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Introduction to New Trends: PLC & SCADA

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Abstract: Over the years demand for high quality, greater efficiency and automated machines has increased in the industrial sector of power plants. Industrial automation supposes the operator responsibility on monitoring and controlling of processes in real time. They require continuous monitoring and inspection at frequent intervals. As the complexity of industrial processes increases, the need for remote controlling and monitoring form a central location also increases. A common term used to describe this solution is SCADA system, which make the operator function easier and also helps to reduce errors caused by human. While the SCADA is used to monitor the system, PLC is also used for internal storage of instruction for implementing functions such as logic, sequencing, timing, counting and various types of machine processes.
This report presents the latest trend of SCADA system architecture, which is usually three layer SCADA system architecture depending on open system technology rather than a vendor controlled proprietary technology. Based on the architecture, in this report SCADA and PLC are described and general procedure to design and development of SCADA system is given. Finally application of SCADA system for 'Control of Boiler' and 'Control of Induction Motor' is described. Thus concluding that, due to recent technological advances, the automation has become technically and economically feasible for developing application in various sectors. Hence there is need to introduce SCADA system in advanced educational courses.

Keywords: Real time monitoring and controlling, SCADA, PLC.

NOMENCLATURE

SCADA : Supervisory Control And Data Acquisition
PLC :Programmable Logic Controller

1. INTRODUCTION

A SCADA "Supervisory Control And Data Acquisition" is the generic terms for the hardware, software, and procedures used to control and monitor industrial process in real time. It can provide information in real time environment that identifies problem as they occur and take corrective actions when assistance is needed. Proper monitoring of process can maintain operations at an optimum level by identifying and correcting problems before they turn into significant system failures.

SCADA is associated with (i) the process industries, where it manages the activities of number of integrated operation units to achieve certain economic objectives for process and with (ii) the discrete manufacturing automation where it coordinates the activities of several integrating pieces of equipment in manufacturing systems, such as machines interconnected group by a material handling system. SCADA encompasses the collecting of information transferring to the central site, carrying out any necessary analysis and control, and then displaying that information on number of operator screens. The requirement control actions are conveyed back to the process.

The control actions are carried out by PLC (Programmable Logic Controller), which are used for system control. PLC is industrial computer in which control devices such as limit switches, push button, proximity sensors, etc provide incoming control signals into the unit. An incoming control signal is called an Input. Inputs interact with instruction specified in the user ladder program, which tells the PLC to how to interact with the incoming signals. The user program directs the PLC on how to control field devices like motor drivers, solenoid etc. A signal going out of the PLC to control a field device is called Output. This report describes recent trends of SCADA system architecture, such as three layer architecture [1]. Design and development of SCADA system based on three layer architecture for some application is included in this report

2. THREE LAYER SCADA SYSTEM ARCHITECTURE

Figure 1, below illustrates the three layer SCADA system architecture [1]. This is the latest trend of SCADA system which depends on open system technology rather than a vendor controlled proprietary environment.

As shown in the above figure1 SCADA system consists of three layers. They are

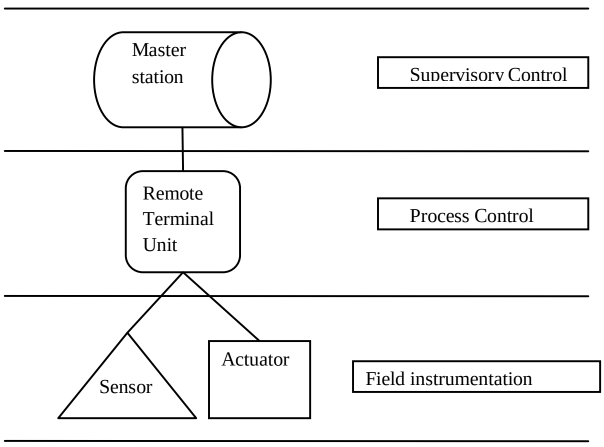

Fig. 1: Three layer SCADA system architecture.

1. **Supervisory control layer:** Master station consist of one or more personal computers which are configured to be dedicated to master station duties, although they can function in a multi-purpose mode. The duties of master station may include trending, alarm handling, logging archiving, report generation, and facilitation of automation. These duties may be distributed across multiple PCs, either standalone or network.

   Master stations have two main functions:
   1) Periodically obtain data from PLCs (and other master or sub-master station).
   2) Control remote devices through the operator station.
2. **Process control layer:** This layer consists of more than one device depending upon the situation, these devices like
   1) Programmable Logic Controllers: PLC is a special purpose computer consists of CPU and different kinds of memory. Typically modern Remote Terminal Unit (RTU) use Ladder Logic programming approach. PLCs are quickly becoming standard in the control system.
   2) Analog Input and Output modules: The configuration of sensors and actuators determines the quantity and the type of inputs and outputs on a PLC. Depending on the model and manufacturer modules can be designed. An analog input and output module 4,8,16 or 32 inputs or outputs.
   3) Digital Input and Output modules: Digital input modules are typically used to indicate status and alarm signals.
3. **Field instrument control layer:** This layer mainly consists of sensors and actuators. Sensors perform measurement and actuators perform control. Sensors get the data and actuators perform actions depending on this data. The processing and determination of what action to take, is done by master control station i.e., SCADA.

Communication among three layer SCADA system is provided with a standard communication interface. At the supervisory control layer between peers, communications are usually through a standard networking protocol such as TCP/IP or IPX over Ethernet. The means of communications between supervisory control and process Control, as well as among process control peers, vary greatly and are usually dependent on hardware manufacturer. Recently used protocols are Modbus, profibus, and UCA “Utility Communications Architecture”, in order to incorporate a variety of manufacturer's equipment.

As communication between process control and filed instrumentation control is typically a point to point running over the wire pairs, transmitting voltage pulses that are interpreted by the RTU based on how it is programmed. Protocols used for this purpose are Foundation Fileldbus and Profibus.

3. SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

The ability to perform operations at an unattended location from an attended station or operating center and to have a definite indication that the operations have been successfully carried out can provide significant cost saving in the operation of a system. This is exactly what is achieved through the SCADA system. A formal definition of SCADA system, as recommended by IEEE, is “A collection of equipment that will provide an operator at a remote location with sufficient information to determine the status of particular equipment or a process and cause actions to take place regarding that equipment or process without being physically present”.

As the name indicates, it is not full control system, but rather focuses on the supervisory control level. It is used to monitor or control may be automatic or initi by operator commands. The data acquisition is accomplished firstly by the RTUs scanning the field inputs connected to the RTU (it may be also called as PLC). It is estimated that there are three million SCADA systems in use. SCADA system provides near real time monitoring and control with time delays ranging between fractions of second to minutes. Depending on the size and sophistication, SCADA systems can cost from tens of thousands of dollars to tens of millions of dollars. They can be used to automate processes such as:

1. Electricity power generation, transmission and distribution.
2. Oil and gas refining and pipeline management.
3. Water treatment and distribution.
4. Chemical production and processing.
5. Railroads and mass transit.

3.1 Components of SCADA:

Typical SCADA system includes following components:

1. Field instruments
2. Operating equipment
3. Local processors
4. Short range communication
5. Host computer
6. Long range communication.

Figure 2, below shows components of SCADA system.

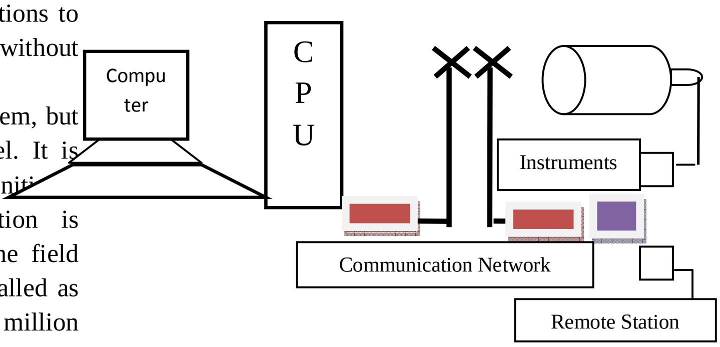

Fig. 2: Components of SCADA

1. Instruments in the field sense conditions such as temperature, pressure, power level and flow rate.
2. Operating equipment such as pumps, valves, conveyors, and substation breakers that can be controlled by energizing actuators.
3. Local processor that communicate with site’s instrument and operating equipment.

These local processors can have some or all the following roles:

   a. Collecting instrument data.
   b. Turning on and off operating equipment based on internal programmed logic or based on remote commands sent by human operators or computers.
   c. Translating protocols so different controllers, instruments and equipment can communicate.
   d. Identifying alarm conditions local processors go by several different names including Programmable Logic Controller (PLC), Remote Terminal Unit (RTU), Intelligent Electronic Device (IED) and Process Automatic Controller (PAC). A single local processor may be responsible for dozens of inputs from instruments and outputs to operating equipment.

4. Short range communication between the local processors and the instruments and operating equipment. These relatively short cables or wireless connections carry analog and discrete signals using electrical characteristics such as voltage and current, or using other established industrial protocols.

5. Host computers that can act as the central point of monitoring and control. The host computer is where a human operator can supervise the process: receive alarms, review data and exercise control. In some cases the host computer has logic programmed into it to provide control over the local processors. In the other cases it is just an interface between the human operator and the local processors. Other roles for the host computer are storing the database and generating reports. The host computer may be known as the Master terminal Unit (MTU), the SCADA server, or a personal computer with Human Machine Interface (HMI) software. The host computer hardware is often but not necessarily a standard PC.
6. Long range communication between the local processors and host computers. This communication typically covers miles using methods such as leased phone lines, satellite, microwave, cellular packet data, and relay.
7.

3.2 Systems concepts:

The term SCADA usually refers to centralized systems which monitors and controls entire sites, or complexes of systems spread out over large areas. Most control actions are performed automatically by Remote Terminal Units ("RTUs") or by programmable logic controllers (PLC). Host control functions are usually restricted to basic overriding or supervisory level intervention. For example as shown in figure 3, a PLC may control the flow of cooling water through part of an industrial process, but the SCADA system may allow operators to change the set points for the flow, and enable alarm conditions, such as loss of flow and high temperature, to be displayed and recorded. The feedback control loop passes through the RTU or PLC, while the SCADA system monitors the overall performance of the loop. Data acquisition begins at the RTU or PLC level and includes meter readings and equipment status reports that are communicated to SCADA as required. Data is then compiled and formatted in such a way that a control room operator using the HMI can make supervisory decisions to adjust or override normal RTU (PLC) controls. Data may also be fed to a Historian, often built on a commodity Database Management System, to allow trending and other analytical auditing.

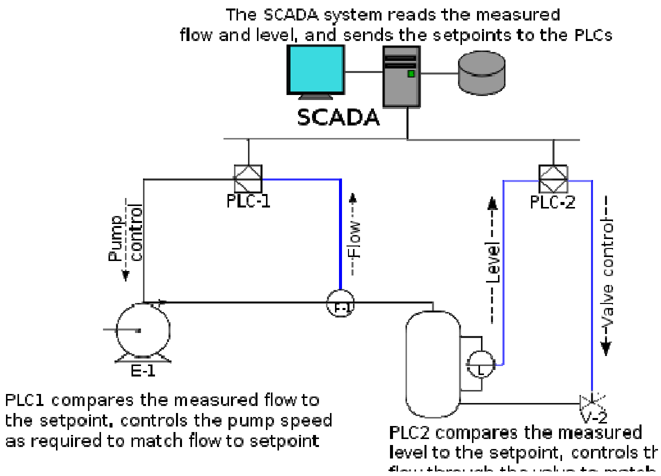

Fig. 3: SCADA system

3.3 Types of SCADA system:

1. **Monolithic SCADA system:** The first SCADA system held all operations in one, usually a mainframe computer. There was little control exercised, and most early SCADA functions were limited to monitoring systems and flagging any operations which exceeded programmed alarm levels. Networks did not develop at that time SCADA was developed. Thus SCADA systems were independent system with no connectivity to other systems. These systems were all vendor proprietary software and usually limited to a single plant or facility. Like the software, SCADA hardware from one vendor was rarely usable in another vendors SCADA system.
2. **Distributed SCADA system:** Later SCADA systems became to known as Distributed system. Since they often share control functions across multiple smaller computer connected by Local Area Network (LAN). Through LAN, processing was distributed across multiple station and they share the information in real time. They performed small control tasks in addition to altering operators of possible problems or tripped alarm levels. Each station was responsible for particular task hence size and cost of each station less than one used in First SCADA system. As network protocols used were still most proprietary, this led to significant security problems for any SCADA system.

3. **Networked SCADA system:** Current SCADA systems are usually networked. The SCADA system utilize open standards and protocols, thus they communicate through Wide Area Network (WAN) systems, over phone or data lines and often transmit data between nodes through Ethernet or fiber optic connectors. It is easier to connect third party peripheral devices like printers, disk drivers, and tape drivers due to use of open architecture. Due to use of standard protocols and the fact that many networked SCADA systems are accessible from the internet. These systems are potentially vulnerable to remote cyber attack.

3.4 Advantages and Disadvantages of SCADA:

Advantages of SCADA system

a. Increased reliability, lower costs.
b. Forecasting accurate demand supply management
c. Reduced maintenance cost, conditioning monitoring
d. Reduce human influence and errors
e. Assists operator for faster decision making
f. Automated meter reading
g. Easy fault diagnosis
h. Analysis of information & Decision making
i. Optimized system operation (competitive environment)

Disadvantages of SCADA system

a. Initial cost is more
b. As it is new technology, it requires training.
c. SCADA systems are now accessible through internet, hence security issues.

4. PROGRAMMABLE LOGIC CONTROLLER (PLC)

The programmable controller is a solid state electronic device designed in the early 1970s to replace electrochemical relays, mechanical timers, counters, and sequencers. Instead of achieving desired control and automation through physical wiring of control devices, in PLC it is achieved through program say software. PLC is industrial computer in which control devices such as limit switches, push button, proximity sensors, etc provide incoming control signals into the unit. An incoming control signal is called an Input. Inputs interact with instruction specified in the user ladder program, which tells the PLC to how to interact with the incoming signals. The user program directs the PLC on how to control field devices like motor drivers, solenoid etc. A signal going out of the PLC to control a field device is called Output.

The PLC is the tool that provides the control for an automated process. Automation will help a manufacturing facility to:

1. Gain complete control of the manufacturing process
2. Achieve consistency in manufacturing
3. Improve quality and accuracy
4. Work in difficult or hazardous environment
5. Increase productivity
6. Shorten the time of market
7. Lower the cost of quality, scrap, and network.

4.1Types of PLC:

It is classified into two types they are

1. **Fixed PLC:** A fixed PLC has all of its components – the input section, CPU and associated memory, power supply and output section – built into, one self contained unit. All input and output screw terminals are built into PLC package, and not removable. This type of PLC is also called packaged controller.
2. **Modular PLC:** the modular comes as separate pieces. A modular PLC is purchased piece by piece. There may be 2 or 3 power supplies to choose from, a handful of different assemblies, called racks, chassis or base plate to hold the pieces together. When purchasing a modular PLC, specific pieces are selected based on the needs of control situation.
3.

4.2 How PLC works

Basics of a PLC function are continual scanning of a program. The scanning process involves three basic steps [3].

1. **Step 1: Testing input status:** First the PLC checks each of its input with intention to see which one has status on or off. In other words it checks whether a switch or a sensor etc., is activated or not. The information that the processor thus obtains through this step is stored in memory in order to be used in the following steps.
2. **Step 2: Programming execution:** Here a PLC executes a program instruction by instruction based

on the program and based on the status of the input has obtained in the preceding step, and appropriate action is taken. The action might be activation of certain outputs and the results can be put off and stored in memory to be retrieved later in the following steps.

3. **Step 3: Checking and Correction of output status:** Finally, a PLC checks up output signals and adjust it has needed. Changes are performed based on the input status that had been read during the first step and based on the result of the program execution in step two – following execution of step three PLC returns a beginning of the cycle and continually repeats these steps.
   Scanning time = Time for performing step 1+ Time for performing step 2+ Time for performing step 3.

At the beginning of each cycle the CPU brings in all the field input signals from the input signals from the module and store into internal memory as process of input signal. This internal memory of CPU is called as process input image (PII).

User program (Application) will be available in CPU program memory. Once PII is read, CPU pointer moves in ladder program from left to right and from top to bottom. CPU takes status of input from PII and processes all the rungs in the user program. The result of user program scan is stored in the internal memory of CPU. This internal memory is called process output image or PIQ. At the end of the program run i.e., at the end of scanning cycle, the CPU transfers the signal states in the process image output to the output module and further to the field control.

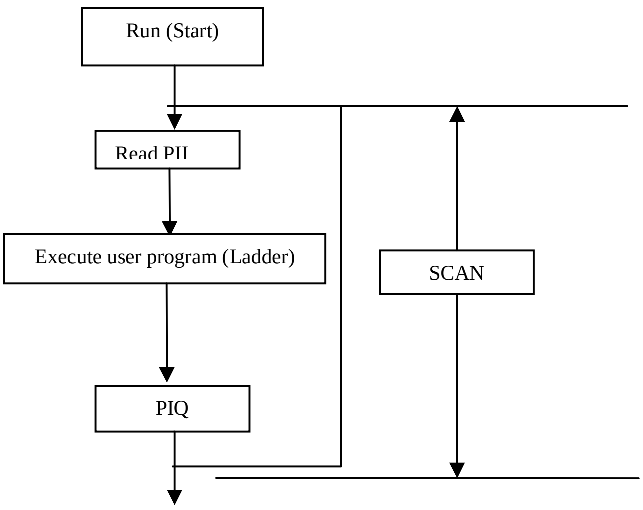

Fig. 4: Working of PLC

I/O driver (SCADA) picks up PII and PIQ and transfers the image to database and this image is called driver image. This driver image available in SCADA database is used for graphical view of process monitoring from operator station (OS) in the central control room.

4.3Advantages and Disadvantages of PLC:

Advantage of the PLC

a. More precise control.
b. Faster response.
c. Flexible Control of complex processes.
d. Ease of programming.
e. Security in the process.
f. Using a small space.
g. Easy installation.
h. Less energy consumption.
i. Better monitoring of performance.
j. Less maintenance.
k. Rapid detection of failures and downtime.
l. Less time in the development of projects.
m. Ability to add amendments without raising costs.
n. Lower cost of installation, operation and maintenance.
o. Ability to govern several actuators with the same automation.

Disadvantages of PLC

a. Skilled labor.
b. Centralizes the process.
c. Appropriate environmental conditions.
d. Increased cost to control very small or simple tasks.

5. DESIGN AND DEVELOPMENT OF SCADA SYSTEM

Based on the three layer SCADA architecture, SCADA system can be designed for many of applications such as, control of Boiler, control of an induction motor, for power system, etc. to design SCADA for all these applications procedure followed are:

I. Connecting field instruments to PLC:

1. After knowing the steps of operations which are carried out in plant, list of parameters to be controlled and monitored can be obtained. The parameters may be temperature, pump, valve, etc.

2. Parameters may be further classified as digital input & digital output and analog input & analog output. Depending on this PLC modules can be selected.
3. Once the parameters are classified they have to be connected to the input and output module of the PLC. Input module serves as link between the field devices and the PLC's CPU. Its function is to take the field device input signal, convert it to signal level that the CPU can work with. Output module serves as link between the PLC's microprocessor and hardware field devices. Its function is to take CPU's control signal and energize the modules switching device to turn on the output field device.
4. With this knowledge, develop program by Ladder Logic (LAD) or other programming tools present in PLC.
5. Configure hardware, networks and communication connections.
6. Download the program to programmable controller and test the program.

II. Connecting PLC and SCADA

1. Create new application in SCADA.
2. Open a SCADA application.
3. Create a tag of type I/O discrete, select the type as discrete
4. Select read only if you don't want to force values to PLC. Selecting read and write allows to the SCADA to read and force values to the PLC.
5. Type an access name.
6. The access name can visualized as a gateway for a group of resources.

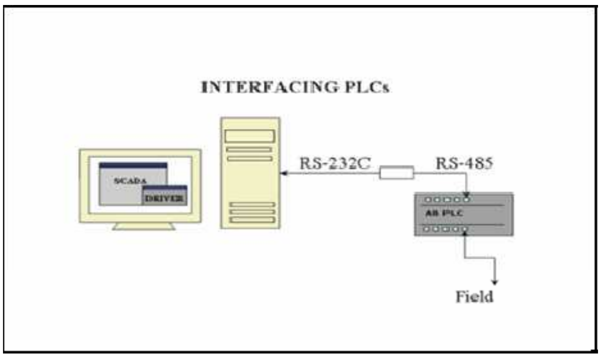

Fig. 5: Interfacing PLC & field

7. Most of PLC drivers communicate with SCADA package using DDE, DDE requires three parameters namely name of the DDE server, topic name and item name. In case of reading a number of items from a particular PLC driver application name topic name are common, so this application name that is name of the DDE server and Topic name combine to form an access name. Access name is required to be defined only once then other items of driver can be accessed by using the Access name and item name. These details will be provided by the driver vendor or developer.
8. Click ok, the access name will be listed finally click done, then type the item name, click save to save the I/O tags. Go to run time to communicate with PLC.

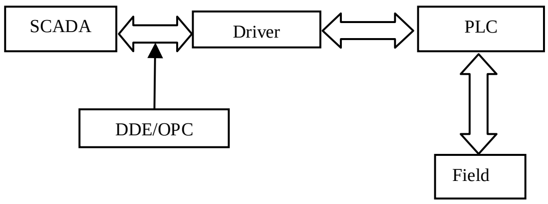

Fig. 6: Interfacing PLC & SCADA

6. APPLICATION OF SCADA & PLC

6.1 Control of Boiler:

Critical control parameters in boiler are (i) Level control (ii) Pressure control (iii) Flow controller (iv) temperature control.

Boiler operation: Water plays a major part in the generation of steam. Inlet water to the steam drum should be in purified form, for that, PH value of the water should be maintained, and stored in de-aerator tank. Feed water pump is switched ON by using feed water pump switch. The water from the de-aerator tank is allowed to pass through two parallel pipes. In one pump the flow rate is maintained at 130% and in another it is 5%. Thus the failure of any one pipe does not affect the boiler operation. The water is passed through economizer, thus the heat in the outgoing gases is recovered, by transferring its heat to the water. Then the heated water is made to flow through steam and water drum. In this, water should be maintained at least at 50%. For sensing water level we use PID controller in AB PLC. When the level is lesser than or greater than 50%, PID controller senses the level change and sends the appropriate control signal to the feed water valve 1 or valve 2. Thus, in spite of any changes in disturbance variable, the water level can be maintained at 50% by proper turning of PID controller [3].

Water in the water drum is maintained at more than 75%. This water is circulated back to steam and water drum, due to difference in temperature, high amount of steam is generated.

The generated steam temperature may be greater or lesser than the desired temperature. So depending on the situation the generated steam is then passed through primary heater followed by secondary heater. The secondary temperature is monitored.

Here we consider three main cases:

1. If the secondary heated temperature is greater than the desired temperature then by using PID controller, approximate control signal is sent to the control valve 3 of the super heater tank, to reduce the temperature, by spraying chilled water from de-aerator tank.
2. If the output of the secondary heated temperature is lesser than the desired, using a PID controller approximate control signal is sent to bunker valve to control fuel flow.
3. If the output of the secondary heated temperature equals the desired temperature, no control action is needed, the stem is taken out.

Flow chart: The operation is summarized as flow chart as below in figure 7 and SCADA result in figure 8.

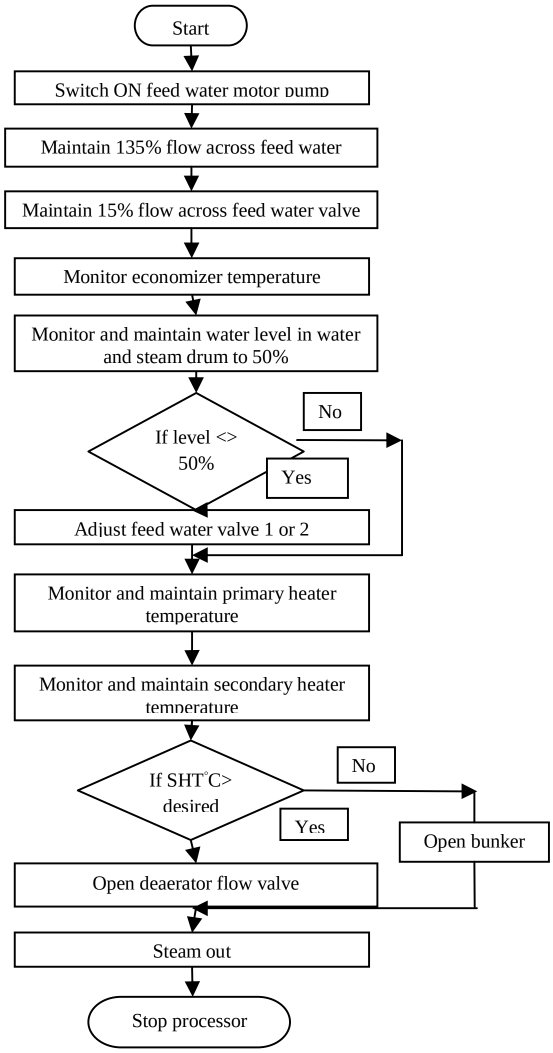

Fig. 7: Flow chart for control of boiler

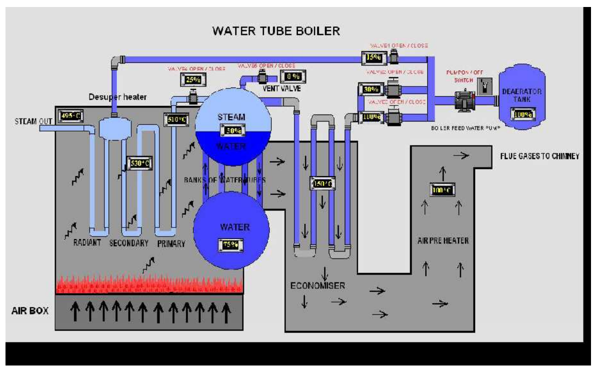

Fig. 8: SCADA result screen.

6.2 Control of 3-ph induction motor:

Using equipment from Siemens SCADA-TIA [2], application of SCADA system to control of Induction motor associated with a frequency inverter, in manual or automatic mode can be achieved. The motor is controlled manually with the predefined frequencies and automatically by sequence.

1. Manual control for frequency inverter: The aim is to implement the manual drive control for frequency inverter. The manual operating mode for the motor assumes the following:
   (a) Start the motor at preset frequency (10, 25 & 50Hz).
   (b) Stop the motor.

Ladder logic is used for programming the manual drive control.

2. Automatic control for frequency inverter: It consists of sequence of steps executed in a defined order. The following sequence will be designed:

a. Step 1 – Run at 10Hz,
b. Step 2 – Hold for 10s 10Hz,
c. Step 3 – Run at 25Hz,
d. Step 4 – Hold for 10s 25 Hz,
e. Step 5 – Slow down to 10 Hz,
f. Step 6 – Hold for 10s 10Hz,
g. Step 7 – Ramp up to 50Hz,
h. Step 8 – Hold 50Hz for 10s,
i. Step 9 – Reverse rotation sense to -50Hz,
j. Step 10 – Hold -50Hz for 10s,
k. Step 11 – Slow down to 0 Hz,
l. Step 12 – Stop.

Both manual control mode and automatic control mode are integrated so that they functions together as a system. Switching between the two subsystems, operating modes of the inverter is possible at any time. A force stop is available in each subsystem, when the inverter brings the motor in its initial state. Only in the manual control mode, when sense module detects an object, the motor is stopped and motor starter is disabled.

Flow chart: The operation is summarized as flow chart as below in figure 9. The result of SCADA screen as shown in figure 10 and the workflow for this application is given as following:

1. Create a script to convert the frequency value from hexadecimal to decimal, and associate the value to an internal tag.
2. Insert into the manual drive control a gauge for the frequency value (Fig. 10a).
3. Create a screen for automatic drive control (Fig. 10b).
4. Create a trend view to monitor the frequency value in a separate screen (Fig. 10c).
5. Create two analog alarms: one for the frequency being below 25 Hz and another one for the frequency being above 45 Hz.
6. Create discrete alarms to notify when the frequency is at 10 Hz, 25 Hz and 50 Hz.
7. Create a screen for the alarm view (Fig. 10d).
8. Insert buttons in both operating modes for trend view and alarms.
9. Finalize the application.

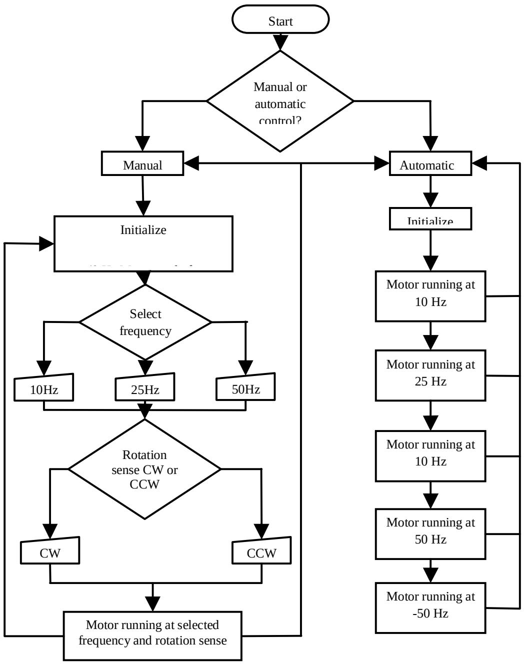

Fig. 9: Flowchart of control of induction motor

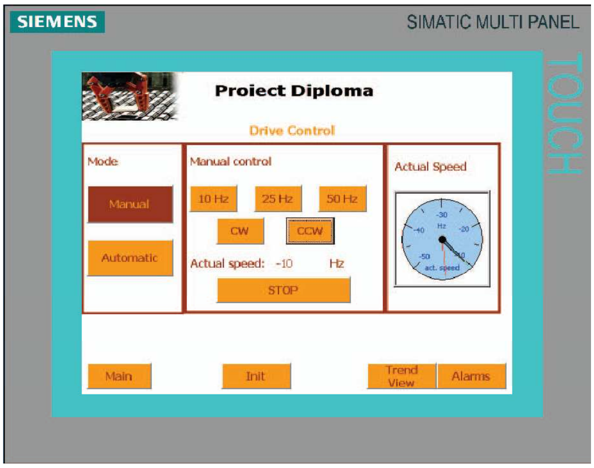

Fig. 10a: Manual drive control mode

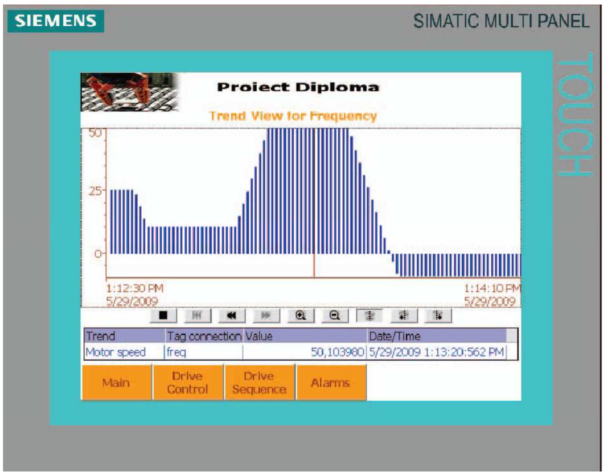

Fig. 10b:Trend view for inverter frequency

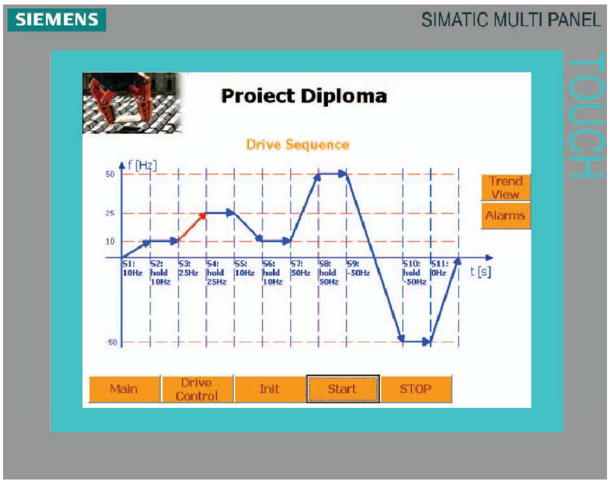

Fig. 10c: Automatic drive control mode – reference sequence

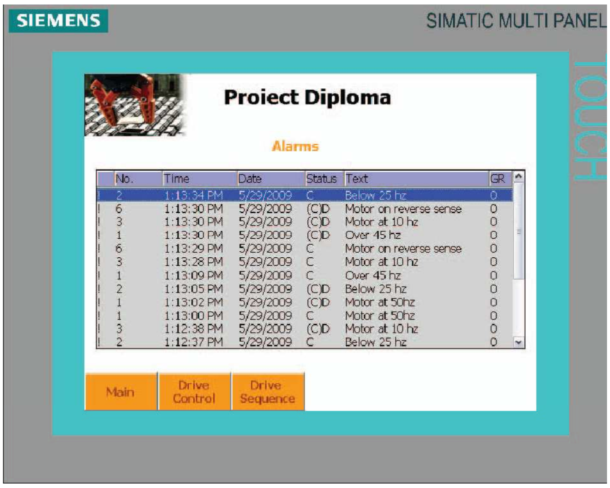

Fig. 10d: Alarms

7. CONCLUSION

In this report, the three layer SCADA system architecture which depending on open system technology is presented. A brief description of SCADA system & PLC and has outlined some application of SCADA system for 'control of boiler' in the report. Using equipment from Siemens SCADA-TIA Democase kit, application of SCADA system to control of Induction motor is depicted in this report. Such systems have greatly increased the ability of system operators to maintain complete and timely on system conditions and to rapidly take appropriate actions during trouble periods. Thus concluding that, due to recent technological advances, the automation has become technically and economically feasible for developing application in various sectors. Hence there is need to introduce SCADA system in advanced educational courses.

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BIOGRAPHY

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