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Current Protection Scheme for Transformers using the Combination of Digital Differential and Microcontroller

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Abstract

The use of transformer protection in electric power systems is very important and critical as transformers are very expensive and they are needed for efficient transportation of electricity to consumers. This paper is aimed at using differential current protection scheme of transformer in combination with microcontroller as its differential relay responsible for sending trip signal when there is fault conduction in the protected zone to the relays responsible to open the circuit. The system is efficient in transformer protection, gives better isolation, as there is fault detection and quick response time to isolate the transformer from the network in other to avoid break down of transformer insulation.

Key words—Transformers, differential current protection, microcontroller, relays, fault conduction.

1.0 Introduction

Electricity demand has become an important necessity in running the activities of societies having major concerns on how to make its delivery constant and reliable with little or no interruptions. This can be achieved with proper maintenance and protection of the equipment or devices used in the generation, transmission and distribution of this electricity. One of such devices is transformers used in transmission and distribution substations.

Transformers are very important devices to electrical power system as they are very critical in the efficient and safe transportation of electricity to consumers. They can be step-up transformers used for stepping up voltages for transmission of electricity in transmission substations and step-down transformers, used in stepping down voltages for distribution at distribution substations. Sometimes even with proper maintenance faults may occur internally on the transformers. These internal faults could be over voltage fault, over current fault or may even be temperature based. Each of these faults have different protection scheme necessary to prevent them from occurring or clear or keep them to the barest minimum when they occur.

2.0 Review of Differential Current Protection Scheme Transformer

Various researches and works have been done in the differential current protection scheme of a transformer with respect to a microcontroller based relay system. Sarfaraz et, al.(2015) designed a differential current protection of a single phase transformer using Arduino with voice alert. The Arduino sends a trip signal to the relay according to predefined program. When the relay is activated by the Arduino the relay will activate the voice alert circuit and after three consecutive alerts, a trip signal is sent to the relay by Arduino.

Bashi et, al.(2002)used Hall Effect current transducers in their design instead of CTs to process the current signal since they have wider range of frequency operation and directly gives voltage equivalent to the current signal. This eliminates the need for current to voltage conversion as the microcontroller used only accepts voltage signals. Ochieng',(2010) designed a microcontroller based power transformer protection system which uses a current sensor as the interfacing instrument between the power transformer and the pic16f690 microcontroller. The current sensor does not offer a fast sensing speed as needed and transfer the signal to the microcontroller and also it cannot be used to reduce the amount of currents in such a way their secondary side currents are equal so as to quickly detect fault when there is difference in the current in both windings of the transformer. A device with a faster and efficient sensing speed such as the current transformer should be introduced to solve the limitation of the current sensor**.** Kajal et, al. (2016) in their implementation of the differential current protection scheme design used a PIC 16F877A microcontroller which is a simple and compact circuit having the advantages of an inbuilt ADC that converts analog to digital values, gives fast response as compared to microprocessor and consumes less power. layne S. et, al.(2016) in their design of transformer differential protection used a SEL-787 relay which is connected to the primary and secondary side of the transformer, comparing current from both sides and cuts the supply when fault occurs due to imbalance of the currents.

3.0 Digital Differential Current Protection Scheme of Transformer

This paper, deals with the implementation of a digital differential current protection scheme of a single phase transformer using a microcontroller as the differential relay. The basic idea of the differential current protection scheme is to provide protection to the transformer if any fault occurs in the protected zone that will cause an imbalance in the differential currents. The output power in a transformer is equal to that of the input power hence, for differential current protection the current which is reduced to measureable value by the current transformers at the primary and secondary sides of the transformer must be equal. An increase or decrease in this current would cause a trip signal to be sent to the relays which would open the circuit in the system.The current transformers (CTs) are uniquely matched so as to achieve the balanced differential current and opposite in polarities at their secondary sides. Only imbalanced or non-zero differential current will flow through the operating coil of the differential relay which would be substituted with a microcontroller that sends a trip signal to the relays needed to open the circuit.The CTs installed at both the primary and secondary sides of the protected transformer have different turn ratios and as such must be carefully selected also considering its magnetizing characteristics. The differential protection scheme is concerned with the faults that arise from associated difficulties such as the magnetizing inrush current and the CTs mismatch and saturation. The magnetizing inrush current is a phenomenon that occurs in a transformer when the magnetic field into its primary side experiences and abrupt or sudden change. It usually occurs during initial energization of the transformer even when the secondary side has no load connected to it and has its current a lot higher than the rated current. It is transient in nature so it lasts for just a few seconds and does not cause any permanent damage to the transformer. Even still, it causes a false differential current which is capable of tripping the differential protection and interference with the proper operation of some circuit elements such as circuit breakers or fuses as well as arcing and failure in primary circuit component like switches.

CTs errors due to saturation or mismatch have an adverse impact on protection functions or devices and hence on the system stability. The CTs mismatch occurs when the primary ratings of CTs at the primary and secondary side of the transformer do not exactly match the rated currents of the transformer. This current mismatch can create a small differential current which is dependent on the amount of the mismatch. CTs Saturation also is a problem associated with the effective operation of the CTs. When this occurs to one or both CTs, there is a false differential current that appears at the differential relay which could cause mal-operation of the differential relay. The saturation can be avoided by increasing the sizes of the CTs hence decreasing the rate which the CTs would get saturated.

3.1 Components Used

Some of the major components needed are listed below:

- Power transformer
- Current transformer
- LCD 20x4
- PIC 16F8877A microcontroller
- Relays
- Loads: 60Wx2, 100W
- Voltage sensor
- Voltage regulator
- Bridge rectifier

3.2 Work Principle

The transformer to be protected has different taps which are used for different function. One of the taps is used to provide power to the microcontroller. The current which is an alternating current is converted to direct current using a bridge rectifier and the voltage is regulated down to the required value or the microcontroller using a voltage regulator. The current transformers which are chosen to specifically match the characteristics and current ratings of the power transformer are connected at both the primary and secondary side. They are also used to reduce the currents to values which can be a measured by the microcontroller.

The microcontroller is used as the differential relay and as a control unit. As a differential relay it is used to compare the currents from the CTs at the primary and secondary side of the protected transformer and then sends a trip signal to the relays required to open the circuits when there is an occurrence fault due to the flow of non-zero or imbalanced current. As a control unit, it is used to monitor and control the working activities of some components such as the voltage sensor, display and relays.

The relays are connected to the source or primary side of the transformer to cut off supply if the faultis from that region and to the secondary side of the transformer to open the circuit in the case of overload or short-circuiting. The LCD display is used to display the differential current values of the transformer and also to monitor the voltage and current level of the system as well.

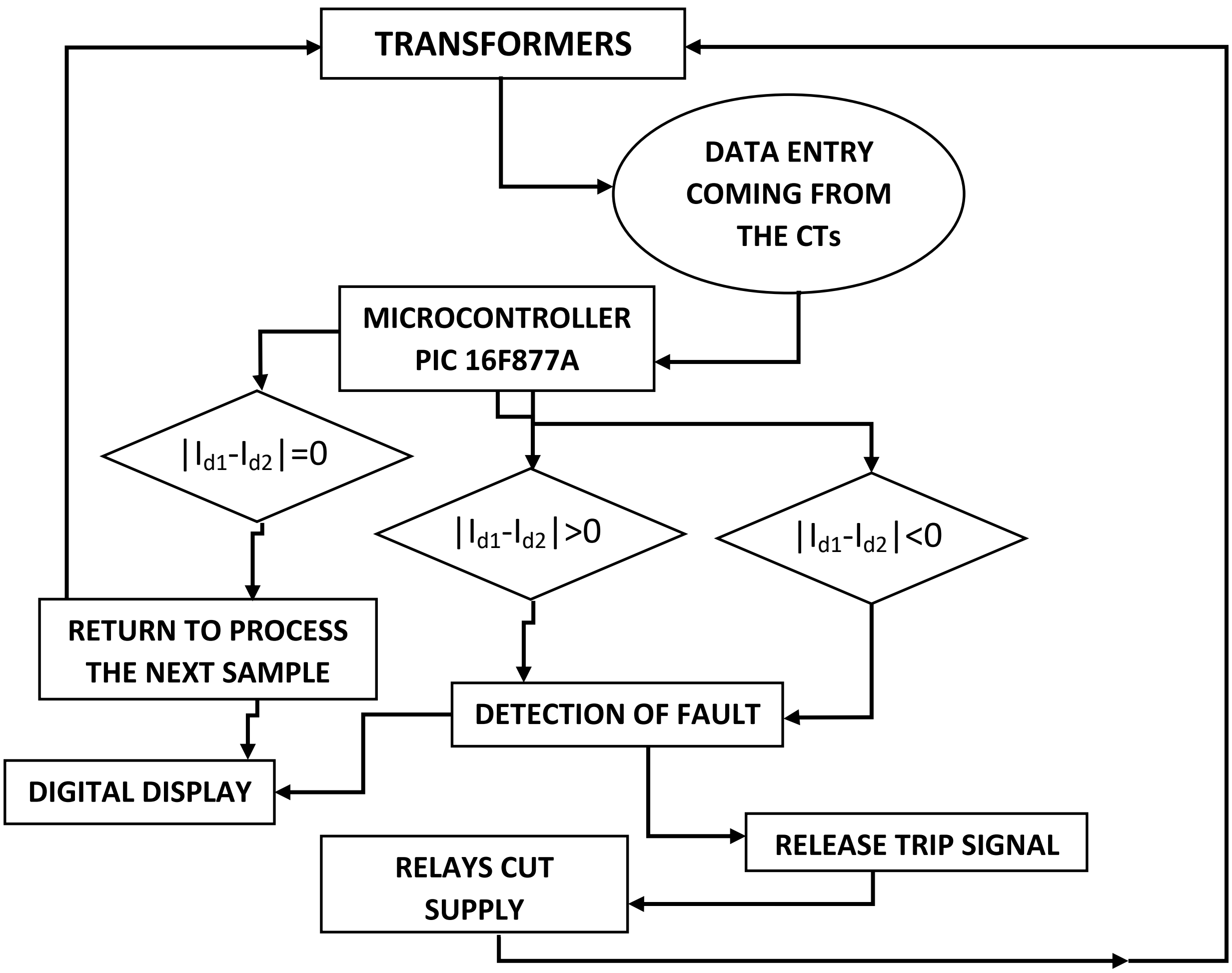

Figure1. Flow chart representation of the differential current protection working principle

The flow chart above is a brief description of how the differential protection scheme works using a microcontroller as the differential relay.

4.0 Simulation and Analysis

Differential current protection scheme can be designed using simulation technique in MATLAB environment to describe the working characteristics of the system which is how it should operate and behave when the differential current is non-zero. In this MATLAB simulation, a subsystem is designed to act as the relay with logic gates, Relational operator and summer as the major components that determine the state of the differential current.

These states are:

$|I_{d1} - I_{d2}| < 0$: trip signal is sent

$|I_{d1} - I_{d2}| > 0$: trip signal is sent

$|I_{d1} - I_{d2}| = 0$: trip signal is sent

Below shows the block diagram of the system and the characteristics of fault due to inrush current from the scope.

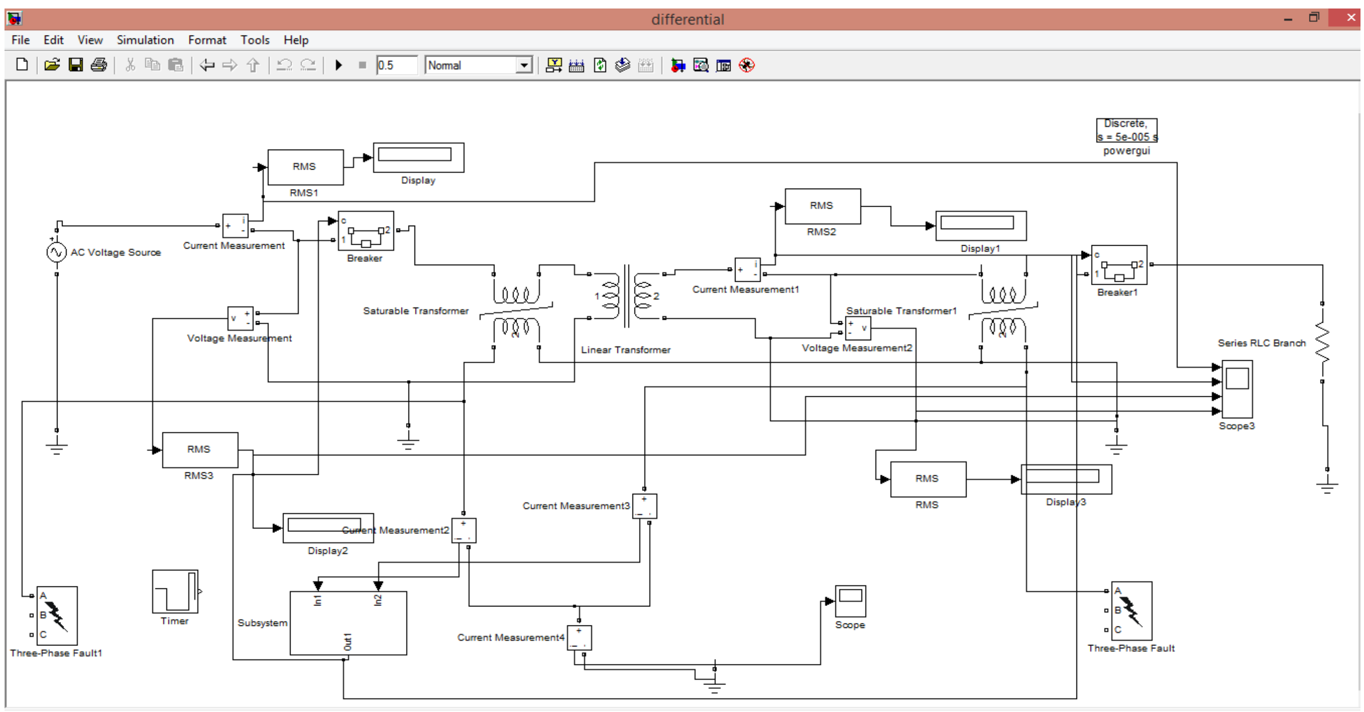

Figure 2 Simulation of differential current protection using MATLAB

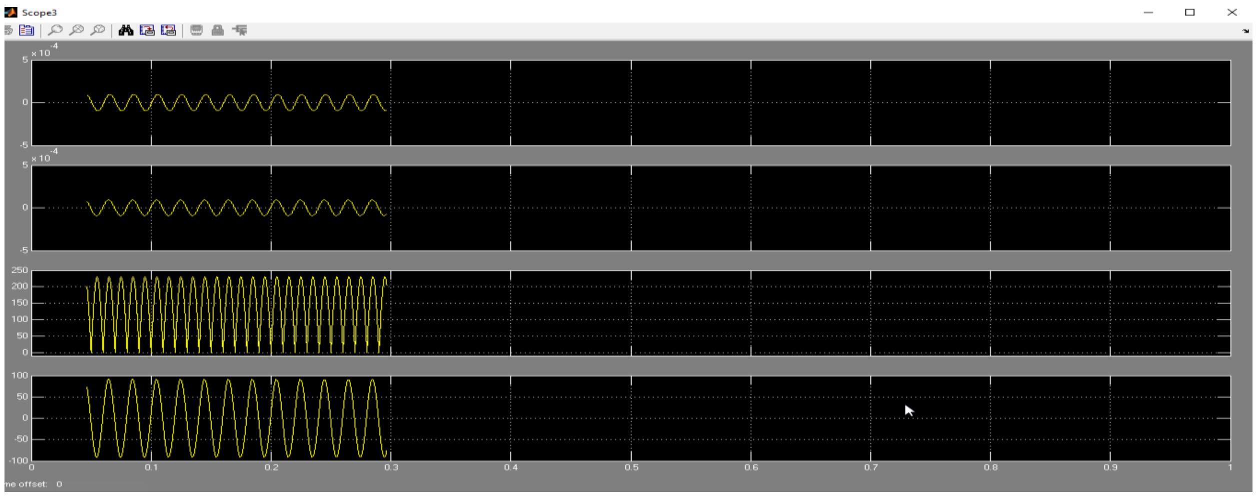

Figure 3 Output from first scope of voltage and current readings

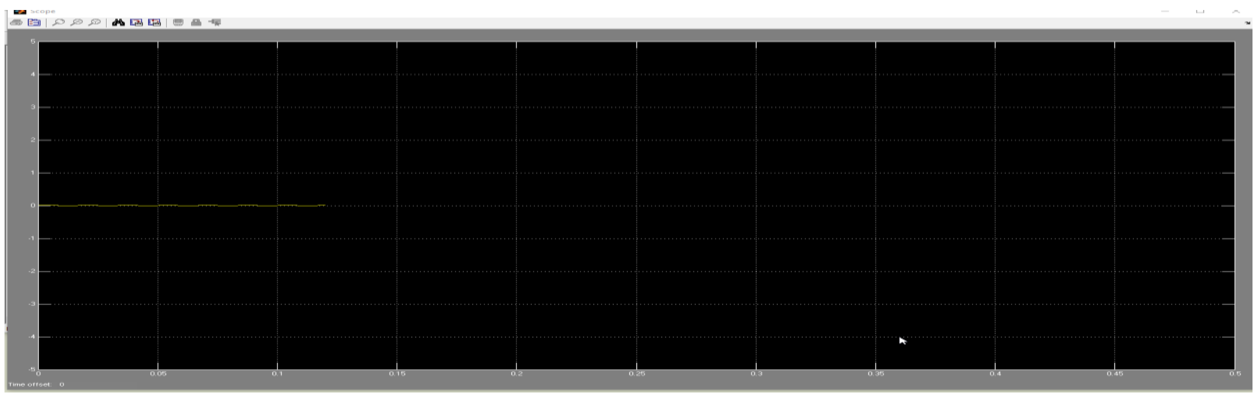

Figure 1 differential current output from second scope

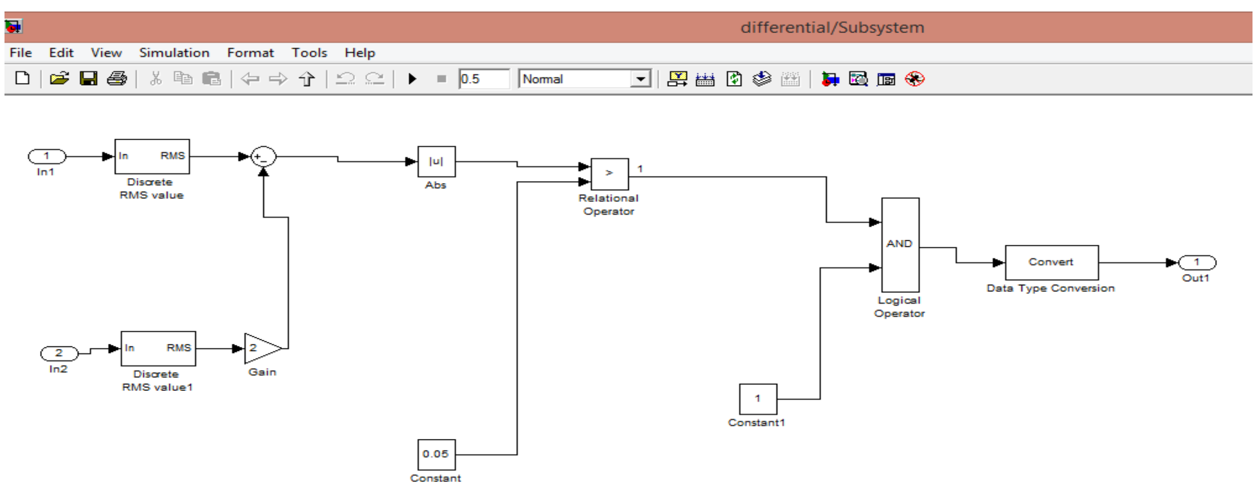

Figure 4 Simulation of differential relay subsystem using MATLAB

When the circuit above is simulated the current and the voltage sensed by the current and voltage sensors respectively are shown using a display and a scope. The saturation transformer (STs) acts as the current transformer which is used to sense the current values from both the primary and secondary side of the transformer. These sensed values are measured by the current sensors acting as ammeter and are displayed.

Faults was introduced with a timer that determines how long the fault would last from both the primary and the secondary side of the transformer which when detected by the differential relay send a trip signal to the circuit breaker to open till the fault clears and the closes back.

4.1 Simulation Analysis

The first and second graph of the scope represents the current graphs for the primary and secondary side of the transformer respectively. This indicates the current readings from both sides when the current transformer is in normal operating condition. The differential current from both saturable transformers is displayed in another scope.The third and fourth graph on the first scope represents the primary and secondary voltages respectively and indicates the voltage readings from the transformer.

The differential relay subsystem is designed to have a set limit of 0.05A which is value to which the differential current should not exceed. The differential current output readings when the transformer is in its normal operating condition is displayed in the second scope.

5.0 Result and Discussion

From the simulation carried out the following data were gathered with respect to the input parameters used;

Table 1. simulation parameters and values

Parameters	Input voltage (220V)	Output voltage	Input current	Output current	Differential current
Readings from simulation	203V	75V	$6.774e^{-5}$	$5e^{-5}$	0

The parameters for the components used in the simulation are given below;

Power transformer;

V_1 - 220V, V_2 - 440V

Norminal power and freq. [P_n(VA) F_n(H_z)]: [250 50]

Winding 1 parameters [V_1(V_{rms}) R_1(pu) L_1(pu)]: [220 0.02 0.08]

Winding 2 parameters [V_2(V_{rms}) R_2(pu) L_2(pu)]: [440 0.02 0.08]

Magnetization Resistance and Reactance [R_{in}(pu) L_{in}(pu)]: [500 500]

Breaker

Breaker Resistance $R_{in}(\Omega)$ – 0.01

Initial state [0 for ‘open’, 1 for ‘closed’]

Snubber resistance $R_s(\Omega)$ - $1e^6$

Saturable transformer 1

Norminal power and freq. [P_n(VA) F_n(H_z)]: [250 50]

Winding 1 parameters [V_1(V_{rms}) R_1(pu) L_1(pu)]: [200 0.02 0.08]

Winding 2 parameters [V_2(V_{rms}) R_2(pu) L_2(pu)]: [40 0.02 0.08]

Saturable Transformer 2

Norminal power and freq. [P_n(VA) F_n(H_z)]: [250 50]

Winding 1 parameters [V_1(V_{rms}) R_1(pu) L_1(pu)]: [40 0.02 0.08]

Winding 2 parameters [V_2(V_{rms}) R_2(pu) L_2(pu)]: [200 0.02 0.08]

These parameters of the simulated system show the working characteristics of the transformer when it is in normal operating condition, hence the protective scheme was feasible.

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