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Distributed Control System Application for Distillation Column

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Abstract: The entangled nature of various continuous production processes, such as chemical processing, oil and gas, and water treatment, continue to require the advanced process control capabilities of the Distributed control system (DCS) in order to aggregate and analyse a large amount of data at the same instant of time. This paper aims to enhance the flexibility in controlling and monitoring of distillation column by configuring and developing a HMI using DCS with SCADA. DCS provides high scalability, solutions to complexity, redundancy, high adaptability to frequent process changes, hybridized to incorporate PLCs and PCs to control complex functions and to provide reporting services. Hence the optimized control of distillation column has been achieved via DCS.

Keywords: Distributed Control System (DCS); Human Machine Interface (HMI); Supervisory Control and Data Acquisition (SCADA); Programmable Logic Controllers (PLCs); Personal Computers (PCs)

Introduction

At present time, most of the process industries are in the position to monitor and control many different processes in their manufacturing process at the same instant of time [1], but they cease to perform these operations at every instance of time. Global monitoring and controlling of all the process at a same time of instance is the key, in which it leads to increase the process productivity and plant safety [2]. This can be achieved by means of Distributed Control System.

The uses of Distributed Control Systems (DCS) are becoming popular and useful to control complex process in the industry that involves multiple variables and control loops. Some top vendors who provide these DCS systems are Yokogawa, Emerson, Siemens, ABB, and Honeywell. The continued development of these DCS systems by manufacturers results in great advantages for the users of this kind of technology [3]:

1. Flexible hardware architecture and software tools which come with advanced algorithms of optimization, modeling and control;
2. Robust communication systems between hardware components such as workstations, smart devices, sensors;
3. Capabilities which manage alarms and abnormal events;
4. Integrated diagnostic features in hardware, communications and control;
5. Capacity to have redundancy in the design of the systems in both hardware and software levels [4];
6. Ability to create historical data bases and efficient manipulation;
7. Security by having limits on the access to the parts of the control system;
8. User friendly graphic tools that is useful in manipulating the system.

Distillation column is one of the most important units in a chemical plant which is used to separate two or more components from a homogeneous fluid mixture. The processes involved in distillation column are multi variable and non-linear in nature [2]. Due to relative uncertainties of the system, the chemical processes are difficult to model as well as complex to control. The quality and purity of distillation is of paramount importance, therefore proper control of the system is necessary. This paper aims to enhance the flexibility in controlling and monitoring of distillation column by configuring and developing a HMI using DCS with SCADA.

Section Organization

The paper is organized into six sections. After the introduction, the second section presents a brief description of the distillation column. The third section illustrates how the DCS display options and alarm management system can provide easy operation of the distillation column by senior undergraduate students. Next, in the fourth section, the Auto-tune tool is used and the performance of the main control loops of the distillation column are evaluated by taking advantage of the DCS's historical data base facilities. The conclusions of this paper are found in the fifth section. Finally the future enhancement of this paper is discussed in the sixth section.

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Distillation Column Project

Brief description of the process

Figure 1 shows the P&ID of the distillation column, the main pieces of equipment involved in the binary distillation process are a Xytel distillation column, reboiler, condenser, accumulator, and reflux pump. To operate the column there are four control loops that need to be working simultaneously: (1) level of the accumulator, which is a cascade controller where the controllers involved are the master level control loop LCACCUM and the slave reflux flow control loop FCREFLX; (2) steam flow rate control loop FCSTEAM; (3) pressure control loop PCCOLMN, which maintains the pressure at the top of the column constant; (4) the cascade temperature controller TCCOND keeps the temperature at the output of the condenser constant by defining the set point of the slave flow control loop FCCOOL, which is the water cooling supply.

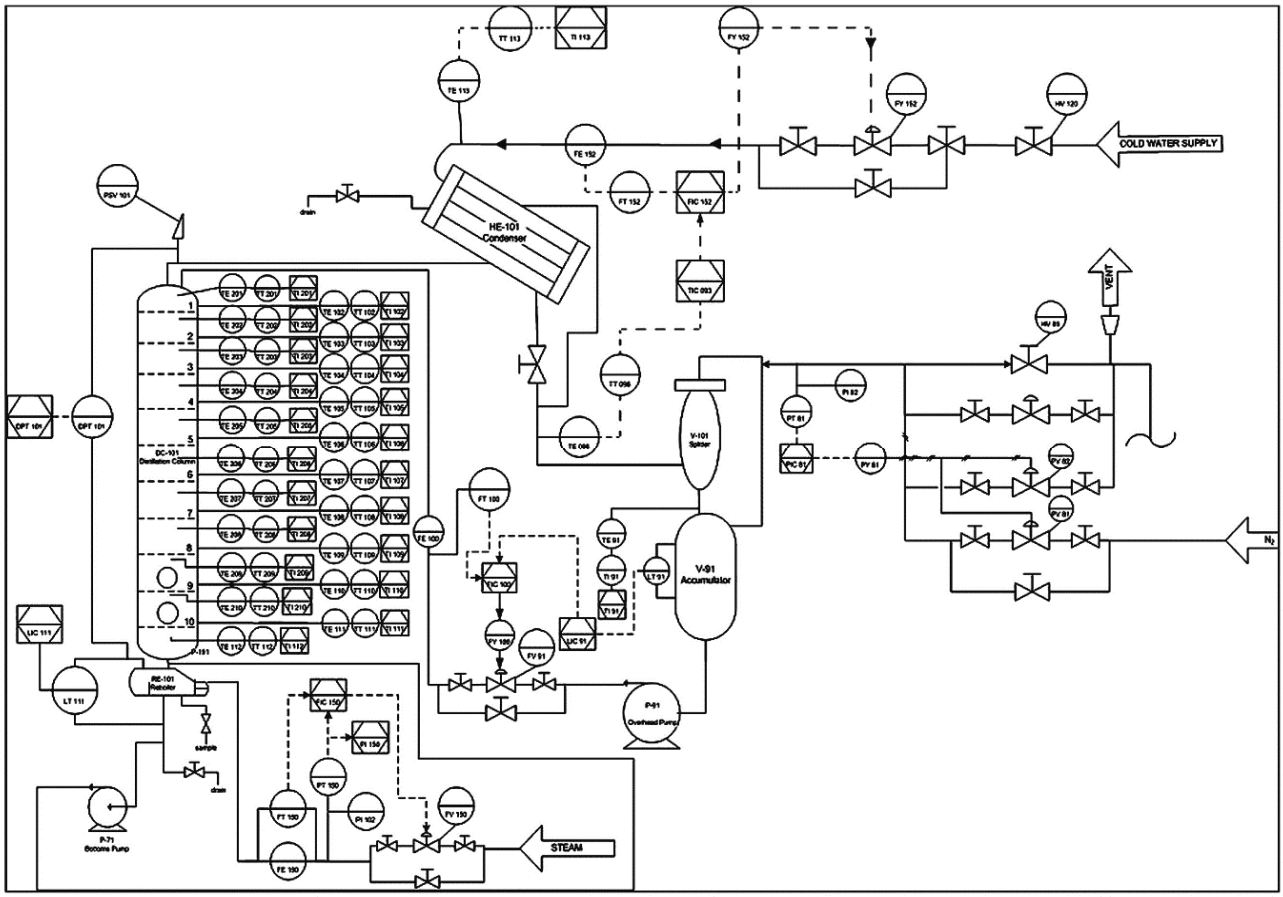

Figure 1: P&ID of the distillation column.

Project Objectives

This project has two main objectives: (1) to enhance the flexibility in controlling and monitoring of distillation column by configuring and developing a HMI using DCS with SCADA and (2) to familiarize the operator with the operation of an industrial DCS system for the control of the distillation column by providing the operator with additional information that may be considered important in critical situations. To accomplish these objectives, the column has to be operated at different operating points. Table 1 shows the operating points of all control loops for the entire experiment.

Safety Hazards

Another important point is the safe operation of the column. The most common problems are located in the level of the accumulator where two possible situations can occur. The first situation is to have a leak in the tank of the accumulator while the second is to have a low level in the accumulator, where it is possible to cause damage in the reflux pump. The next section will present how these hazards can easily be addressed by designing interlocks in the DCS system.

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Control Loop Tag Name	Operating Points	Units
LCACCUM	**18**	Cm
FCREFLX	**0-1.875**	Litres/min
FCSTEAM	**0.35**	Kg/min
	0.45	
	0.55	
	0.65	
	0.75	
	0.85	
PCCOLMN	**101**	Kpa
TCCOND	**57**	Degree Celsius
FCCOOL	**0-13**	Litres/min

Table 1: Operating Points of Distillation Column

Human Machine Interface (HMI) of the DCS System

The use of the DCS graphics interface results in easier operation of the distillation column for operators. The HMI has three main functions: (1) to provide visualization of process parameters; (2) to enable interaction with the process; (3) to provide alarms and event notification to the operator about any abnormal situations in the plant. Detailed information about these three functions is included in this section.

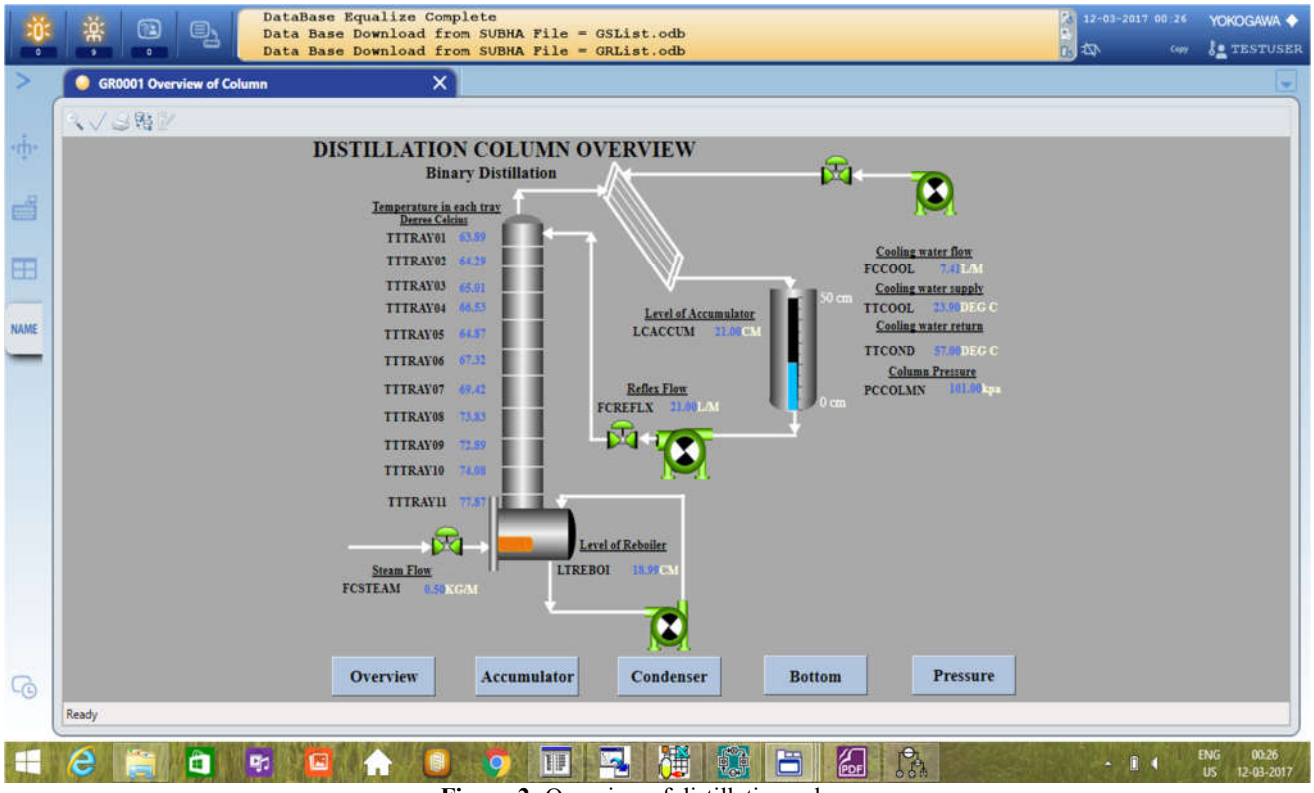

Figure 2: Overview of distillation column.

Figure 2 shows the overview graphic display of the distillation column, which provides a representation of the process and makes it easier for operators to visualize what, is happening. Through this overview display, it is possible to monitor the main variables of the column, check the conditions of the most important control loops, and identify the on/off status of the discrete components which are operating in the process [5]. For instance, the temperature in every tray of the column can be monitored by checking the tag names TTTRAY01 to TTTRAY11 in Figure 2. Moreover, the key variables of the control loops FCSTEAM and LTREBOI

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can be viewed. Finally, the pump status, which belongs to the control loop LCACCUM, is identified by its colour (green means that the pump is on while red means that the pump is off).

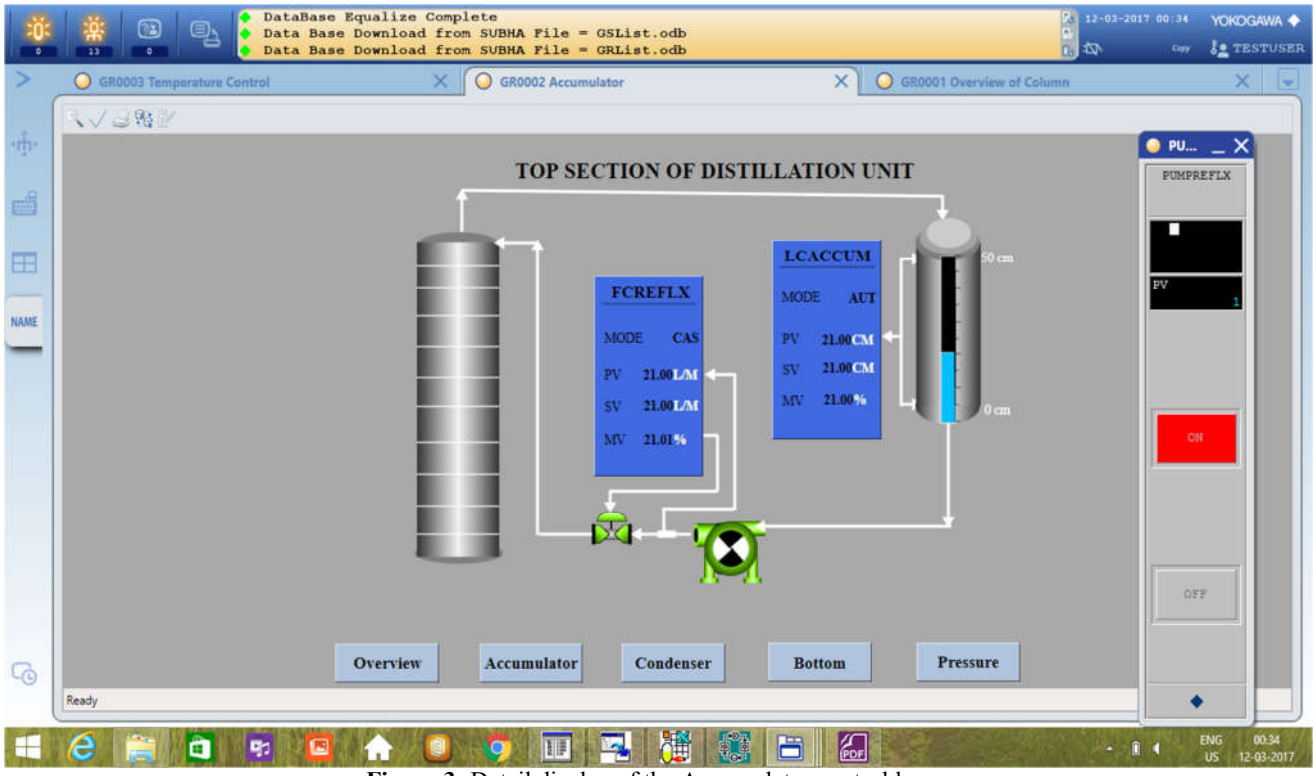

Figure 3: Detail display of the Accumulator control loop.

To interact with the process, detailed displays, which contain specific control functions to operate the column, can be used. Figure 3 shows one of the four detailed displays available in the distillation column. With this detailed display, it is possible to control the level of the accumulator by setting up a cascade control loop. The operator has the choice to configure these two controllers (FCREFLX and LCACCUM) in three modes. For manual mode (MAN), shown in Figure 3, the operator manipulates the final control element directly. In Figure 3, the operator is able to manipulate the opening of the valve of the control loop FCREFLX, which determines the reflux flow to the column. In automatic mode (AUTO), the final control element is manipulated automatically through a PID controller and the set point for the control loop is entered by the operator. For the detailed display of Figure 3, both control loops FCREFLX and LCACCUM are able to set up in the automatic mode, but the LCACCUM control loop does not have any control element to manipulate. In cascade mode (CAS), where two master and slave controllers are operating, the master controller sets the set point for the slave controller and the set point for the master controller is set by the operator [6]. In order to set up the cascade control strategy in Figure 3, the mode of the controller FCREFLX is set to CAS mode and the mode of the controller LCACCUM is set to AUTO mode.

The another operator display is also explained, that uses single PID controller PCCOLMN which is operated in the AUTO mode under reverse action of the controller i.e. when the process variable is greater than the set variable then the output of the controller (manipulated variable) gets increases and vice versa [7]. The aim of this pressure control loop is to maintain the pressure of the column constant at 101 kPa the figure 4 shows the detail display of pressure control loop.

On the other hand, with the idea of having specific information about the separate loops that operating in the distillation column, Figure 5. Illustrates a typical faceplate display; this faceplate corresponds to temperature control loop TCCOND. Usually, the faceplate display shows the controlled process variable and the output of the control loop. Furthermore, the set point, and the operating mode of the control loop can be changed. The operator can monitor maximum of eight faceplates at the same instant of time shown in Figure 5.

The tuning window is the system defined window in which tuning view is automatically created when a function block is created on the Function Block Overview Builder [8]. Alarm setting parameters and loop tuning parameters can be altered with the help of this tuning window. At the bottom of this

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Window we can see the trend display this trend view can be used for displaying various graphs of process variable set variable and manipulated variable each of different colours changed along with time axis.

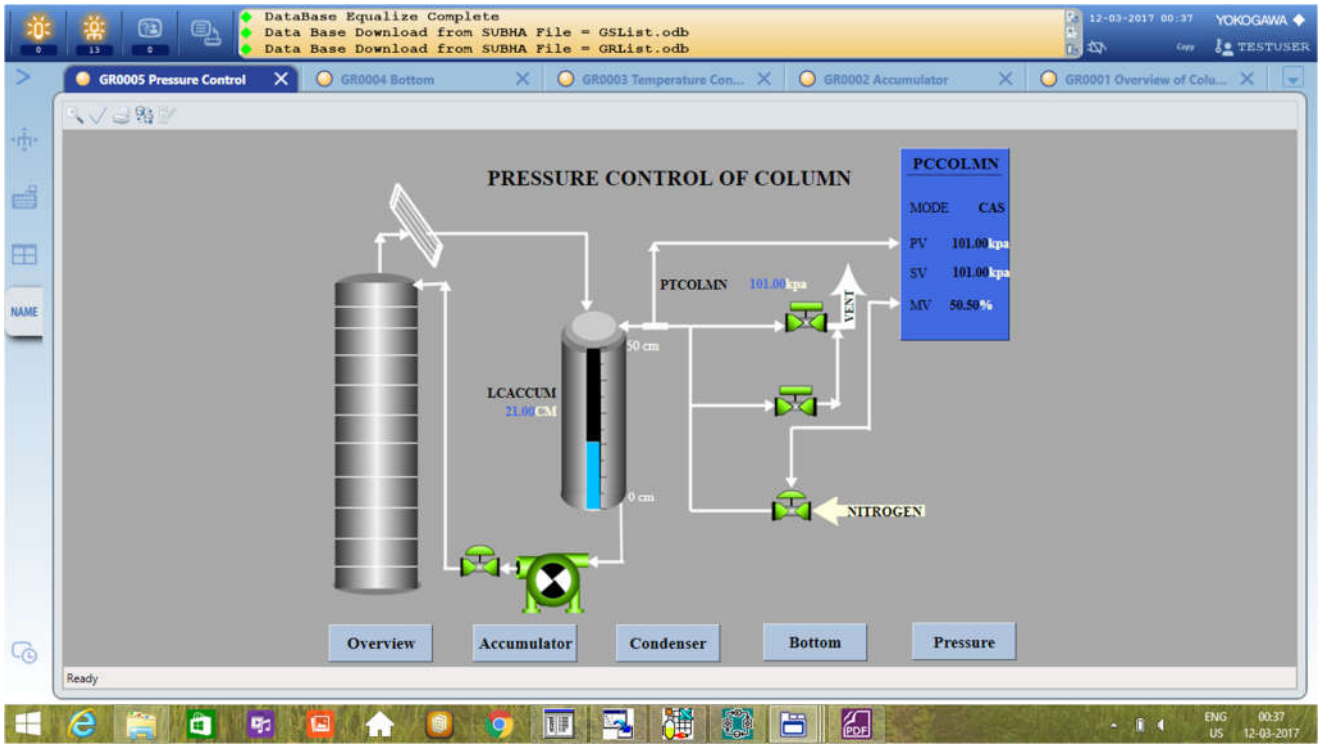

Figure 4: Detail display of the Pressure control loop.

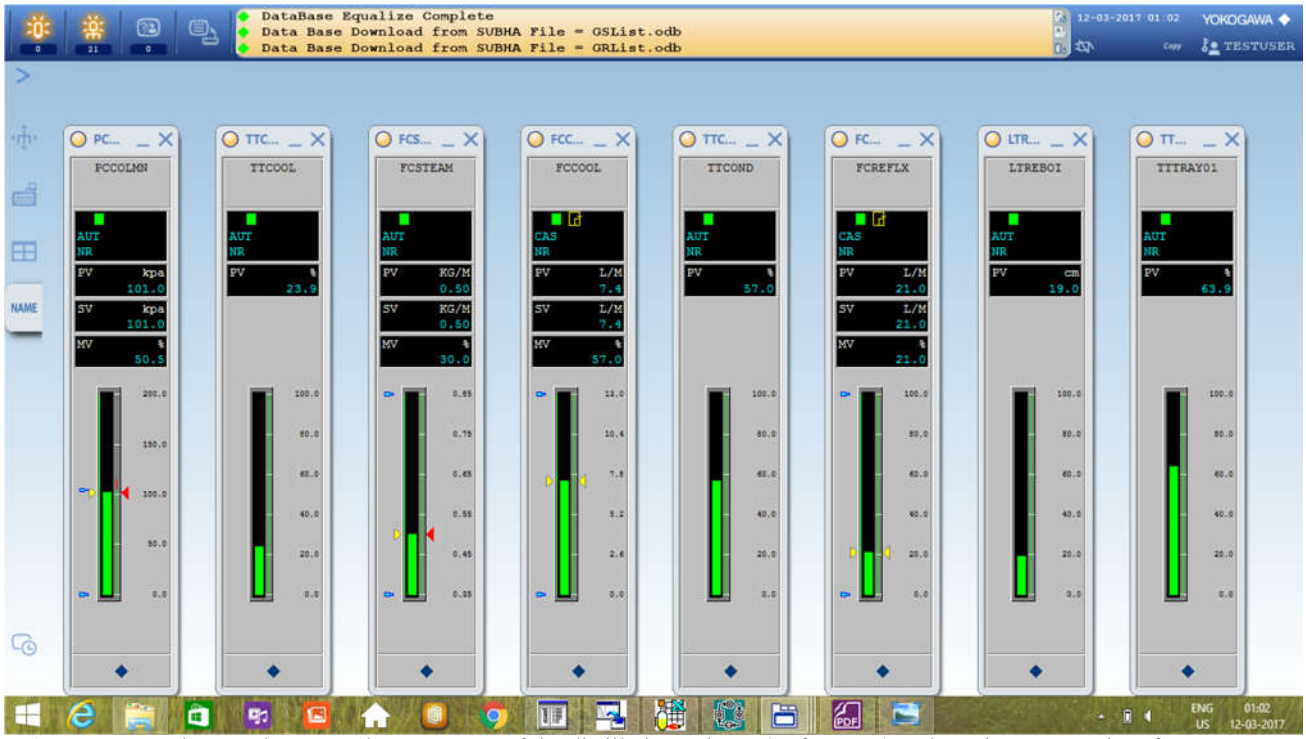

Figure 5: Faceplate used to control temperature of the distillation column (Left corner) and maximum capacity of HMI screen (Right side)

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To obtain a better understanding of the plant, trends of the key variables of the process can be visualized and analysed. Figure 7 shows the trend display of the key variables of the column over a period of time such as the differential pressure of the column DPI-081 (blue line), reflux flow (light red line), accumulator level (purple line), steam flow (green line), etc. Based on these trends, the set point values as well as the mode of the different controllers of the column can be changed with the purpose of improving the performance of the plant. In addition, by using the historical databases accumulated throughout the experiment, new control strategies can be created, controller parameters can be customized, and abnormal situations can be detected.

Figure 6: Tuning window of accumulator level controller.

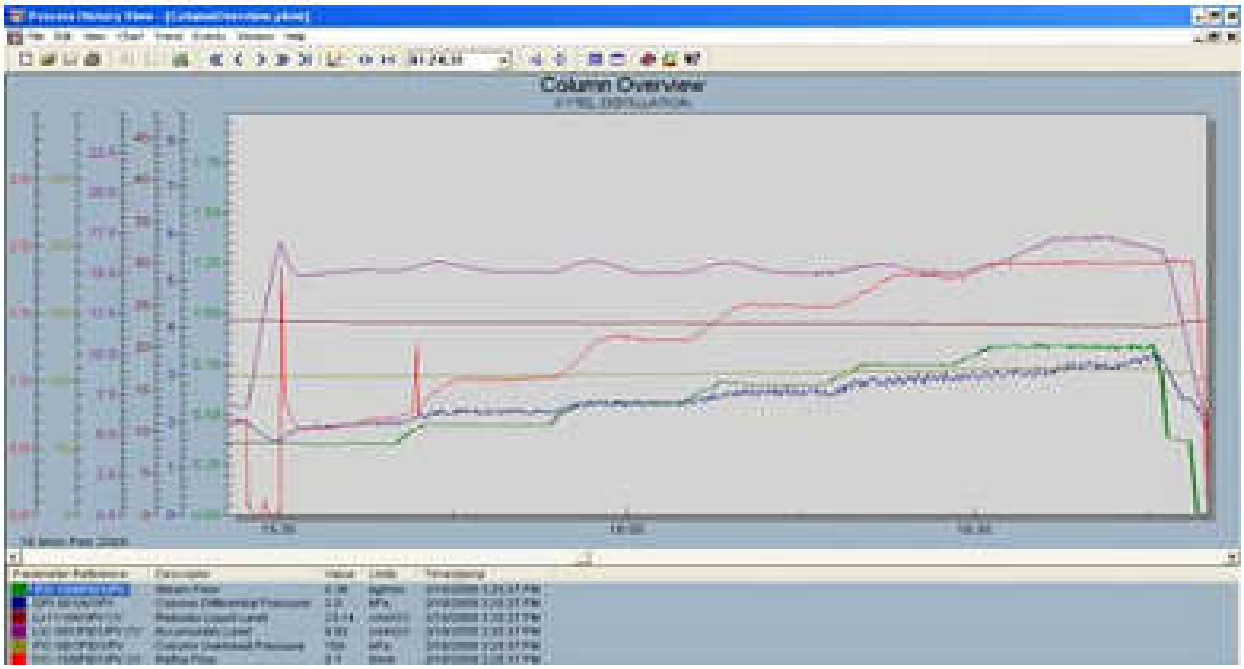

Figure 7: Trend Display of the Column.

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Now the Figure 8 shows the Process Alarm view displays process alarms in the order they are generated, starting with the most recent alarm. A Process Alarm view displays process alarm messages and annunciator messages in the order that the most recent message appears on the top. When an alarm occurs, the icon of the alarm displayed on the System Message banner will start to blink along with an audible sound to notify the operator. In this list of alarms, each sensor or control loop is associated to a traditional process alarm such as pre-high alarm (PH_ALM), pre-low alarm (PL_ALM), high alarm (HH_ALM), low alarm (LL _ALM), velocity limit alarm (VL_ALM), etc. These process alarms have been associated with a priority parameter like warming, advisory or critical alarm. For example, the control loop LCACCUM has enabled four different alarms: PH_ALM, PL_ALM, HH_ALM and LL_ALM. At the moment that an alarm has been detected, a report message is created. The alarm is maintained active in the system and it is shown in the top part of displays of Figures 2, 3 and 4 until there is confirmation about the receipt of the notification, or confirmation of acknowledgment, which means that the alert has been processed. Then, by using these alarms over the level of the accumulator, the safe operation of the process is increased by alerting operators to any abnormal situation. On top of this complete alarm information provided by the DCS system, it is also possible to create interlocks which are discrete algorithms used to prevent damages in equipment. For example, if the level of accumulator drops to lower than 6 cm, an alarm is activated (LL_ALM) and the reflux pump is turned off automatically with the intention of protecting the equipment from any damage.

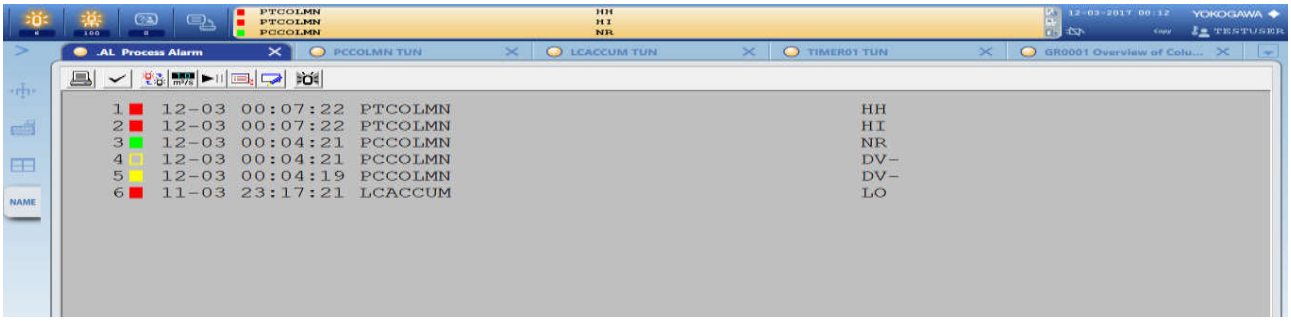

Figure 8: Process alarm display.

Finally Figure 9 Shows the Process Report view displays an overview of the control station process status such as status of all discrete components, current values of transmitters, controllers and their alarming conditions. The process report is to collect information on the system operating status and displays it in a window or prints to a printer depending on the user's request.

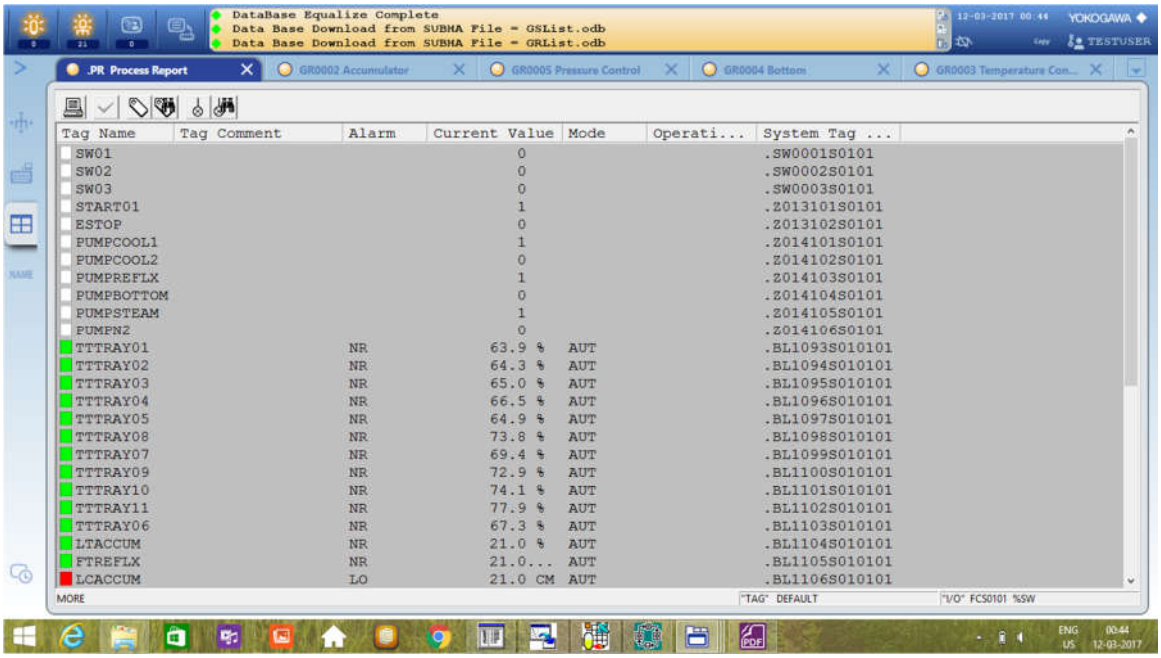

Figure 9: Process report view of distillation process.

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Tuning Capabilities of Controller

In process control, PID is one of the basic controls which play major fundamental roles [9]. Proper setup and tuning are required for stable column operation and are a prerequisite for advanced process control. Yokogawa provides a standardized approach to the implementation of regulatory control stabilization with fixed procedures and methods that ensure optimum and safe control of distillation column [10]. In order to attain a stable process, plants must determine and improve the effectiveness of regulatory control loops (e.g. control configuration, PID tuning, instrumentation). The Auto-tuning method available in the Yokogawa Centum VP system gives optimum control of the distillation column. Also PI controller is the best option for column control other than P and PID controller [11], here also we prefer PI controller for the control of column by just making the derivative gain as zero shown in Figure 6 with the capability of auto tuning option.

Conclusion

Distillation Column is the most crucial process and has many impacts on the entire industry which is considered here and it is controlled perfectly in PI controller mode by using Yokogawa DCS. DCS gives the industrial platform of controlling and the SCADA provides high level human machine interface. So the perfect control and monitoring of distillation column is highly achieved via Distributed control system.

Future Enhancement

At present industries uses DCS and advanced safety PLCs for the control of distillation column. The development of industrial intelligent control is in the mainstream. Intelligent control is a class of control techniques that use various artificial intelligence computing approaches like neural networks, Bayesian probability, fuzzy logic, machine learning, evolutionary computation and genetic algorithms. In future Advanced Process Control (APC) such as Model Predictive Control (MPC) or Neural Network Controller (NNC) can be used with those DCS systems especially for process industries with many controllers.

Appendix

P&ID	Piping and Instrumentation Diagram
LCACCUM	Tag name used to define the accumulator level controller
FCREFLX	Tag name for reflex flow controller
FCSTEAM	Tag name for steam flow controller
PCCOLMN	Tag name for pressure controller of the column
TCCOND	Tag name for temperature controller in condensation unit
FCCOOL	Tag name used to define the flow controller in cooling supply system
TTTRAY01	Tag name of temperature transmitter in tray 1 of the distillation column
TTTRAY11	Tag name of temperature transmitter in bottom tray (near reboiler) of the distillation column
LTREBOI	Tag name of level transmitter in the reboiler tank
DPI-081	Tag name for differential pressure indicator of the column

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