r}{2}(I_1 + I_2)\right]$

Restraining torque = $M\left[N_r \frac{(I_1 + I_2)}{2}\right]^2$

Ampere-turn acting on operating coil = $[N_o(I_1 - I_2)]$

Operating torque = $M\,[N_o(I_1 - I_2)]^2$

Relay will give trip signal if operating torque is greater than restraining torque.

That is $M\,[N_o(I_1 - I_2)]^2 > M\left[N_r \frac{(I_1 + I_2)}{2}\right]^2$

$$(I_1 - I_2) > \frac{(I_1 + I_2)}{2}$$

Where, M = constant of proportionality

K = represents the setting of restraining coil.

To check whether the implementation and operation of restraining coil is justified or not, we consider the following conditions.

1. External fault.

   In case of external fault, the current I1 and I2 flowing from the left and right side of the restraining coil has the same direction.

   So naturally, the current adds up and thus restraining and thus restraining torque is generated. Now, no matter what is the current in operating coil due to CT error, its quit natural that the will be less than the current in the restraining coil.

   Hence, the armature will bend towards right (see fig). And we can conclude that restraining coil was successful in avoiding unnecessary tripping of CB in case of external fault.

2. Internal fault.

   In case of internal fault and multi-machine system, the direction of current in both sides of the restraining coil will be opposite to each other, hence cancelling the effect of restraining torque.

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Now the operating coil will have current in same direction, making the operating torque effective enough to trip the CB.

If a three phase transformer is connected in delta-star fashion (as shown in Figure. 5), then the CT connections of primary and secondary winding will be connected in star and delta fashion respectively.

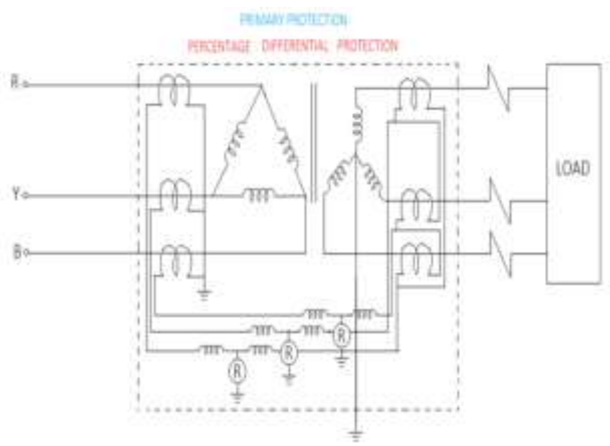

Figure 5. Three phase percent differential protetion scheme

Percentage differential protection is preferred over simple differential protection. Since it provides a restraining torque proportional to the ‘through fault’ current. And the operating torque still being proportional to the spill current.

V. MICROCONTROLLER BASED RELAY

The role of ‘balanced beam structure’ can also be performed by simply writing a program in a microcontroller[3]. Replacement of mechanical relay (balanced beam relay) by microcontroller relay is beneficial, and the merits are pointed out below.

- Microcontroller relays are compact and are more reliable.
- One microcontroller relay can be used to provide complete primary and back-up protection scheme to the transformer (no need of additional equipments).
- The VA burden of microcontroller based relay is small compared totraditional relay. So current transformers (CTs) with lower VA rating can be used.
- Microcontroller relay can communicate the fault status and Circuit Breaker (CB) open/close status to PMS (Power Management System) / SCADA (Supervisory Control And Data Acquisition).
- Microcontroller relay can measure current in all phases, voltage in all phases, power consumption in all phases, power factor, frequency, etc. No separate CTs or PTs are required for measuring electrical parameter.

VI. INTERFACING WITH MICROCONTROLLER

Before directly sending the signal to the microcontroller for being processed, few tasks have to be done so that the signal becomes compatible with the microcontroller. The various steps are described in Figure. 6. First of all, the current signal coming from the CT has to be converted in voltage form and then amplified. Since our signal is AC and microcontroller works on DC, so the signal needs to be converted to DC with the help of rectifier.

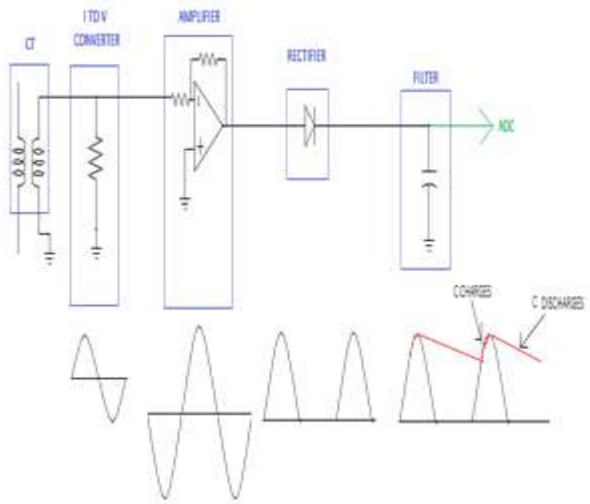

Figure 6. Circuit diagram showing conversion of primary current to the digital form compatible with microcontroller

An ADC 0808 will convert this analog signal to the digital signal. And then our signal will be ready for being processed by microcontroller as shown in Figure. 7. Pin named as A, B and C selects which input data has to be be selected, because ADC 0808 can convert only one signal at a time. We use ALE to latch in the address. SC is for start of conversion. EOC is for end of conversion and OE is for end of conversion (READ). IC 555 gives the clock pulse.

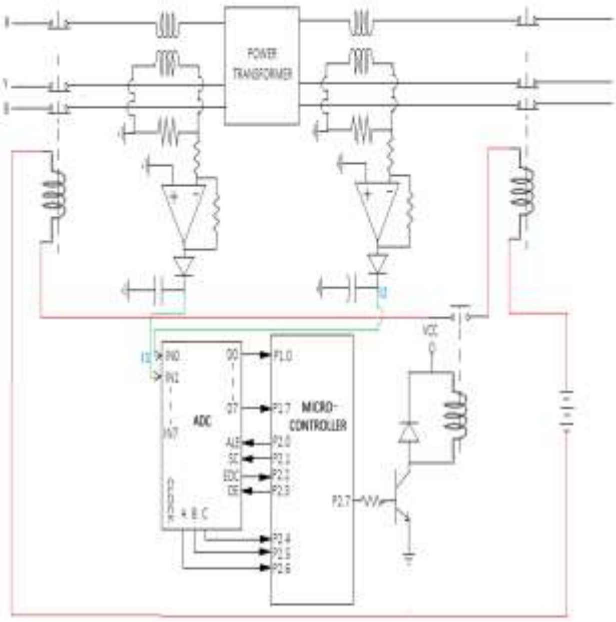

Figure 7. Interfacing with microcontroller

Instead of the simple capacitor, one can use Teflon capacitor which gives removes the ripple more efficiently and gives better DC output. Again instead of half have rectifier,

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full wave bridge rectifier can be used to convert AC TO DC. For the interfacing between hardware and software, MAX 232 is placed, so that software simulation with different faulty conditions can be checked before the hardware is applied to real conditions. Relay is placed parallel to the diode which will energize its coil when faulty condition arises.

When there is faulty condition, signal is send to P.2-7, due to which transistor base completes its circuit and current flow through collector to emitter, and thus the coil of relay gets energized and circuit breaker is opened.

Thus once the signals become compatible with microcontroller, program written in microcontroller processes the signal and accordingly trip signal is issued if there is any faulty condition detected.

VII. ALGORITHM

Figure 8 shows the flow chart [1], which explains that first of all the microcontroller has to read the primary and secondary currents which needs to be processed. Then the operating torque and restraining torque is calculated. There is no need of any predefined value, rather a condition has to be checked that if operating torque is greater than restraining torque, then microcontroller sends the trip signal, otherwise it is considered as external fault and microcontroller need not take any action and read the next real time value of primary and secondary current. A time delay has to be provided so that the relay does not operate for magnetizing current, other methods to block the tripping of circuit breaker in case of inrush current are wave shape reorganization, second harmonic restrain [2].

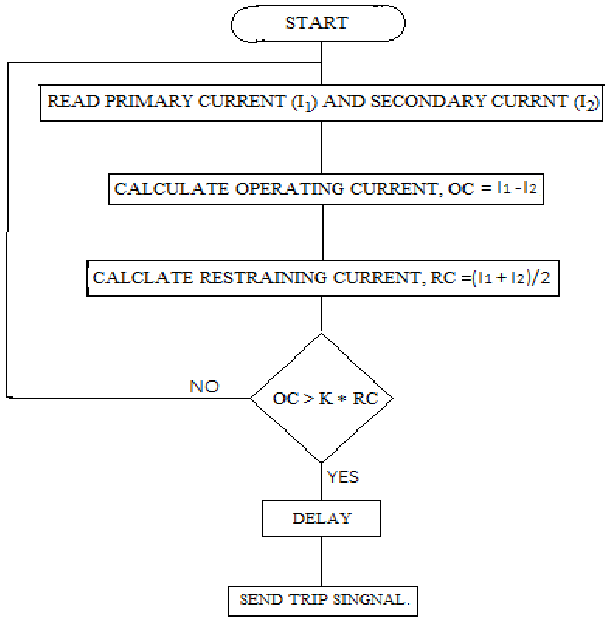

Figure 8. Flow chart for percent differential protection

VIII. SIMULATION AND STUDY

Figure. 9 shows the simulation model of microcontroller in PROTUES, in which programming is done for differential protection with the help of RIDE software. The first block shown is of ADC-0808 which converts analog to digital signal and is interfaced with microcontroller. Channel A, B and
C selects the input pin in case of multiple inputs, after getting converted into digital signal, microcontroller takes care of giving the trip signal in case of faulty condition[5].

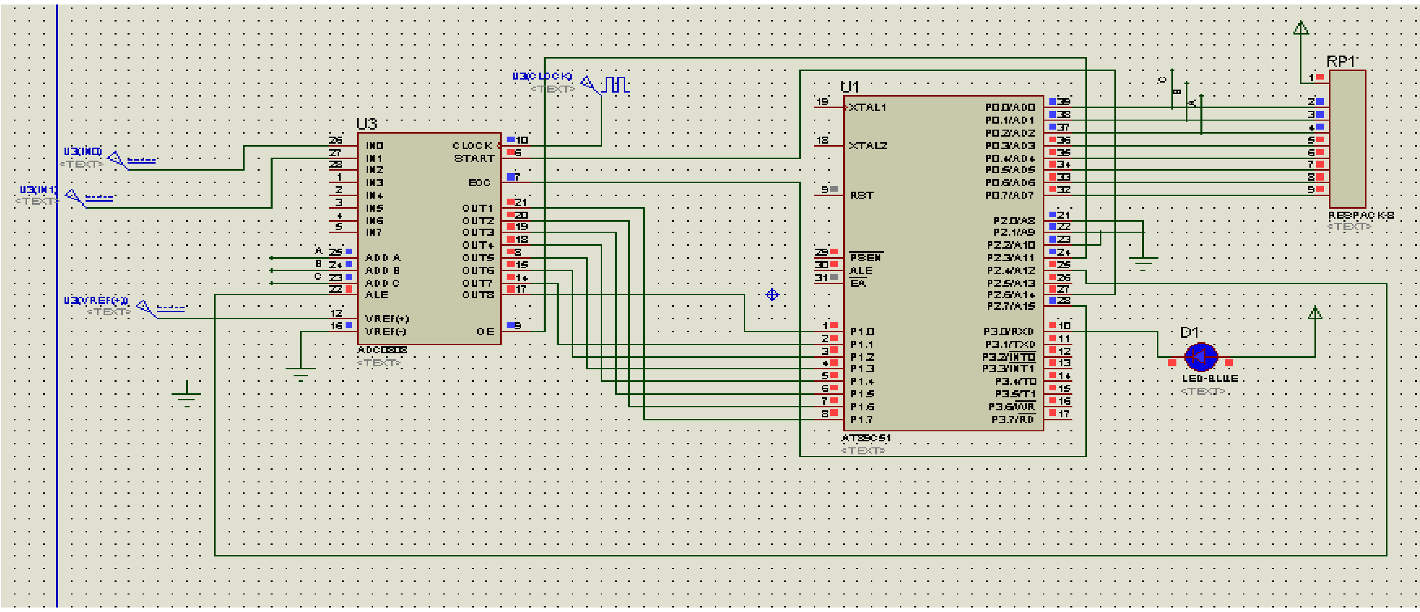

Figure 9. PROTUES simulation for percent differential protection

TABLE 1. STATUS OF LED AT DIFFERENT CONDITIONS

	CONDITION	OUTPUT AT P3.0	STATUS OF LED
X>Y	FAULTY	0	GLOW
X<Y	NORMAL	1	OFF

The status of LED is tabularized in Table. 1. In case of hardware implementation the led will be replaced by driver circuit as shown in Figure. 7. The driver circuit will energize the trip coil if the fault condition arises and then the trip coil will open the circuit breaker which will avoid the further damage of transformer. The programmer will transfer the program written in RIDE software to the microcontroller.

IX. CONCLUSION

Thus we can conclude that the microcontroller relay will be proved efficient for the protection of transformer. And it is cost effective since VA burden of it is small compared to electromagnetic relay. So current transformers (CTs) with lower VA rating can be used. Microcontroller being compact and reliable can be applied in power system. Also it can measure current in all phases, voltage in all phases, power consumption in all phases, power factor, frequency, etc. No separate CTs or PTs are required for measuring electrical parameter. The CTs and PTs used for protection are sufficient for measuring these electrical parameters.

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