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PLC Based Transformer Monitoring & Protection System

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Abstract: Pakistan is currently facing huge hurdles to maintain round the clock supply of electric power in the major areas. This makes more annoying when a short fall increase by the failure of the power transmissions and even this increases more in summer season when due to overload and high-level environmental effects of heat power transformers failure rate increases numerously. The transformers being damaged due to the over heat and high load across one or two of its three phases. Mismanagement of the power distribution causes most of the problems when a heavy power load observed on single phase whereas other phases were not equally loaded. The system design will provide a systematic solution to protect transformer and fault detection using PLC, phase monitoring and temperature sensing with power management of particular distribution and give notification through GSM and information sharing with control room/Grid station through Internet of Things (IoT). In case of overloading and heating the system will automatically cutoff the breakers of load, which will help to save the life of transformer. The operator in control room is only required to monitor updates from system regularly, to achieve real time data acquisition through GSM technology, which is adopted to update in time. The prime aspect of this solution is efficiently handling of the system load while maintaining the equipment in good condition. The protection schemes so far designed can successfully protect the transformer and mitigate the risk of enormous destruction caused by transformer explosion, protecting major and expensive power system equipment and human life.

Keywords: Monitoring, Protection, Programmable Logic Controller (PLC), Ladder Logic, Analog I/O module, GSM, Transformer, Instrument transformers, Relays.

I. INTRODUCTION

Shortage of Power in Pakistan is at worst level. This makes more annoying when a short fall increase by the failure of power transformer. The failure of power transformer occurs when heavy load observed on transformer.

Electrical failure typically involves line surges, which is a very common cause of transformer failure. The other issues which are involved in transformer Failure rate are temperature increasing, oil and moisture leaking in the transformer tank. Whereas Voltage spikes, switching surges and line faults are a few more collective malefactors of electrical failure. High reliability of the transformer is therefore essential to avoid disturbances in transmission of power.

When a fault occurs in a transformer, it has to be shifted/replaced and transported to a workshop and repaired to reinstall in the power transmission systems. Therefore, in order to avoid such destruction and losses, protective circuits are often used as protection schemes to provide safe and secure power to the customers round the clock. These devices not only protecting the equipment but also preserve human life and secure the system from impairment.

The proposed system designed by using programmable logical controller (PLC) to control and monitor the load condition of each one of three phases of transformer. The control circuit designed to monitor three phase voltages, current power and temperature during the load connected round the clock. In this sense, the current sensor CT and potential transformer (PT) used to sense the current level and voltage level-sensing device on each phase respectfully. Within rated load system works smoothly, while reaching threshold mark system will switch to auto shut down to protect the transformer from any harmful impact or any damage.

To achieve auto shutdown analogue module[FBS-6AD] has been adopted, whereas the overload conditions caused by short circuit overload and over heat conditions will be sent to control room through the GSM module and also displayed on the HMI application on android as well as control room.

Table 1: Protection used for ratings above 5 MVA

List of protection types used for transformers of rating above 5 MVA
Gas detector relay (Buchholz relay)
Overload protection (thermal relays or temperature monitoring systems)
Over current protection
Ground fault protection

Differential protection
Pressure relay for tap-changer compartment
Pressure relief device

A. Aim and Objective

1. To protect the transformer from heavy load and burning condition.
2. To attain the efficient distribution of power and Control by PLC.
3. To display notification in GSM (shows overall behavior and condition of system performance).
4. To display the fault condition where it doesn't meet to the given requirement

II. RELATED WORK

The various research work was carried out in this field of the transformer protection and secure transmission. Most of the work was related to the circuit safety and used multiple techniques to achieve the best possible results.
In 2008 Protecting Power Transformers from Common Adverse Conditions. Control the effect of overload, through fault detection, and over excitation on the power transformer by using a method to set the parameters according to (ANSI/IEEE) standard to protect the transformer[1].

Early in 2014 A Review of Transformer Protection by Using PLC System designate the PLC based system which is used to monitor the voltage, current or temperature values whether it decrease or increase can be identified through PLC. PLC online monitoring system to monitor the load conditions automatically[2].

In 2015 Transformer Fault Detection and Protection System based on PLC only to monitor the level of temperature. This paper basically working on the temperature when the temperatures increase the cooling fan starts to control and decrease the temperature level. The RTD (Resistor Temperature Detector) is the sensor which is used to sense the increase or decrease level of temperature and relay used to disconnect the transformer from the transmission line for protection purpose[3]. In 2017 Monitoring of distribution transformer parameters using PLC. Major focus on Faults detection of distribution transformer and lack consideration of protection. By using this technique to rescue the distribution transformer in power system network against the internal and external faults. To maintains the load parameters to prevent it from further damage[4]. In 2017 presented the study of the use of GSM technology, to provide a reliable monitoring and fault detection system. Appropriate designed specific sensors were used to monitor the changes in transmission parameters and fault occurred the data acquired were transmitted to the utility mobile phone as SMS via the GSM wireless network. The system hardware was modeled using Proteus simulation tool while Mikro-C was used for the software. With this system, power transmission fault can be detected and isolated at the shortest possible time[5].

III. CONSTRUCTION & REQUIRED HARDWARE

In this project, the following tools and techniques are used to develop and construct the Transformer monitoring and protection system.

- PLC
- Analog I/O module
- Transformers
- Current Transformers
- Potential Transformers
- Temperature Sensors
- GSM module
- 3 Phase Relay
- Relays Drive
- Power Supply
- Load bank
- Ladder Logic
- HMI
-

A. Three Phase Transformer

Three phase transformers are widely used in power distribution system and having capability to handle the high voltage transmission from the power houses. Conversion of high voltage to low is carried out by step down transformers. Three phase transformers are more economical to supply large loads and large power distribution. Even though most of the appliances/ equipment's used at homes are single phase, where this could not be a suitable choice.

In Pakistan majority of industrial load is using three phase systems, therefore step down transformers are widely used. As compared with the single-phase transformer, there are various advantages with three phase transformer such as smaller and lighter to construct for the same power handling capacity, better operating characteristics, etc. [6].

B. Phase angle

Phase angle denotes the relationship ship between x and y, where y denotes the instantaneous voltage or current with respect to time x. In three phase transformer each phase is 120º out of phase. Each phase makes an angle of 360º the graphical representation shown in Figure 1:[7].

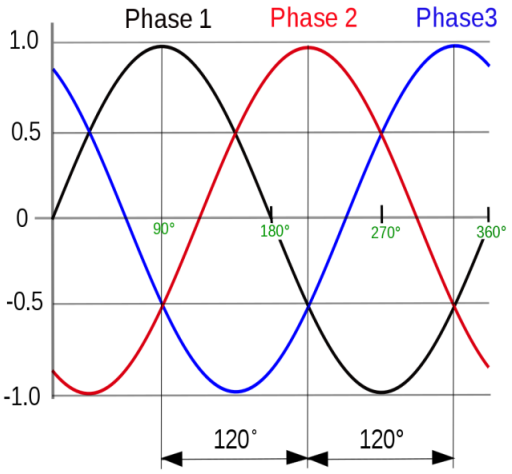

Figure 1: Phase Shift

C. y-y Connection of transformer:

In project we use y-y connection of the transformer it means Y source to Y load. Y-Y connections are easy to implement.

- Achieving in phase voltage, it is necessary to have primary and secondary windings to be connected in Y-Y configurations.
- In this, current flowing through both primary and secondary windings are equal to the currents of the lines according to KCL to which they are connected (supply source and load). And voltages between line phases on either end equal to√3=1.732 times respective winding voltages.
- Due to neutral availability, it is well suited for three phase four wire system.
- This type connection properly works if the load is balanced. But if the load is unbalanced, the neutral point shift causes unequal phase voltages.

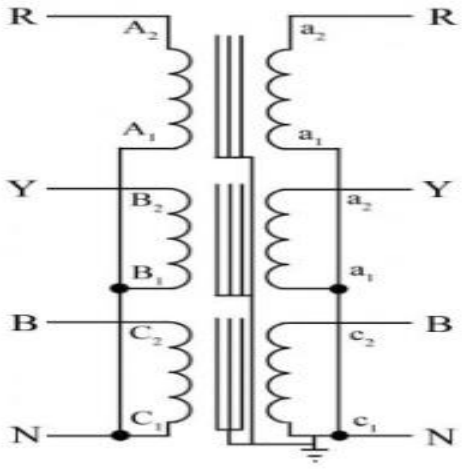

Figure 2: y-y connection[8]

The parameters for Y-Y connections:

$$line\ voltage = \sqrt{3} \times phase\ voltage$$

$$(A_1 - B_1), (B_1 - C_1), (C_1 - A_1) = \sqrt{3} \times 220 = 381$$

$$phase\ voltage = \frac{L.v}{\sqrt{3}} = \frac{381}{1.732} = 219$$

In star connection, there is a neutral between two phase voltage and the angle between two phase voltage is 120°, so for symmetric connection, on vector summation:

$$Line\ voltage = 2 \times phase\ voltage \times \cos\left(\frac{120^\circ}{2}\right)$$

$$= 2 \times 220 \times \cos(60^\circ) = 2 \times 220 \times 0.5$$

$$Line\ voltage = 220$$

1) POWER:

$$Apparent\ power = \sqrt{3} \times line\ voltage \times line\ current$$

$$= \sqrt{3} \times \left(\sqrt{3} \times phase\ voltage\right) \times phase\ current$$

OR

$$Power = 3 \times power\ in\ each\ phase$$

$$= 3 \times phase\ voltage \times phase\ current$$

2) Current:

The value of line current and phase current is same in star or wyes connection

$$KCL = I_R + I_Y + I_b = 0$$

D. Programable Logic Controller (PLC)

PLC is like a specialized PC. The system of PLC is based on microprocessor, it has all the fundamental parts contained in the personal computer, a central process unit, memory and input/output interfacing. It utilizes a configurable memory for the storing purpose of user-defined instructions for performing particular functions like logic, arithmetic, timing, sequencing and counting. PLC is programmed in order to sensing, activating, controlling industrial applications and, hence, incorporates many of Input/output sections that permit electrical signals to be incorporated. I /O devices are connected to the Programming logic controller and the programs for controlling devices are entered into the Programming logic controller memory. Additionally, the PLC endlessly monitors the inputs and actuates the outputs according to the control program. It is designed in order to control the industrial applications and is supplied with input/output interfaces with an impressive programming language. Initially the PLC was used to replace larger relay logic; however, its ever-increasing variety of functions includes counting, timing, comparing, calculation, and the process of analogue signals. The design or architecture of a PLC is quite similar to some equivalent principles as those used in personal computer design or architecture[9].

E. Design of PLC Based Transformer Monitoring & Protection System

The block diagram of Transformer Monitoring & Protection System by using PLC is as shown in figure 3 consists of different blocks.

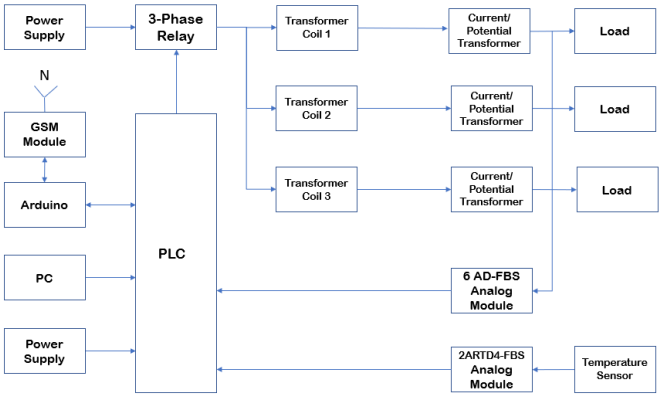

Figure 3: Project Block Diagram

The project designed by using programmable logic controller (PLC) to control and monitor the load condition of each one of three phases of transformer. The control circuit designed to monitor each phase voltage, current and power rating during the load connected round the clock. The CT (current sensor) used to sense the current level at the load whereas the PT is potential transformer used as a voltage-sensing device on each phase to monitor the voltage level. If it is in the under load condition and in the range the system works smoothly, as it reaches to mark where load has remarkable position and touching to overload mark, system will auto shut down to protect the transformer from any harmful impact or any damage. At the same time information of the overload conditions caused by short circuit overload and over heat conditions will be sent to control room through the GSM module and also displayed on the IoT application on android as well as PC in control room.

The PLC based monitoring and protection system was made with the help of the main controller which controls throughout the system is PLC, GSM, Analogue module, Glass type relay for protection, three CTs (Current Transformer) used as a current sensor to give the information of current increment and decrement, three PTs(Potential Transformer) used as a voltage sensor to give the information of under voltage and over voltage, GSM used to give the notification of load condition of system on mobile phone [9].

Transformer are design in three phases because distribution and substations have high power ratings, here we show distribution of electricity through three phase transformers. When talk about the technology, now a day's IR (Infra-red), RF (Radio frequency), GPRS (General Packet Radio Service) and GSM technologies became very famous, it is convenient to use for any applications with the help of PLC controller like industrial automation and status of data [10].

F. Control System Unit

The advance controllers used in automation are very effective in providing operational control and functionality in embedded systems electronics. Their Addressing designs have an excellent architecture for interfacing different electronic/electrical devices via the same controller. Through this method, device communication will surely in order. This reduces the time of processing and shortens chances of data collision malfunctions. The Figure 4 shows the Control System Unit designed for this project.

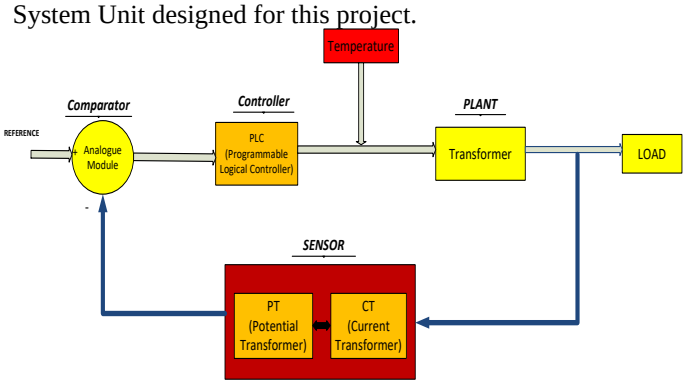

Figure 4: Control System Unit

G. Working Flow Chart

The Figure 5 shows the sequential operation of Transformer monitoring & protecting system. When system start it continuously monitor voltage, current and temperature. If the value of voltage is under/over voltage, over current & over temperature more than the predetermined value, the command window send to the signal YES, shown on HMI and SMS send through GSM, to control room & gives trip command to the relay circuit. If the values are in the range, it gives ON command and continuously monitor. At the same time, it monitors L-L, L-L-L, L-G fault as well.

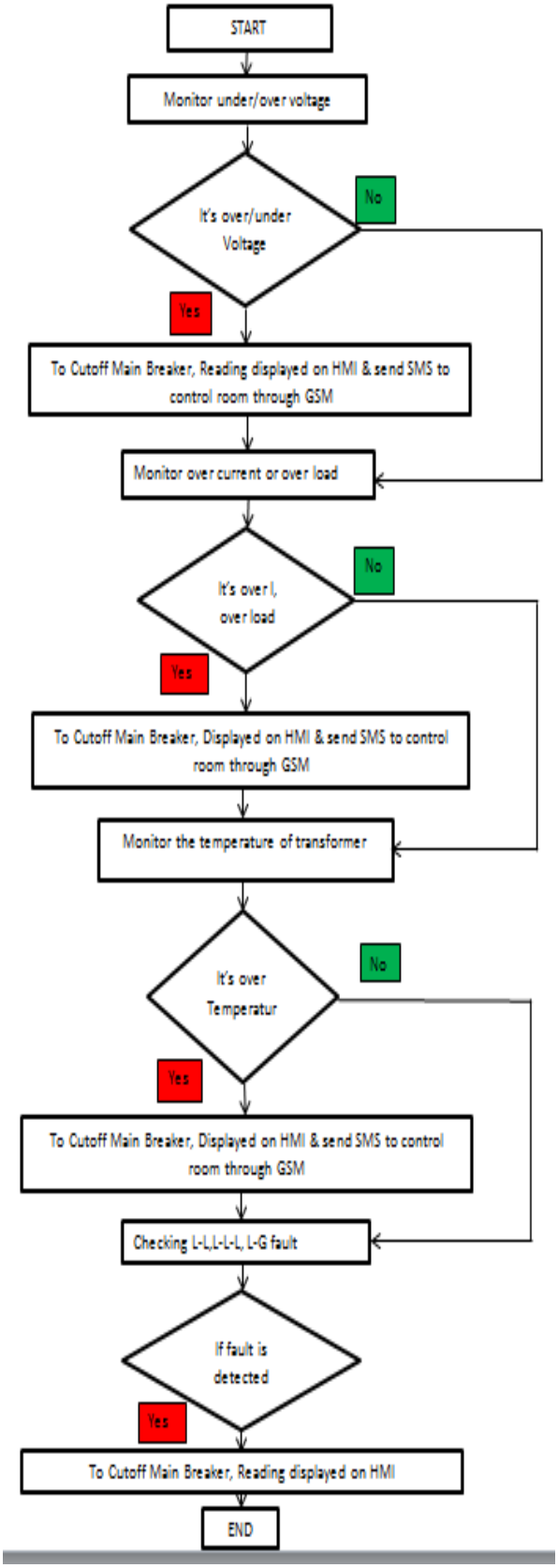

Figure 5: Project Working Flow Chart

IV. RESULT

The final results shown in figure 6-8 it shows the ratings of voltage, current and temperature and also that information will have provided to Control room through GSM. The ratings of the over/under voltage is set from 180-250V in an analogue module which compare the load coming with the rated voltage, if it is in the range the system will work properly otherwise trip the main circuit breaker. if above 250V it will cause harm to the transfomer so that for the protection of transformer, relay will switch off the connection from the load line, in this way we get the protection of the transformer.

The current is set to be 2Amps, above 2Amp over current condition occurs and the system will start to heatup from above range limit which is 35-45◦C and it can damage the transformer, so the PLC will send signal to relay to switch off the system.

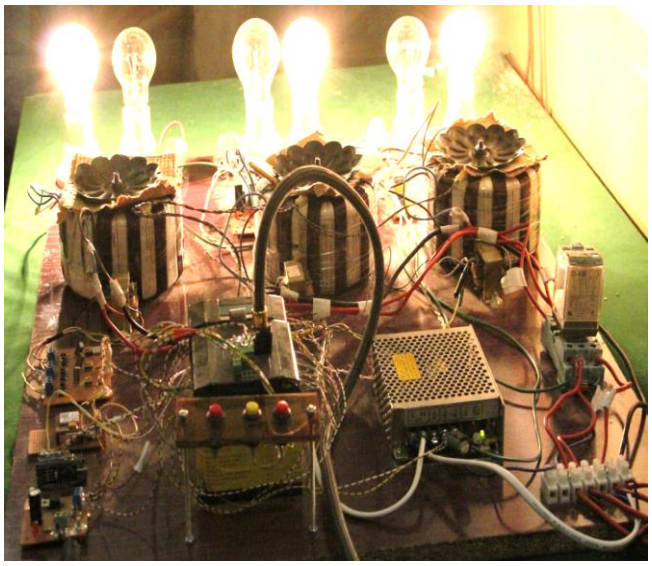

Figure 6: Project display

PLC mainly performs these tasks: It reads the parameters of the Transformer and displays them on the HMI and personal computer, which is on the actual field.

It sends digital code to perform the application's transmission and distribution functions. Regarding the first task it is simple one as it displaying the parameter on the HMI on the field. These parameters can be viewed by control room operators in the control room to judge the Transformer's condition, as well as it confirms whether the sensing circuits are working properly or not.

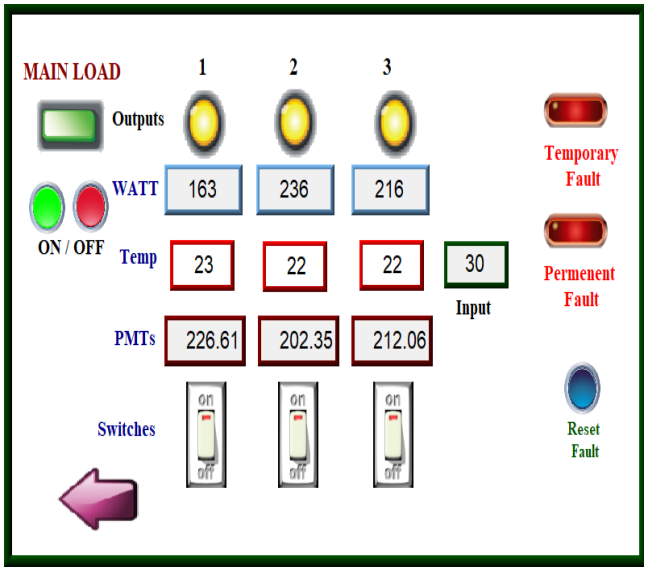

Figure 7: Parameters value display on HMI

1) GSM NOTIFICSTION

Notification of under/over voltage, over load and over temperature is shown in fig.8 and sending these parameters value in the form of text message through the GSM TX/RX. This task requires a complex program. Messages are sent after every change in Transformers current, voltage and temperature's rating, similarly with the change in load. So as the data can be updated at the RX side.

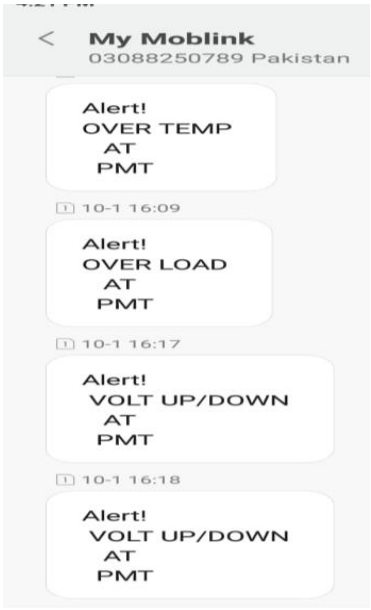

Figure 8: Notification received in mobile

B. DISCUSSION

Discussion to be made to design a system which assure the protection of transformer, and provide the reliable system which can implement on various hub power stations and the country will get relief from burning transformer most of the days. The shortfall of electricity is the major problem in which every people striving for, shortfall occurs due to the old transformers, which are not properly checked, and wires are damaged. Old transformers are burnt every day and repairing the transformer is very much expensive and time consuming processes as no one takes in a count the major cause to overcome this problem. We noticed another point that the technician feel difficulty to find the fault in transformer winding, so we produce a notification technique, which give the readings of phase to phase load and as well as show the phase to phase fault. In this idea technician will easily find where the fault occurs. Another question arises if the distance is long the fault happen in transformer winding do not the transformer burn until the technician reach? Yes, we take several steps to resolve this issue which is when it happens the overall system will shut down and transformer will be protected from any hazard situation. We reached at the thought to create a proposed system, which will be beneficial for the transformers and may help to save the life of transformer.

V. CONCLUSION

This research work explains the basic information and provides a solution on transformer protection. The proposed protection technique, can successfully protect the transformer and mitigate the risk of enormous destruction that can be caused by transformer explosion due to overheat, high load consumption and short circuit. The system designed is also providing a facility of protecting major and expensive power system equipment as well as human life and home appliances. The outcome of the project is the reduction of the maintenance cost by the Power Company can successfully achieved.

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