IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 3, Issue 2, September 2014)

A Review of Transformer Protection by Using PLC System

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***Abstract*— Distribution transformers of substation are one of the most important equipment in power system network. Because of, the large number of transformers and various components over a wide area in power systems, the data acquisition, condition monitoring, automatic controlling are the important issues. This paper presents design and implementation of automatic control circuits which is used in PLC automation to monitor as well as diagnose condition of transformers, like load currents, transformer temperatures and voltages. The proposed on-line monitoring system integrates a solid state device named PLC (programmable logic controllers) and sensor packages. The suggested plc monitoring system will help to detect the internal fault as well as external fault of transformer and also diagnose these faults with the help of desired range of parameters which is setting by programmer.**

***Keywords*— Monitoring, Distribution Transformers, PLC Automation, Relays, Sensors, Transducers, Ladder Logic.**

I. INTRODUCTION

In modern age, PLC automation has been placed on power reliability and economy. A power transformer is a very valuable and important link in a power transmission system. A monitoring is essential to evaluate transformer performance and safe operating conditions. High reliability of the transformer is essential to avoid disturbances in transmission of power. Due to wide range of PLC automation, the various types of fault in power transformer can be detected and diagnosed by using PLC system. Some papers show that transformer protection a challenge to researchers. Rohan Perera's paper [1] discusses protection applications of the in-line transformers where a transmission line of power system terminates on a transformer and a single protection zone includes both the line as well as the transformer.

A high quality power transformer properly designed and supplied with suitable protective relays and monitors is very reliable. When a fault occurs in a transformer of electrical substation, the damage is normally severe due to high rating of power. The ultimate aim is that to minimize the response time after occurring fault. V. Thiyagarajan & T.G. Palanivel's paper [2] presents an innovative design to develop a system which is based on AVR microcontroller that is used for logging the voltage, current and temperature of a power transformer in a substation and to protect the system from any uncertainty conditions. Reference [3] research work has been done in GSM based fully automated system in power transformer. To operate a power distribution system with a transformer out of service is always very difficult. The impact of a transformer fault is more serious than a transmission line outage. There are various types of fault which occurs on transformer. These faults are mainly internal and external faults of power transformer.

The main concern of this paper with transformer protection is rescued the transformer against internal faults as well as ensuring security of the protection scheme for external faults [4]. Overloading of power transformers beyond the nameplate rating can cause a rise in temperature of both transformer oil and windings. Overloading is nothing but it is an over current fault which occurs on secondary side of distribution transformer. If the winding temperature rise exceeds the transformer limits, the insulation will deteriorate and may fail prematurely. Power system faults external to the transformer zone can cause high levels as well as low level of voltage on transformer. It leads to over voltage fault and under voltage fault.

The fault impedance of power line being low, the fault currents are relatively high. During the occurrence of faults, the power flow is diverted towards the fault and the supply to the neighbouring zone is affected and voltages become unbalanced [6]. A comprehensive transformer protection scheme needs to include protection against transformer overload, over voltage fault and low voltage fault as well as protection for internal faults.

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II. Hardware Required For Prototype Model

An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

A. Three Phase Transformer (230V/12V)

It is used to step down three phase transformer as rating of 230V/12V.

B. Relays

This relays are used to three simple electromechanical relays which are connected in three phase connection of primary winding of transformer. Each relay is placed on each phase of transformer.

C. Transducers

This project consists of three types of transducers like as Voltage transducer, Current transducer and temperature transducer.

D. Rectifier Circuit

This circuit is used to supply to sensors. This circuit is converted from 12V AC to 12V DC.

E. PLC System

In this project, PLC system is used to Programmable Logic Controller of Schneider Company. In this system, we are used to analog inputs.

F. Power supply

A 230V three phase power supply is required to supply the three phase transformer.

G. Load

For convenient and reliable operation of this project, we are used to 10 LED lights which are connected to rectifier output (12V DC).

III. Transformer Fault Detection

A. Under Voltage Fault

When the operating voltage decreases to lower limit of voltage rating, the under voltage fault will occur. This fault can detect by voltage sensor. The rating of this sensor is Input – (0 - 300 V) and Output – (4 – 20 mA).

B. Over Voltage Fault

There may be always a chance of system over voltage due to sudden disconnection of large load. The magnitude of this voltage is higher than its normal level but frequency is same as it was in normal operating condition. Over voltage in the power system causes an increase in stress on the insulation of transformer. As we know that, voltage $V = 4.44\Phi.f.T \Rightarrow V \propto \Phi$, increased voltage causes proportionate increase in the working flux. The increase flux is diverted from the transformer core to other steel structural parts of the transformer. An increase in transformer terminal voltage or a decrease in frequency will result in an increase in the flux [7]. Core bolts which normally carry little flux may be subjected to a large component of flux diverted from saturated region of the core alongside. During this condition, the bolt may be rapidly heated up and destroys its own insulation as well as winding insulation. When the operating voltage increases to upper limit of voltage rating, the over voltage fault will occur. This fault can also detect by voltage sensor. The rating of this sensor is Input – (0 - 300 V) and Output – (4 – 20 mA).

C. Over current fault(Overload)

Over current fault is mainly due to overload in secondary side of distribution transformer. Over current conditions are typically very short in duration (less than two seconds) because protection relays usually operate to isolate the faults from the power system line. Overload is current drawn by load, a load current in excess of the transformer name-plate rating at secondary side. Current increases the hottest-spot temperature (and the oil temperature), and thereby decreases the insulation life span. When the operating current increases to upper limit of current rating, the over current fault will occur. This fault can detect by current sensor. The rating of this sensor is Input – (0 – 10A) and Output – (4 – 20 mA).

D. Under Current Fault

When the operating current decreases to lower limit of current rating, the under current fault will occur. This fault can also detect by current sensor. The rating of this sensor is Input – (0 – 10A) and Output – (4 – 20 mA).

E. Over Temperature Fault

Not only over load current may not result in damage to the transformer but also the absolute temperature of the windings and transformer oil remains within specified limits. Thr ratings of transformer are based on a 24-hour average ambient temperature of 30°C (86°F). Due to over voltage and over current, temperature of oil increases which causes failure of insulation of transformer winding. When the temperature of transformer increases to upper limit of temperature rating, the over temperature fault will occur. This fault can detect by temperature sensor. The rating of this sensor is Input – (0 – 100°C) and Output – (4 – 20 mA).

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ISSN: 2319-4863

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F. Phase to Phase Fault

Faults between phases within a transformer are relatively rare; if the fault occurs it will lead rise to a substantial current compare to the earth fault currents. Phase to phase fault (L-L fault) in the transformer are very rare. When this type of fault occurs, it will result rise to substantial current to operate the instantaneous over current relay on the primary side as well as the differential relay both. Three relays are placed on each three phases of input lines. This relays are used in two ways. First way is that it will trip the main circuit when any fault occurs. And second way is that PLC will check continuously to main current. If phase to phase fault will occur then relay trips the circuit automatically. In the case study of reference [8], it is believed that the failure zone was related to one individual phase, which was subjected to faults and experienced the initial asymmetrical component of the fault in transient [8].

IV. Design Of PLC Based Transformer Fault Detection

The schematic block diagram of this model has been shown in fig.-1. It consists of different blocks.

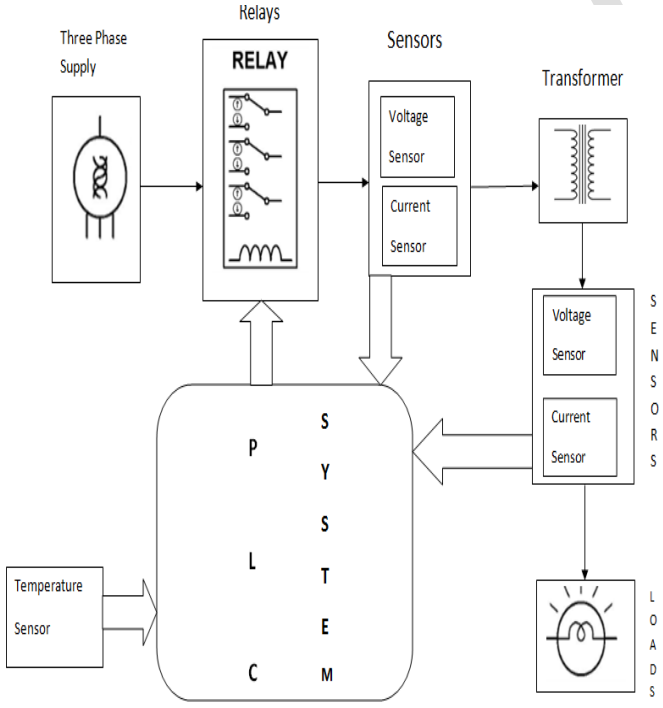

Fig.1- Block diagram of proposed project

A. Three Phase Power Supply

In substation, three phase power supply is used for power transmission. A three-phase system is usually more economical than an equivalent single-phase or phase system at the same line to ground voltage because it uses less conductor material to transmit electrical power.

B. Three Phase Autotransformer

An autotransformer (sometimes called auto step down transformer) is an electrical transformer with only one winding. In an autotransformer, portions of the same winding act as both the primary and secondary sides of the transformer in below fig.-2. The winding has at least three taps where electrical connections are made. Autotransformers are often used to step up or step down voltages in the 110-115-120 V range and voltages in the 220-230-240 volt range for example. Providing 110 V or 120 V (with taps) from 230 V input, allowing equipment designed for 100 or 120 volts to be used with a 230 volt supply. In this project, autotransformer is used to change the voltage which analyze to under voltage fault as well as overvoltage fault. The behavior of current and volt age transformer during and after the occurrence of fault is critical in electrical protection since error in signal from transformer can cause mal operation of the relays [9].

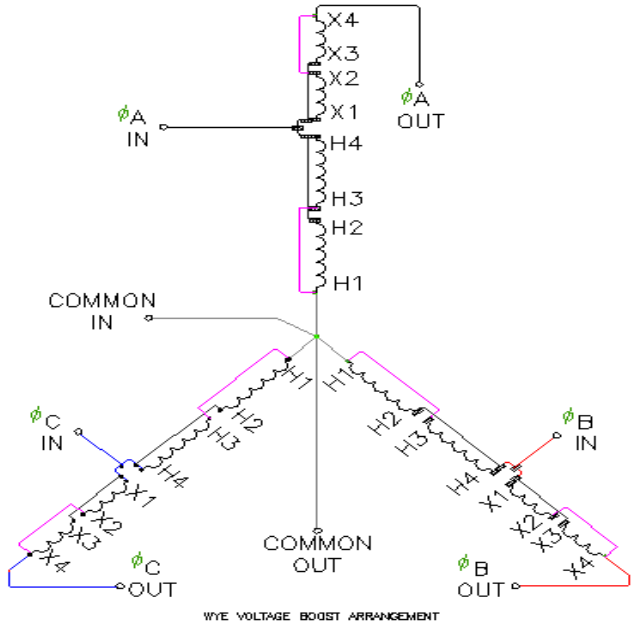

Fig. 2 - Three phase transformer arrangement

C. Relays

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state

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relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. It is shown in below fig.- 3.

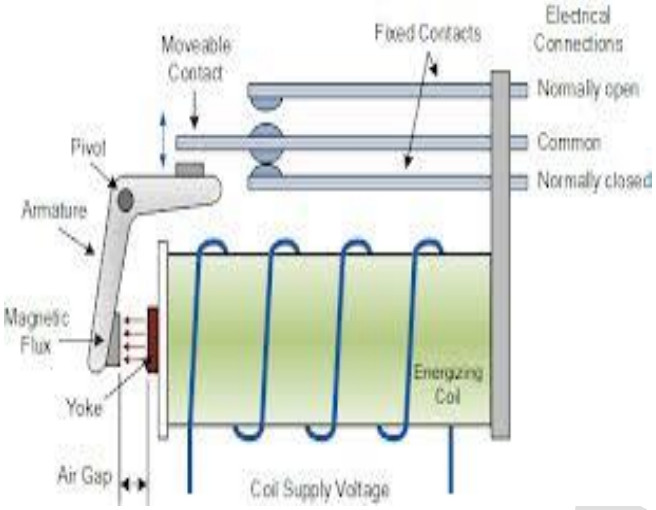

Fig. 3 - Electromagnetic relay

D. Main Transformer

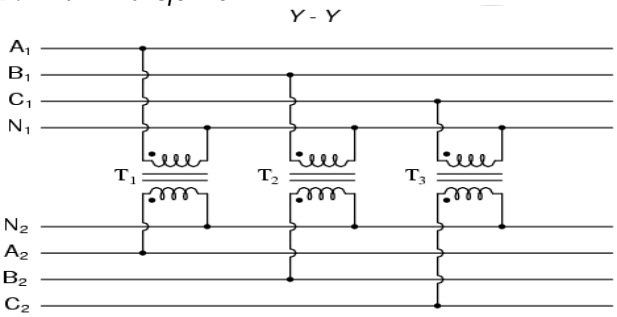

Fig. 4 - Three phase transformer in star- star connection

The working principle of transformer is very simple. It depends upon Faraday's law of electromagnetic induction. Actually, mutual between two or more winding is responsible for transformation action in an electrical transformer. The flux is continually changing in its amplitude and direction in primary winding, there must be a change in flux linkage in the second winding or coil. According to Faraday's law of electromagnetic induction, there must be an EMF induced in the second. If the circuit of the later winding is closed, there must be the current flowing through it. This is the simplest form of electrical power transformer and this is the most basic of working principle of transformer. In this project, transformer is used as 230 V/12 V rating of transformer. According to this project, it detect s the internal as well as external faults of this transformer. It is shown in fig. - 4.

E. PLC System

A Programmable Logic Controller is an industrial automation or computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices. Automated system can be a machine or a process and can also be called a process control system. Function of a process control system is constantly watched by input devices (sensors) that give signals to a PLC controller [10]. It can be used to PLC of Schneider Company. "SO machine" software is required to program in ladder logic format. The snapshot of the model is shown in fig. – 5.

Fig. 5 – Snap shot of model

F. Loads

This load can be used as a LED light which acts as a load in secondary side of transformer. It can also use high load at secondary side of current sensor which is placed in primary of transformer.

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V. CONCLUSION

In this paper we have presented a design of a system based on PLC that is used to monitor and control the voltage, current and temperature of a distribution transformer in both sides. The proposed PLC system which has been designed to monitor the transformer's essential parameters continuously monitors the parameters throughout its operation. When the PLC recognizes any increase or decrease in the level of voltage, current or temperature values the unit has been made shutdown in order to prevent it from further damages with the help of relays in three phase system. The system not only controls the distribution transformer in the substation by shutting it down, but also displays the values throughout the process for user's reference in SCADA system. This claims that the proposed design of the PLC system makes the distribution transformer more robust against some key power quality issues which make the voltage, current or temperature to peak. Hence the distribution is made more secure, reliable and highly efficient by means of the proposed system.

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