International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979, Impact Factor: RJIF 5.72
www.allsubjectjournal.com
Volume 3; Issue 6; June 2016; Page No. 149-155

Smart transformer using PLC and SCADA

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Abstract
An electrical substation is an integral part of electricity generation, transmission and distribution system. Electric power may flow through several substations between generating plant and consumer, and voltage is step up or step down according to the requirement using a transformer at several stages. By making use of a smart transformer we can monitor and control an entire substation. In this project automation is done using PLC & SCADA using wireless technologies system. PLC (Programmable Logical Controller) plays crucial role in automation field where many process are automated. On the other hand SCADA (Supervisory Control and Data Acquisition) act as human interfacing medium with machine, where voltage, current and temperature fluctuations are monitored and corrected if necessary.

Keywords: SCADA and PLC

1. Introduction
Electricity is an extremely handy and useful form of energy. It plays an ever growing role in our modern industrialized society. Electrical power systems are highly non-linear, extremely huge and complex networks. Such electric power systems are unified for economic benefits, increased reliability and operational advantages. Electric utility substations are used in both the transmission and distribution system and operate independently to generate the electricity. A typical substation facility consists of a small building with a fenced-in yard that contains transformers, switches, voltage regulators, and metering equipment that are used to adjust voltages and monitor circuits. A reliable working of these networks alone is not sufficient. Generators, variable loads etc. coerce the continuous dynamic behavior. So when considering various parameters such as voltage, current, temperature output power some form of control is needed.

Essential factors in substation protection and control design are high availability and expedient return-to- service following a system failure. Electromechanical relay and control schemes lack self-test and continuous monitoring features needed to speedy return-to-service. Without continuous monitoring, availability of an electromechanical scheme is not really known until it is called on to operate. Self- monitoring features are provided in new electronic relay packages and in PLCs. The application of these features to utility protection and control schemes promises to improve knowledge of system availability and reduce troubleshooting times by identifying failures.

In this project a Step down distributed substation is well monitored and controlled by PLC & SCADA system as a prelude to substation automation. PLC plays crucial role in automation acting as a controller while SCADA act as human interfacing medium.

1.1 Objective
Power transformers requires regular maintenance and proper supervision. As if now operators and technicians are responsible for every process. Sometime there will be a big gap between request of process and response. This delay may cause failure of components connected to transformers and hence interruption of process.

Through this project, we can achieve smart controlling technique in the emerging field of automation. PLC and SCADA controls the entire substation well. The proposed system should be efficient and can be effectively used

- To reduce operation cost and Operation time of substation process
- To achieve reliable operation
- To make automated operation
- For Data logging, which helps in analyzing the fault in future time

2. System Features
The following task can be performed by the control system designed

- Load shedding
  - Without considering critical load
  - Considering critical load

- Tracking the load status, data logging, historical trend
- Temperature protection by sensors
- Enabling alarm in abnormal cases
- Tripping entire operation in extreme cases
- Alerting concerned staff at the time of abnormalities.

3. Literature Survey
Transformer Automation
Transformer automation refers to using data from Intelligent Electronic Devices (IED), control and automation capabilities within the system, and control commands from remote users to control power-system devices

Power-system automation includes processes associated with generation and delivery of power. Monitoring and control of power delivery systems in the substation and on the pole to reduce the occurrence of outages and shorten the duration of outages that do occur. The IEDs, communications protocols, and communications methods, work together as a system to perform transformer automation. It is composed of several tasks.

- **Data acquisition**

Data acquisition refers to acquiring or collecting data. This data is collected in the form of measured analog current or voltage values or the open or closed status of contact points.

- **Supervision**

Computer processes and personnel supervise or monitor the conditions and status of the power system using this acquired data. Operators and engineers monitor the information remotely on computer displays and graphical wall displays or locally, at the device, on front-panel displays and laptop computers.

- **Control**

Control refers to sending command messages to a device to operate the I & C and power-system devices. Traditional supervisory control and data acquisition (SCADA) systems rely on operators to supervise the system and initiate commands from an operator console on the master computer. Field personnel can also control devices using front-panel push buttons or a laptop computer.

4. Block Diagram

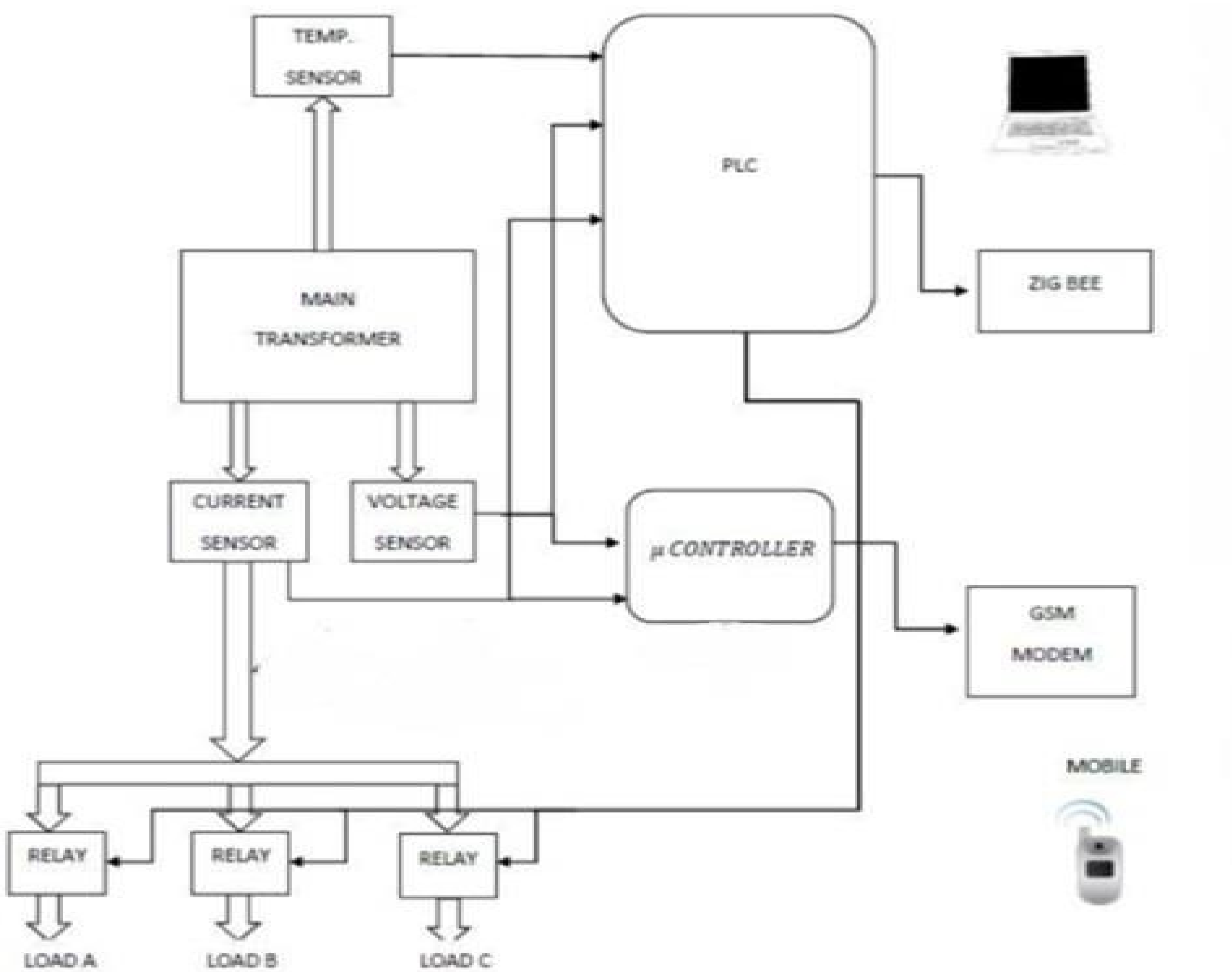

Fig 1: Block diagram

Working

The main component of this proposed system is PLC and SCADA, the sensors (current, temperature etc.) senses corresponding parameters such as current, voltage and temperature and send its electrical equivalent to PLC module. The preprogrammed PLC module processes and it displays, different parameters on SCADA screen on laptop. The present status of load and condition of transformer is determined and accordingly a corrective action (manual/automated) can be set and implemented.

If there is a rise in temperature on transformer, PLC first informs the operator by alarm if there is no response for a set period of time such extreme cases lead to circuit isolation (tripping). Also if load demand is higher than it can process load balance is achieved by load shedding considering/ not considering critical load.

5. Circuit Design

Each section of the circuit is described in the following pages.

Power Supply Section

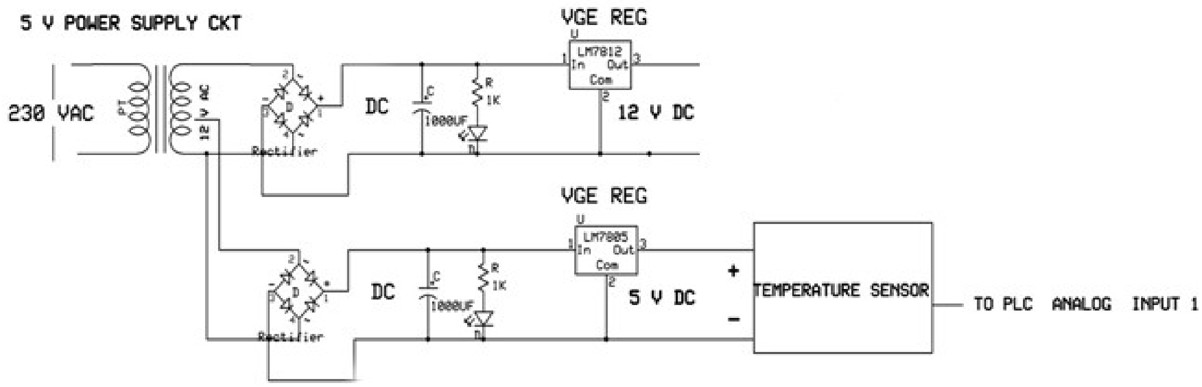

Fig 2: Power supply section

The power supply section is shown in fig: 2 supplies power to various components in the project. A 230/12 step down transformer steps downs the 230 V to 12 V AC. Series diode bridge rectifier rectifies AC voltage to DC regulator IC's

The power supply section is shown in figure supplies power to various components in the project. A 230/12 step down transformer steps downs the 230 V to 12 V AC. Series diode bridge rectifier rectifies AC voltage to DC regulator IC's 7805 and 7812 regulator regulates voltages to 5V and 12 V respectively and given to Temperature sensor. Output of Temperature sensor is given to PLC input pins.

Power Circuit Section

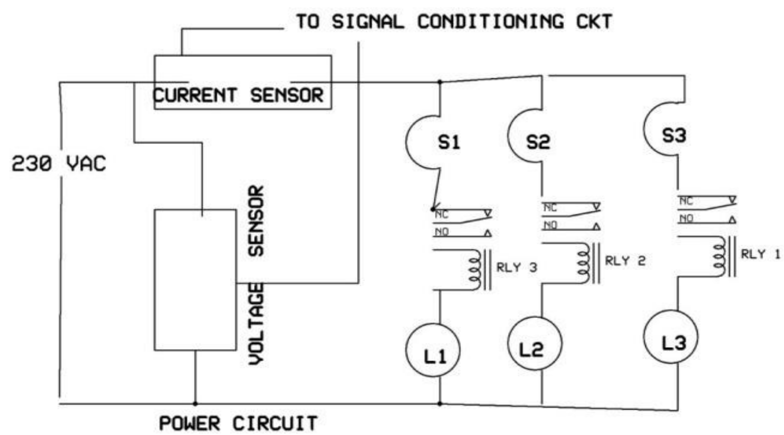

Fig 3: Power circuit section

Power circuit section is shown in fig 3.Voltage sensor and current sensor are given to line to measure current and voltage respectively, sensor outputs are given to signal conditioning unit, Parallel lamps are used as load and switches and relays are provided for controlling the loads.

Signal Conditioning Unit

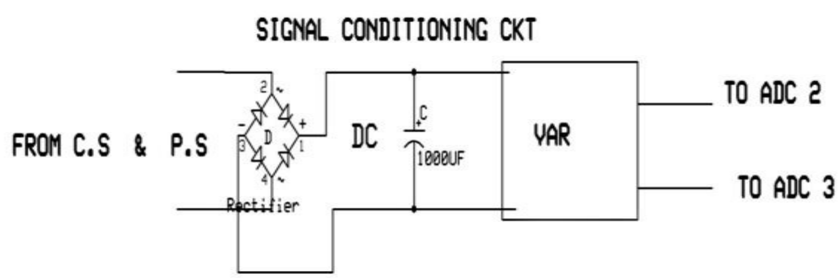

Fig 4: Signal conditioning unit

Signal conditioning unit is shown in fig 4.Since outputs of current sensor and voltage sensor are analog for the input to PLC we need digital outputs, hence a reverse diode rectifier is used for converting analog signal to digital then to PLC.

6. PLC Controller

A PLC is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. Here we are using PLC branded Delta with model DVP20Ex. The pin diagram is shown in fig 5. The PLC control all the PLC inputs, processes and provides outputs here the outputs are put to relays, loads and PLC to GUI communication is set through Zig Bee and one control is to the controller.

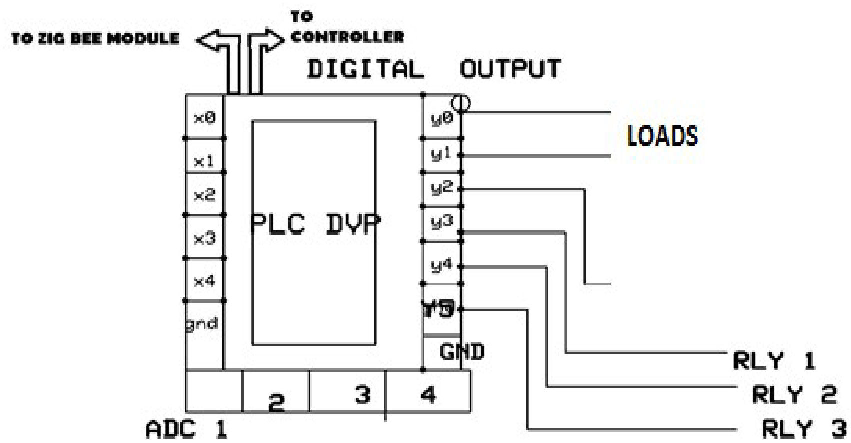

Fig 5: PLC controller

Microcontroller

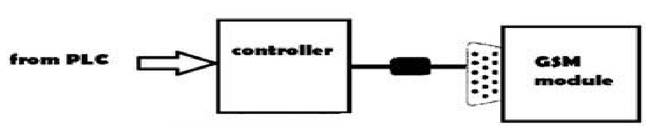

Fig 6: Microcontroller

PLC control signal is fed to controller where GSM module is interfaced and used for sending SMS at normal conditions and also it acts as P.F. correcting circuit by switching ON/OFF of capacitor banks. Relay front end is a series of relays used for turning ON/OFF capacitors online.

Current Transformer

A current transformer is a type of "instrument transformer" that is designed to provide a current in its secondary which is accurately proportional to the current flowing in its primary. Current transformers are designed to produce either an alternating current or alternating voltage proportional to the current being measured. Current transformers measure power flow and provide electrical inputs to power transformers and instruments. Current transformers produce either an alternating current or alternating voltage that is proportional to the measured current.

Potential Transformer

The standards define a voltage transformer as one in which the secondary voltage is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections. The output of PT is fed to PLC and controller.

Relay

The operating frequency of these devices is minimum 10-20ms. That is 50Hz-100Hz. The electromagnetic relay operates on the principle of magnetism. When the base voltage appears at the relay driver section, the driver transistor will be driven into saturation and allow to flow current in the coil of the relay, which in turn creates a magnetic field and the magnetic force produced due to that will act against the spring tension and close the contact coil. Whenever the base voltage is withdrawn the transistor goes to cut-off. So no current flows in the coil of the relay. Hence the magnetic field disappears so the contact point breaks automatically due to spring tension. Those contact points are isolated from the low voltage supply, so a high voltage switching is possible by the help of electromagnetic relays. The electromagnetic relay normally has 2 contact points, namely, normally closed (NC) and normally open (NO). Normally closed points will be a short CKT path when the relay is off. Normally open points will be a short CKT path when the relay is energized.

GSM Module

A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. A GSM/GPRS module assembles a GSM/GPRS modem with standard communication interfaces like RS-232 (Serial Port), USB etc., so that it can be easily interfaced with a computer or a microprocessor / microcontroller based system. The power supply circuit is also built in the module that can be activated by using a suitable adaptor.

The connection diagram with microcontroller unit is shown in fig 7.

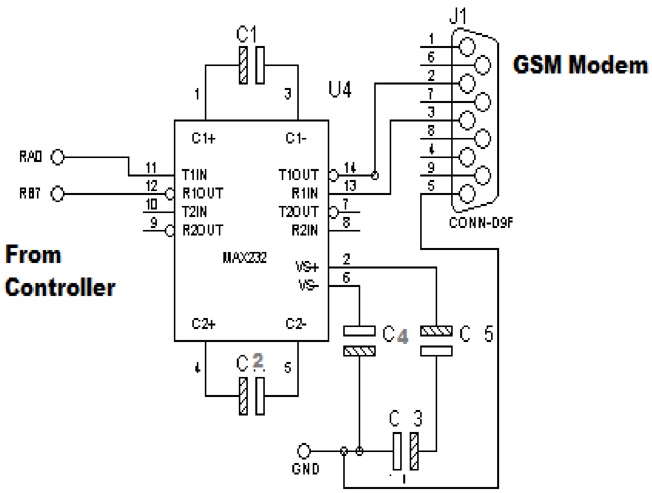

Fig 7: GSM module connection

Zig Bee Modem

ZIG Bee is a specification for a suite of high-level communication protocols used to create personal area networks built from small, low-power digital radios. Zig Bee is based on an IEEE 802.15 standard. Though its low power consumption limits transmission distances to 10–100 meters line-of- sight, depending on power output and environmental characteristics, Zig Bee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones.

The role of Zig Bee modem in this project is to establish communication between PLC and computer wirelessly.

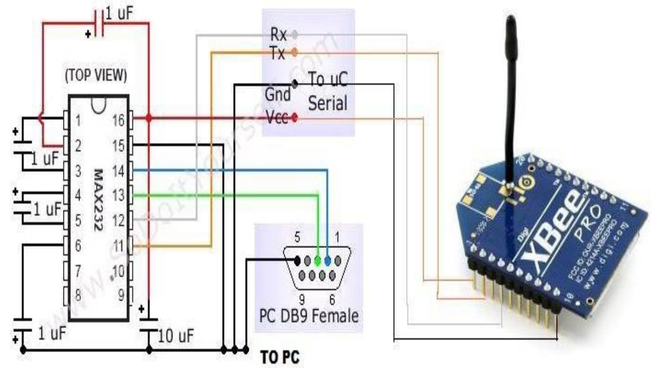

Fig 8: Zig bee modem

7. PLC Simulation

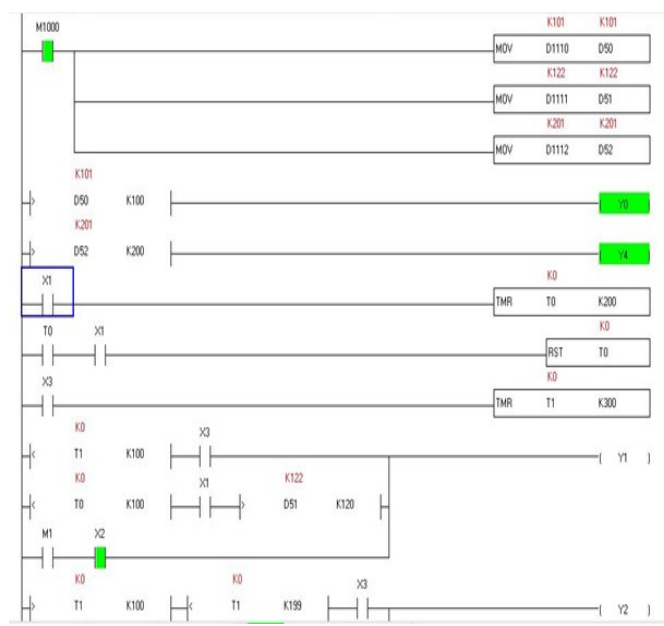

Fig: 9

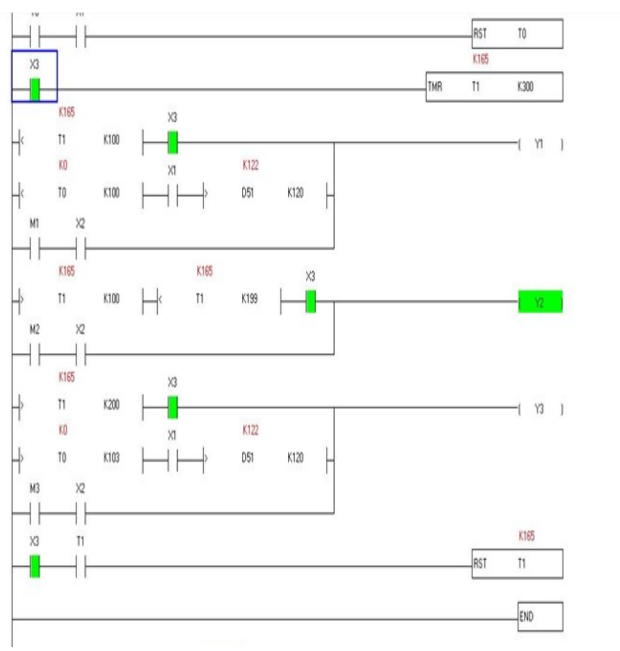

Fig: 10

Fig 9 and fig 10 shows PLC coding, based on this the system is operated the register M100 should be ON for the entire operation the parameters voltage, current and temperature have three registers.

8. SCADA Screen

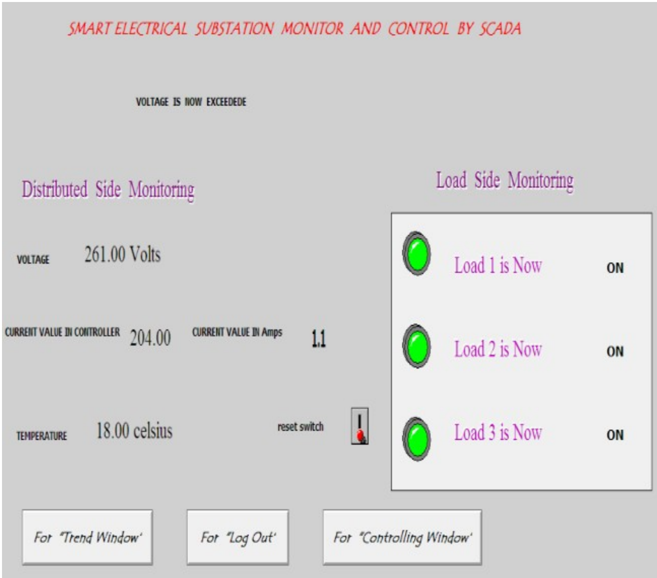

Fig 13: Operation window

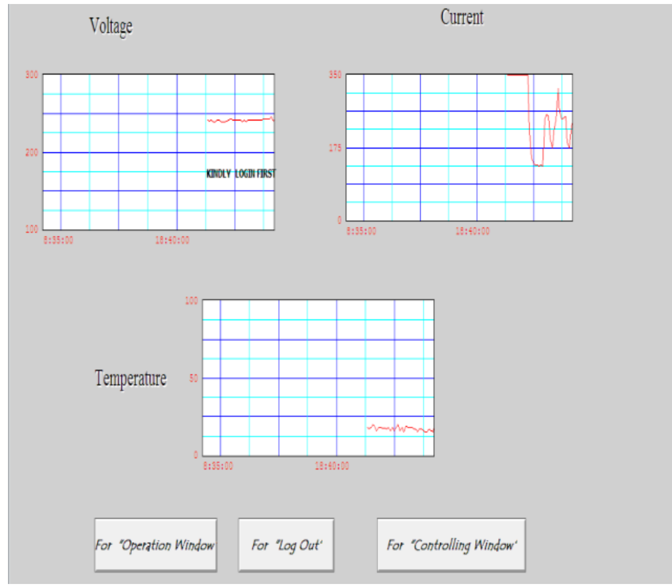

Fig 14: Trend window

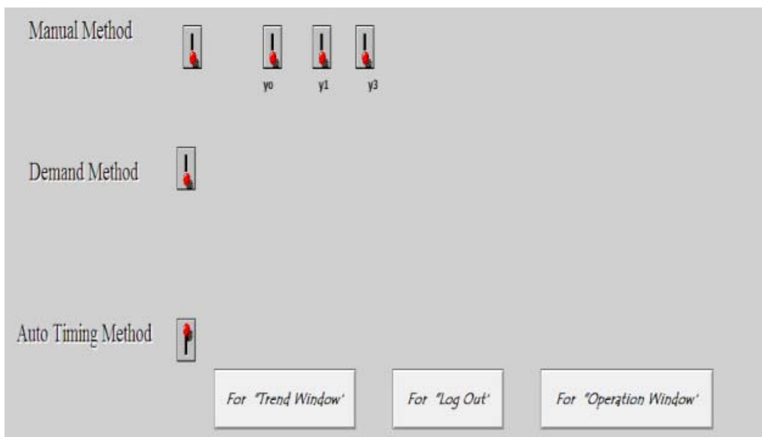

Fig 15: Control window

Fig 13 indicates the status of loads 1,2 and 3 ie whether it is on or off and it also displays analog values of voltage current and temperature. Fig 14 is trend window showing the previous values of voltage current and temperature in graphical format. Fig 15 shows the control window here we can control the entire system in three ways:

- Auto timing method: Here the system operate in a time based mode according to the ladder logic made in PLC. Each load is on for a preset period of time when auto timing switch is turned ON.
- Demand method: Here the load operates on the basis of demand by just clicking on the switch provided near demand method on the control to turn on the demand mode, only two loads having the highest priority will be on this case ie load 1 and load 2 are ON or load 1 and load 3 are ON.
- Manual method: This can be done manually by clicking on the manual switch provided in the controlling window according to the load available, any load can be turned ON and OFF after turning ON the manual switch according to the demand by just click on the switches Y0 Y1 and Y2.

9. Hardware Setup

Fig 16: Hardware setup

10. Result
The proposed system can be used for controlling parameters like voltage, current & temperature in a substation and load shedding can be done with and without considering loads using PLC and SCADA. Here drimmer port is provided for varying the value of voltage and current. Temperature is varied with the help of soldering iron placed over the temperature sensor.

11. Conclusion and Future Scope
The design of proposed model 'Smart transformer' is completed. PLC and SCADA System is used for monitoring the various parameters (voltage, current, temperature etc). By using these parameters, we can easily control any load in our system to improve system operation, system reliability, etc. Alternatively, SCADA and PLC communication system make it possible to integrate protection control and monitoring electrical parameter together for maximum benefit.

One of the main advantage of this design is that the parameters like voltage temperature and current can be controlled wirelessly, i.e. when the operator is not at cabin with PC, or somewhere on the substation with Laptop.

Smart transformer combined with automated components like relay, circuit breaker etc. can lead to a smart substation. Combination of several smart substation will lead to an automated grid.

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