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Implementation of PLC-SCADA Based Generator Protection System

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Abstract:
Generator is an essential device in power system which generates electric power at specific voltage and current. It can be categorized into two based on the nature of supply; first one is DC generator and next is AC generator or Alternator. Due to the recurrent power failures in our state, generators are becoming an in evitable part of both industries and residences. Government has taken strict rules regarding the installation and commissioning of generators. This work aims to the safety of generator, can be used for generators of any capacity may be up to 750 KVA. This system comprises of the modern controllers like PLC (Programmable Logic Controllers) and monitoring through SCADA (Supervisory Control and Data Acquisition package). This work can be implemented in modern ship where the operator in the wheel house can obtain the generator safety parameters through computer. Since most of the industries are using DG set, the proposed work with very little modification can be implemented in any industries for generator safety.

Keywords: Generators, Power System, Alternator, Commissioning, PLC, SCADA and Generator safety.

I. INTRODUCTION

In the conventional system of generator protection in marine and industrial field are differential protection schemes and protection using various sensors which are measuring the physical quantity. These facilities are not communicated with control engineer's room. Thus protection for the generator is not effective and a lot of dangerous situations shall be faced. It is also effect the economy of the firm such as ship, industries having multi storied buildings etc. The proposed system introduced a new generator protection using PLC and SCADA [1].This is applicable for marine automation and large multi storage industries. PLC is the short form of Programmable Logic Controller. The special packing, reliability, software programming capability, easy trouble shooting, computer connectivity etc make PLC an integral part of modern automation system. This work is done by using Allen Bradley make micrologix PLC with 12 Digital Inputs, 8 Digital outputs, 4 analog inputs and one analog output. This PLC can accept 2 analog voltage inputs and two analog current inputs. The Proposed work considering both electrical and mechanical parameters of the generator. The mechanical parameters such as cooling water temperature, fuel level and lubricating oil pressure where as voltage level, current ratings are regarding for the electrical parameters. Each parameter having a safe value. If any abnormalities present special indication systems such as buzzer, hooters are provided for the indication and adapting corrective action against the fault in the control room. Thus a control engineer who is working in the top floor can able to control the generator which is lying in the ground floor. Thus the scope of this work can be expanded into wide areas. So the need of this work is considerable in present systems.

II.SYSTEM DESCRIPTION

The heart of generator protection scheme is PLC and SCADA. SCADA can be controlled by using PLC. Both electrical and mechanical parameters can be controlled by PLC and monitoring is done by SCADA system. The overall block diagram is shown in Fig. 1. The electrical parameters such as voltage, frequency and current are taken into consideration. Cooling water temperature and lubricating oil pressure are the mechanical parameters considered in this system. The proposed system monitoring different electrical parameters such as Voltage, frequency and current in SCADA. In case of Voltage monitoring: Voltage in different phases is stepped down using Potential Transformers and is converted to PLC analog input format. It may be either 0 – 10 V format or 4 – 20 mA format. The corresponding input is scaled in SCADA to obtain the actual voltage plotting.

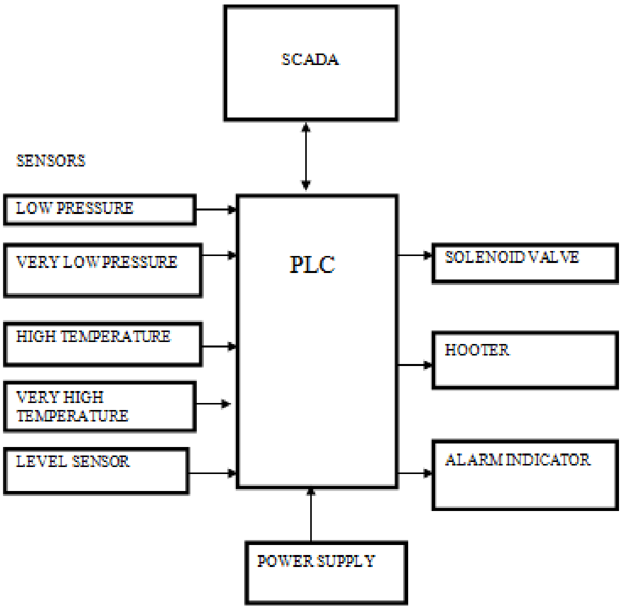

Figure. 1. Overall block diagram of generator protection system

In case of Frequency Monitoring: Frequency can be accurately plotted in SCADA with the help of frequency transmitter whose output is 0 – 10 V corresponding to the line frequency. It is possible to adjust the zero and span in the transmitter itself, thus same transmitter can be used for different frequencies. In case of current monitoring: Current measurement require Current Transformer (C.T). Modern digital panel meters are provided with adjustable C.T ratio for variable applications. The standard input in PLC is 4 – 20 mA for current measurement.

Regarding mechanical parameters fresh water temperature and lubricating oil pressure are two important critical safety parameters for a generator. For high capacity generators these parameters are to be continuously monitored. All high capacity generators are coming with option to fit sensors to monitor these parameters. Most of them are controlled by conventional relay logic circuits with hardware timers and relays. Here modernizing these controls with PLC and SCADA interfacing allows remote monitoring and control at control room. Another parameter used is fuel tank level. If the fuel level remaining is for one hour the alarm is activated such that the operator can fill the fuel. When the temperature or pressure becomes beyond a set point the alarm get activated. If the parameter goes beyond critical value the generator get shut down. In case of colling water temperature: In a diesel engine the fuel is fired because of high temperature developed by compressing fuel air mix. The efficiency of an internal combustion engine is directly proportional to the difference in temperature of inside chamber and outside combustion chamber. In diesel engines the cooling water is circulated to reduce the temperature outside combustion chamber. When the engine is working properly the temperature of cooling water coming from engine will be below 65 degree. The temperature increases because of any overload or any other engine malfunctioning. Thus high temperature in cooling water line indicates a major complaint in the engine working. In case of lubricating oil pressure: The lubricating oil is used in all engines irrespective of size of engine. In an internal combustion engine, the piston moves inside cylinder so that the force of movement is converted to torque. If lubricating oil is not used the piston will become damaged. In large engines, lubricating oil pumps are connected to main shaft so that the pressure of lubrication oil is maintained above 2.2 bar. The lubricating oil which is pumped by oil pump is finally collected in a sump and is again circulated so that a constant pressure is maintained. The pressure reduces due to the following reasons i) leakage in pressure lines ii) oil pump complaint and iii) excessive overload in engine. As shown in Fig. 1. there are interfacing of different type of sensors voltage level, temperature and pressure to the PLC. These discrete inputs are connected to digital input port of PLC.

III. PLC BASED CONTROL

Control engineering has evolved over time. In the past manual control were the main methods for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls. PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer:

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

The Fig. 2 & 3 shows the comparison of relay logic system with PLC. In relay logic system we are using a number of relays to accomplish one control sequence. In relays, the number of poles is limited to three so that more relays are to be used if same input is coming in many places. In the Fig. 3 it is clear that the wiring is very less and all functions of relays are replaced by single PLC. Ladder logic is the programming language used for programming PLCs [2]. It is similar to relay wiring diagram so that technicians can easily understand the working of each part. The example in Fig. 2 does not show the entire control system, but only the logic. When we consider a PLC there are inputs, outputs, and the logic. Fig. 3 shows a more complete representation of the PLC. Here there are two inputs from push buttons. It is possible to imagine the inputs as activating 24V DC relay coils in the PLC. This in turn drives an output relay that switches 115V AC, which will turn on a light. Note, in actual PLCs inputs are never relays, but outputs are often relays. The ladder logic in the PLC is actually a computer program that the user can enter and change. Notice that both of the input push buttons are normally open, but the ladder logic inside the PLC has one normally open contact, and one normally closed contact. Do not think that the ladder logic in the PLC needs to match the inputs or outputs. Many beginners will get caught trying to make the ladder logic match the input types.

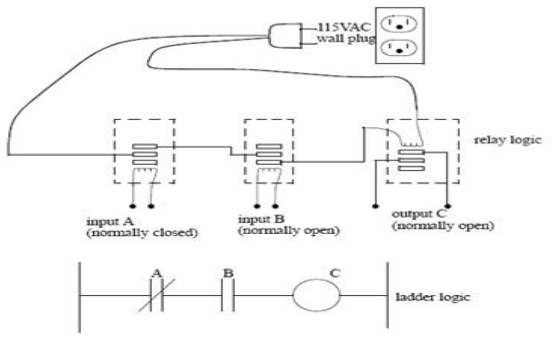

Figure. 2. A schematic representation of simple relay control

The first PLCs were programmed with a technique that was based on relay logic wiring schematics. This eliminated the need to teach the electricians, technicians and engineers how to program a computer - but this method has stuck and it is the most common technique for programming PLCs today.

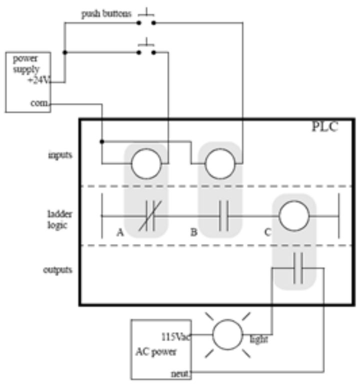

Figure. 3. A PLC illustrated with relays

Different Programming Languages are available in PLC such as Ladder Diagram (L.D), Instruction List (I. L), Structured Text (S.T), Sequential Function Chart (S.F.C) and Functional Block Diagram (F.B.D). However the proposed generator protection system is implemented by using Ladder Diagram (L.D). An example of ladder logic can be seen in Fig. 4. To interpret this diagram, imagine that the power is on the vertical line on the left hand side, we call this the hot rail. On the right hand side is the neutral rail. In the figure there are two rungs, and on each rung there are combinations of inputs (two vertical lines) and outputs (circles).

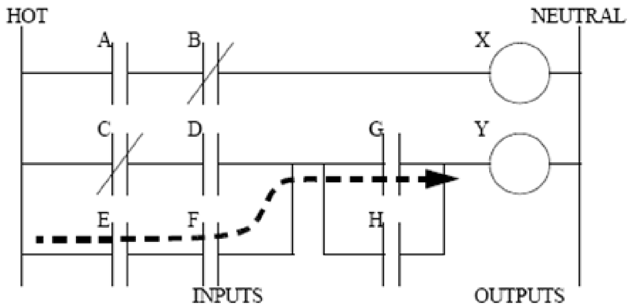

Figure. 4. A simple logic ladder diagram

The second rung of Figure 4 is more complex; there are actually multiple combinations of inputs that will result in the output *Y* turning on. On the left most part of the rung, power could flow through the top if *C* is off and *D* is on. Power could also (and simultaneously) flow through the bottom if both *E* and *F* are true. This would get power half way across the rung, and then if *G* or *H* is true the power will be delivered to output *Y*. In later chapters it can examine how to interpret and construct these diagrams. Which means if input *A* is on and input *B* is off, then power will flow through the output and activate it? Any other combination of input values will result in the output *X* being off. The PLC mainly consists of a CPU, memory areas, and appropriate circuits to receive input/output data. The PLC can be considered as a box full of hundreds or thousands of separate relays, counters, timers and data storage locations. These counters, timers, etc. don't "physically" exist but rather they are simulated and can be considered software counters, timers, etc. These internal relays are simulated through bit locations in registers. Fig. 5 gives the details of PLC architecture in brief.

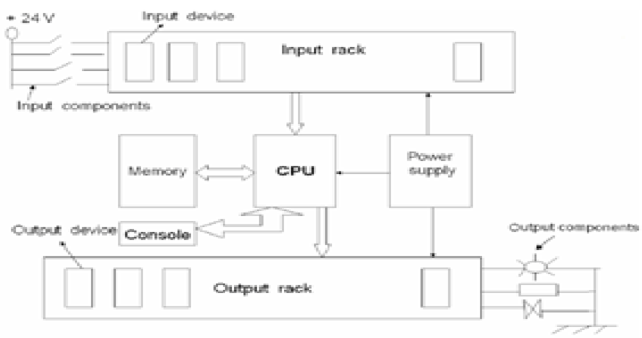

Figure. 5. Architecture of PLC

PLC programming comprises of three steps. Step 1: Check Input Status-First the PLC takes a look at each input to determine if it is on or off. In other words, it checks whether the sensor connected to the input on. Step 2: Execute Program-Next the PLC executes the program one instruction at a time. May be the program said that if the first input was on then it should turn on the first output. Since it already knows which inputs are on or off from the previous step it will be able to decide whether the first output should be turned on based on the state of the first input. It will store the execution results for use later during the next step. Step 3: Update Output Status-Finally the PLC updates the status of the outputs. It updates the outputs based on which inputs were on during the first step and the results of executing your program during the second step. After the third step the PLC goes back to step one and repeats the steps continuously. One scan time is defined as the time it takes to execute the 3 steps listed above which is shown in Fig. 5.

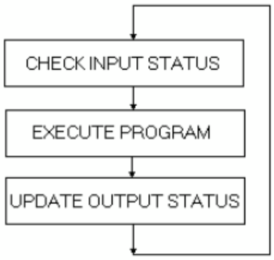

Figure. 5. Operation steps involved in PLC

IV. PLC PROGRAM FOR THE IMPLEMENTATION OF GENERATOR PROTECTION SYSTEM

The Ladder Logic diagram is implemented for the generator protection [3] scheme which is shown in Fig. 6, Fig. 7. and Fig. 8.

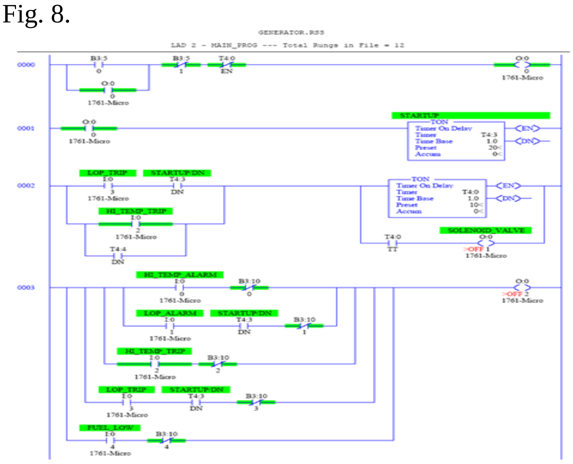

Figure. 6. Program for generator protection using PLC (a)

The first rung is for starting the generator from SCADA. The start button in the SCADA is pressed for starting and stop button is pressed for stopping the generator. We are using timer T4:3 for startup delay. When a generator is starting up the lubricating oil pressure in the system will be zero. At this time the LOP Alarm and LOP trip signals are activated so that generator will go to trip condition. In order to correct this error we are skipping the pressure sensor output at the startup. We are using timer T4:0 to energize the solenoid valve for 10 seconds. This operation is done when any of the trip signals are activated. Rung 003 is for switching on the hooter when any of the measured parameters goes beyond the set value.

The corresponding acknowledges bit will reset the hooter.

We are generating a one second pulse using a pair of timers T4:1 and T4:2. Rung 005 is for high temperature alarm indication which is shown in Fig. 7.

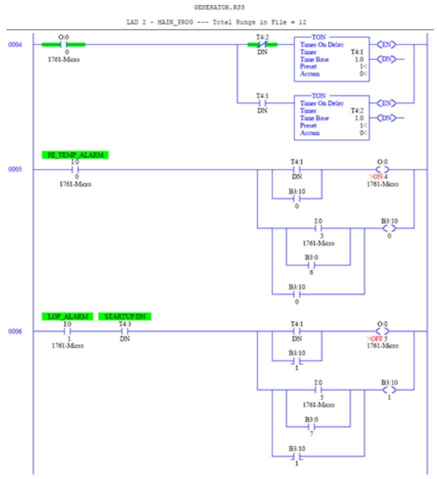

Figure. 7. Program for generator protection using PLC (b)

When the cooling water temperature goes beyond 72 degree this indication light will blink and also the indication in SCADA also blinks. The hooter is energized. When the acknowledge button is pressed the hooter become off and the light become steady. The light will vanish if the alarm condition is cleared. Rung 006 is for low pressure alarm indication. When the lubricating oil pressure goes below 1.8 bar this indication light will blink and also the indication in SCADA also blinks.

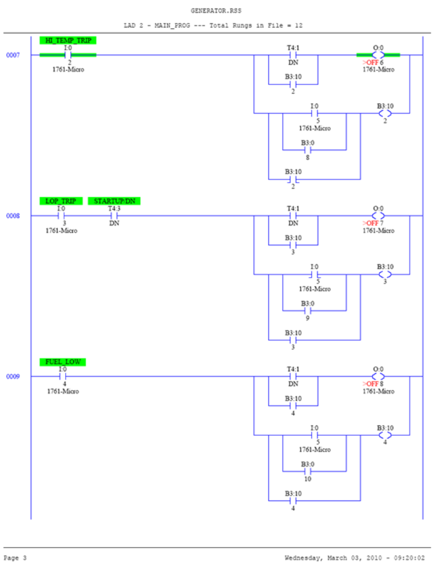

Figure. 8. Program for generator protection using PLC (c)

The hooter is energized. When the acknowledge button is pressed the hooter become off and the light become steady. The light will vanish if the alarm condition is cleared. Rung 007 is for high temperature trip indication.

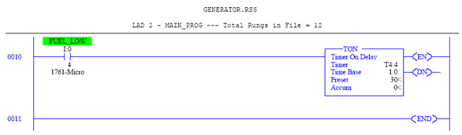

Figure. 9. Program for generator protection using PLC (d)

When the cooling water temperature goes beyond 88 degree this indication light will blink and also the indication in SCADA blinks. The hooter is energized. When the acknowledge button is pressed the hooter become off and the light become steady. The light will vanish if the alarm condition is cleared.

V. SCADA MONITORING SYSTEM

SCADA stands for Supervisory Control and Data Acquisition. SCADA can communicate with a number of controllers like PLC. Wireless remote monitoring is possible using special type of Remote Terminal Units (RTU) [4]. In this work Wonderware Intouch SCADA version has been used. The main features of SCADA which are utilized in this work are Real time trend, Historical trend, Alarm display, Report generation and Application security using password. SCADA is a powerful tool for industrial automation. We can monitor and control the whole process plant with SCADA. It contains complete list of drawings of all instruments and components used in process industries. Now a day's different SCADA packages are available. The programming in SCADA is known as script. Two types of scripts are there: VB script & C script. As their name indicates the programming syntax determines the C script or VB script. We are using Wonder ware Intouch SCADA for monitoring and controlling the generator and different parameters. Alarms are acknowledged through SCADA. It is a commonly used SCADA package developed by Wonder Ware Company. It is user friendly platform for application development made this SCADA popular. Intouch is world's leading supervisory control and data acquisition software. The In Touch software package consists of Tags (Memory + I/O). The package is available in 64, 256, and 1000 and 64,000 Tags with the two options: Development plus Runtime plus Network (DRN) and Runtime plus Network (RN). With DRN package you can develop as well as run the application but in case of RN you cannot develop/modify the application. The application can be developed by using DRN package and can be installed on RN package. Wonderware has a package, Factorysuite, which can be used for monitoring the process. It's a Runtime software with no control i.e. output from the factoryfocus software to hardware/external devices is not possible. Creating new application, Creating windows / MIMIC page, Tag definition, Drawing objects, Animation properties, Writing scripts, Real-time Trends Historical Trends and Alarms and Events are the applications of SCADA In Intouch [5].

VI. SCADA PROGRAMMING FOR MONITORING

Monitoring is performed by using SCADA software. Control engineer can be monitored the status of both electrical and mechanical parameters of generator. Based on the data reading on the screen, control engineer can locate exact location of fault and proceed for clearing the fault occurred in generator.

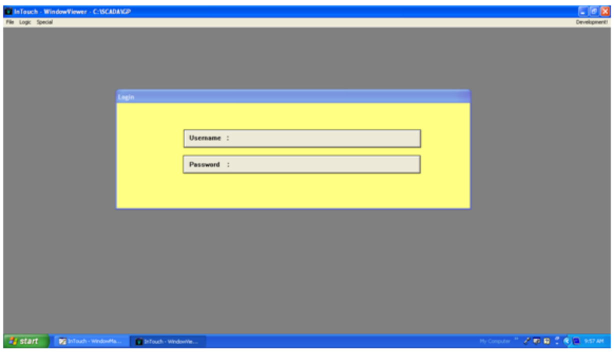

Figure. 10. Opening page of SCADA

This window is set to open when the SCADA is switched to run mode. Here control engineer has to login. If one types the user name and password correctly, he will be automatically login and the home window will be appeared.

OPERATION OF SCADA SOFTWARE FOR MONITORING MECHANICAL PARAMETERS

- In home window we have links to each sub windows. If any link is clicked that particular window will be shown. If the log off link is pressed the user will be automatically log off. And the login window will be shown in Fig 11.

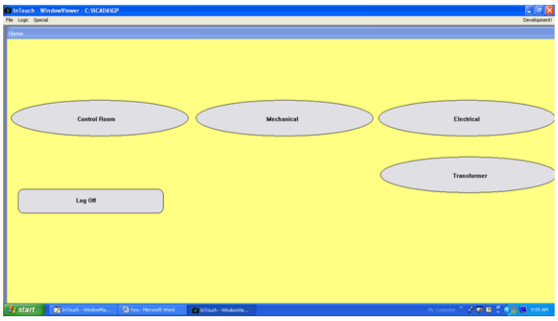

Figure. 11. Home (Log in) page of SCADA

Control window provides the control for the whole generator unit. The start button is used for sending start command and stop button is for stopping the generator. The generator start command will be given to the related equipment through PLC output O: 0.0/0. The solenoid value is placed in the fuel supply part to the generator. When the generator becomes low, the fuel supply is cut off and thus we ensure the shut down or termination of generator action.

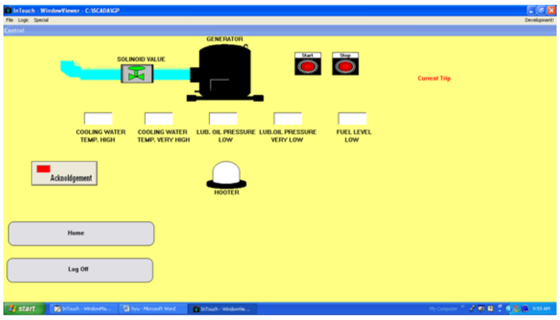

Figure. 12. Monitoring of mechanical parameters

When the low pressure alarm signal is detected the corresponding light will blink in the SCADA screen and hooter is energized. When the acknowledge button from field or from the SCADA screen is pressed then the light become steady and the hooter is switched off. When the alarm condition is cleared the light will become off.

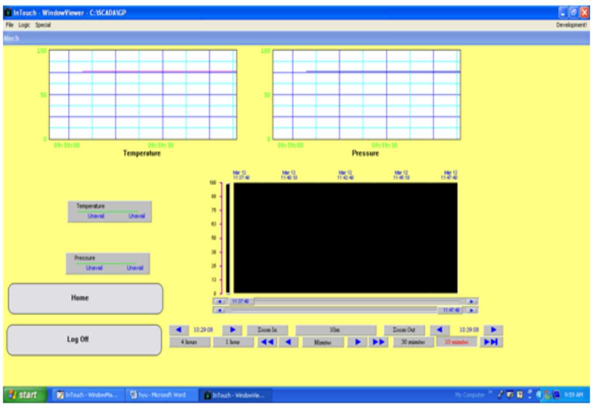

Figure.13. Checking of mechanical parameters

If the very low pressure alarm trip signal is detected the indication light and hooter are energized. When we press the acknowledge signal the hooter will become off and light become steady. When the trip condition is cleared the light will become off. When this sensor becomes high generator is switched off. So the timer for solenoid valve will be energized and the solenoid valve will work for 10 seconds. The generator can be started again only after clearing the trip condition to provide maximum protection. Similar is the case with high temperature alarm also. The high temperature signal is detected the indication light and hooter are energized. When we press the acknowledge signal the hooter will become off and light become steady. When the trip condition is cleared the light will become off. If the very high temperature alarm trip signal is detected the indication light and hooter are energized. When we press the acknowledge signal the hooter will become off and light become steady. When the trip condition is cleared the light will become off. When this sensor becomes high generator is switched off. So the timer for solenoid valve will be energized and the solenoid valve will work for 10 seconds. The generator can be started again only after clearing the trip condition to provide maximum protection. When the fuel low signal becomes high, the light indicator blinks and hooter are energized. When we press the acknowledge signal the hooter will become off and light become steady. When the trip condition is cleared the light will become off. In right side of the on and off switches of the generator indicates trip conditions which are prevalent. If that is shown the generator will be automatically switched off. The generator will only be on if that trip condition is avoided. If the home link is pressed the SCADA will jump to the home window. If the log off link is pressed the user will be automatically log off. And the login window will be shown.
This window shows us a plot of mechanical parameters which are been measured. The real trend of temperature and Pressure is been shown above. The bottom part consists of historical trend [6]-[7]. The historical trend is a plot of past values. This trend the plots the past values if we make any change in the historical trend. If the home link is pressed the SCADA will jump to the home window. If the log off link is pressed the user will be automatically log off. And the login window will be shown.

OPERATION OF SCADA SOFTWARE FOR MONITORING ELECTRICAL PARAMETERS

This window shows us a plot of electrical parameters which has been measured. The Real trend of Voltage, Current and Frequency is been shown above. The bottom part consists of historical trend. The historical trend is a plot of past values. This trend the plots the past values if we make any change in the historical trend.

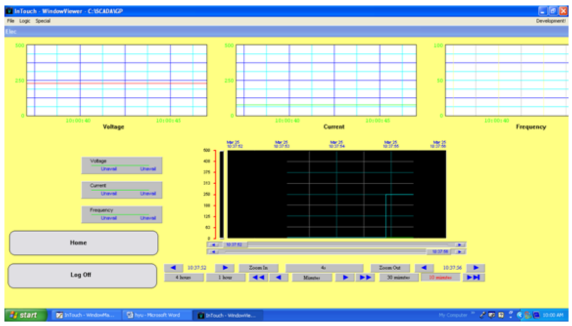

Figure.14. Monitoring of electrical parameters

If the home link is pressed the SCADA will jump to the home window. If the log off link is pressed the user will be automatically log off. And the login window will be shown

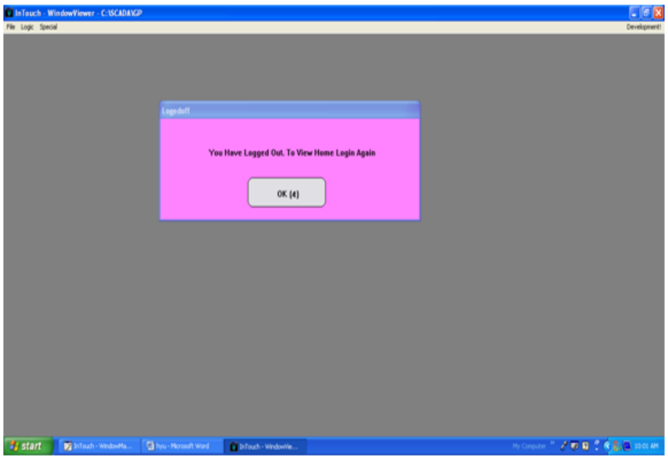

Figure.15. Log in page of SCADA software

This window is been shown when the user has logged off the system. This is just to give the user information that he has been logged off. The start button is used for sending start command and stop button is for stopping the generator. The generator start command will be given to the related equipment through PLC output O:0.0/0. The figure for generator is getting animated. When the low pressure alarm signal is detected the corresponding light will blink in the SCADA screen and hooter is energized. When the acknowledge button from field or from the SCADA screen is pressed then the light become steady and the hooter is switched off. When the alarm condition is cleared the light will become off. Similar is the case with high temperature alarm also. In SCADA each parameter is having individual acknowledge buttons. When the low pressure trip signal is detected the indication light and hooter are energized. When we press the corresponding acknowledge signal the hooter will become off and light become steady. When the trip condition is cleared the light will become off. Also the timer will energize the solenoid valve for 10 seconds. At this time the generator is switched off. The generator can be started again only after clearing the trip condition so that maximum protection is provided. When the fuel low signal becomes high, the timer will work and also indicator and hooter are energized. If the operator cannot fill the fuel within pre programmed time then the system is safely shut down by energizing solenoid valve.

VII. CONCLUSION

PLC SCADA system can be effectively implemented in generator protection system. Both electrical and mechanical parameters of generator can be monitored separately and could be taken a suitable decision for generator protection. Man power requirement will be reduced by using PLC SCADA automation systems. This work can be expanded into marine automation, Building Management Systems and Industrial Automation [8]-[10]. The proposed system can be protected generators completely from all kinds of fault. Furthermore Maintenance cost can be minimized completely. Therefore proposed work is totally feasible to in build in an Industry.

Advantages of the Proposed PLC SCADA Generator Protection System

- Since PLCs are used, the project is reliable. Normally PLCs can work continuously for many years without any faults.
- SCADA is a computer package which needs no other external devices. SCADA can be installed in any computer in the industry.
- This system occupied with discrete sensors for sensing high temperature and low pressure. So generators of any capacity can be monitored and protected by using this work.
- Compared to continuous temperature measurement, discrete sensors are much reliable and accurate.

VIII.REFERENCES

[1] Robert Lemos (2006-07-26). "SCADA system makers pushed toward security". Security Focus. Retrieved 2007-05-09. http://www.securityfocus.com/news/11402.

[2] J. Slay, M. Miller, Lessons learned from the Maroochy water breach, Critical Infrastructure Protection,, vol. 253/2007, Springer, Boston, 2007, pp. 73-82

[3] James H. Harlow, Electric Power generator Engineering, 2nd Edition, CRC Press

[4] http://ab.rockwellautomation.com

[5] http://www.wikipedia.com

[6] http://plc-scada-dcs.blogspot.com

[7] http://dicesamexico.com

[8] http://dicesamexico.com

[9] http://www.slideshare.net

[10] http://electrical-engineering-portal.com

IX. FUTURE EXPANSION OF THIS WORK

This sophisticated system can also be modified later. In the current system we are monitoring the parameters and provide alarm and further tripping on critical conditions. The automatic parameter correction on alarm condition can be incorporated. i.e. say when temperature rises above preset level high temperature alarm will be triggered along with that an it can reinforce the cooling mechanism So that the temperature level can be lowered, thus bringing the system out of alarm condition. Another future expansion is to provide redundancy or similar parallel system to ensure no black out at all. That parallel similar DG System can be controlled by PLC system and monitored and controlled from a centralized SCADA terminal.

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