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CONTROL AND MONITORING OF AN AUTOMATED DESALINATION PLANT USING PLC-SCADA

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Abstract*—Desalination is the process of removing dissolved minerals (including but not limited to salt) from seawater, brackish water or treated wastewater. A number of technologies have been developed for desalination, including reverse osmosis, distillation, electro dialysis, and vacuum freezing. In this paper we present a low cost, locally developed customized remote monitor- ing and controlling system for desalination plants providing the operator with functions including GUI, generating reports and keeping logs in historical database. This paper presents a scheme for controlling the major loops in the desalination process using distillation technique. In actual plants there are systems available to monitor conductivity, pH, corrosion rate, turbidity, dissolved oxygen, sodium, fouling, biological activity and halogens. The paper focuses on systems instantaneously generating real time records and alarm conditions for the analysis of water using pH measurement. Necessary control actions are taken when alarm conditions are raised. The paper describes a model for the automated treatment of a batch of saline water including processes of filtration, distillation, pH measurement, collection of product water and drain. Field devices are used for sensing while the process controlling and monitoring is done using PLC-SCADA systems. PLC is used for maximum automation of the process. SCADA software is used to give a virtual display of the proposed system. Nowadays the application of PLC-SCADA is widely known and used in the digital world. In high security applications, access control is also required so as to authorize the controller and keep the system secure.

I. INTRODUCTION

Water has always been considered as one of the most valuable and precious natural resources for humans and ecosystems. Over the past few decades, the tremendous population growth, the increased urbanization and the boom in industrial and commercial development have resulted in a significant high demand for fresh and clean water. Additionally, this development around the world has led to the pollution of available water resources, the degradation of natural sources, the deforestation and the climate change owing to global warming, all of which play a vital role in the reduction of average rainfall and runoff. During the last century, the world population increased from 1.65 billion to 6 billion, while it is expected to increase further in this century. The rapid growth in population and industrialization place pressure on the remaining water resources and the need for discovering new resources of potable water is getting an imperative urgent issue. Nowadays, about 20% of the world's population is lacking of access to safe drinking water. According to the latest figures from the United Nations World Water Development Report, by 2025 more than 50% of the world's nations will confront water crises, nevertheless by 2050 the possibility for the 75% of the total population of facing serious water shortage will be significant.

Desalination, despite the high cost, is one of the most valuable alternative water resources applied to many countries around the world which can produce a significant quantity of fresh water. In the last 10-15 years, desalination has become a predominant technology in a wide spectrum of suitable applications. Thus, desalination process has been embraced to accomplish the basic human right for available clean and fresh water.

II. LITERATURE SURVEY

Most industrial water treatment systems are dynamic. They constantly undergo changes because of seasonal variations in water chemistry, varying plant operating conditions, new environmental laws, and other factors. Because of this, proper monitoring is essential to ensure that the water treatment program applied to a boiler, cooling, wastewater or other industrial water system is satisfactorily controlled so that the desired results are achieved. Some of the value added benefits obtained through proper monitoring of a water treatment program include:

- reduced risks associated, with chemical underfeed or overfeed
- continuing compliance with environmental regulations
- improved quality of plant operation
- increased water and energy savings
- improved plant productivity

Industrial water treatment systems may be monitored by manual methods or by continuous systems employing automatic instrumentation.

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A. Manual Monitoring

Manual monitoring typically involves plant operators or technicians conducting chemical tests and comparing the results to specified chemical control limits. The testing frequency can vary from once per day to once per hour, depending on the plant resources available. The tests run can include pH, conductivity, suspended solids, alkalinity, hardness, and others. Using the test results, the plant operator manually adjusts a chemical feed pump or blowdown valve, making an estimate of the degree of change necessary. Manual monitoring is satisfactory for noncritical water systems or systems in which water and plant operating conditions change slowly. Many systems operate with manual monitoring.

B. Continous On-line Monitoring

Because of the dynamic nature of many water treatment systems and the worldwide need for improved reliability and quality, a higher degree of precision is required in the monitoring and control of water treatment programs than that obtained through manual monitoring. To achieve the degree of precision needed, continuous on-line monitoring with automatic instrumentation is required.

III. HARDWARE

A. P & ID

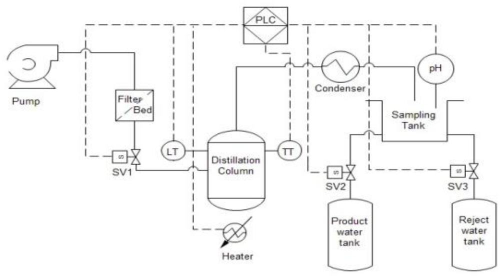

Fig. 1: Piping & Instrumentation Diagram of the Proposed System

B. Construction

It consists of a distillation tank, input filtration tank, drain collection tank & product water tank, which are interconnected through various pipe fittings & control valves. A heater is placed at the bottom end of the distillation tank along with level switches and temperature transmitters fit into it. All the process control components are interfaced to PLC through proper wiring, for automatic controlling & monitoring.

The main distillation tank is made up of iron material, which is best suited for the temperature of the process. Iron is chosen such that it can withstand the pressure of steam developed inside the vessel during the process. The flow of fluid entering and leaving the distillation tank during the distillation process is controlled through the solenoid valves. The size of the solenoid valves chosen is 0.25 inch. Also, the pipe material used for the fluid flow is PVC type and the size is chosen to be of 0.5inch.The valves & pipes being different in size, are connected through the brass connecters.

C. Design Calculations

1) Tank calculations:
Radius of the Distillation column (r) = 5cm
H eight of the Distillation column (h) = 20cm
$V = \pi \times r^2 \times h$
V = 1.6 L

2) Heating Calculations:
$Q = m \times Cp \times \delta t$
where, Q = heat required(kJ),
m = M ass of water = 1.6 kg
δt = dif f erential temperature
Cp = 4.19K/J H ence, Q = 502.8 kJ

Heater rating(Qw) = 2 kW
So, T ime required f or sterilization(t) = 2514 s = 20 mins

3) Flowrate Calculations:
$m \times g \times h = 0.5 \times m \times v2$
$v = (2 \times g \times h)0.5$ where, h = 0.6096m g = 9.8 m/s2
v = 3.4566m/s

N ow, C ross sectional area of pipe(A) = $\pi \times r2$
r = 0.003 m
So, A = $28.26 \times 10{-}6$ m2

Flowrate of liquid f rom tank1 (F) = v × A F = 225 lph

IV. SOFTWARE

As mentioned earlier the main expectation of the overall system is providing remote monitoring and controlling capabilities for the operator at the desalination plants. Focusing on the user requirements, following capabilities have been provided for the user in the software.

Monitoring: This is the feature of the system where extracted information is presented for the operator in near real- time. Monitoring has been divided into two sections: Full graphical data representation and Text base data representation.

Full graphical data representation: In this section, the user is able to monitor the plant in a very user friendly manner where details are represented in dynamic graphical interfaces. Text base data representation: In this section, the near real time details are represented in tables without graphical objects. In addition to that, both the real time and non- real time data can be observed using graphs.

Controlling capabilities: Controller capabilities are required to initialize the pump on/off conditions of four pump houses in the implemented system.

Report Generation: This is an important feature of the software for the user where the reports are generated in a given format using the real time information and the

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extracted database information.

User Administration: The users are divided into different user levels. Each user is given a user name and password where users have to pass authentication procedure to get the access for the system.

A. Programmable Logic Controller

Programmable Logic Controller or PLC is an intelligent system of modules, which was introduced in the control and instrumentation industry for replacing relay based logic. Over a period of time, better I/O handling capabilities and more programming elements have been added along with improvement in communication. Basics of a PLC function are continual scanning of a program. The scanning process involves three basic steps.

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.

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 step.

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.

Advantages offered by PLCs:

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

In this project we have worked using Micrologix 1200 Series B PLC (Allen Bradley make).It is programmed in Ladder Logic.

B. Input-Output Configuration for PLC

1) Input Configuration

- Start, Stop and Emergency stop
- Temperature transmitter (Analog signal 4 - 20 mA)
- pH transmitter (Analog signal 4 - 20 mA)
- Level switch (Digital signal 0 or 5 V)

2) Output Configuration

- Solenoid valves (3 digital outputs)
- Heater (relay switching)

3) Total 2 Analog and 3 Digital Inputs and 5 Digital Outputs are required for the given system.

C. Interfacing

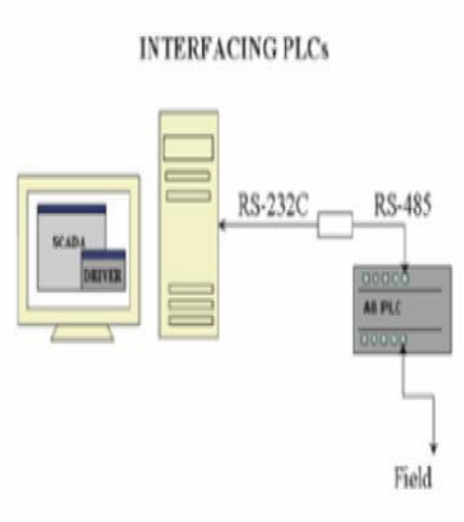

Fig 2: Interfacing diagram of PLT

D. SCADA

SCADA stands for Supervisory Control and Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. It is used to monitor and control plant or equipment. The control may be automatic or initiated by operator commands. The data acquisition is accomplished first by the RTUs scanning the field inputs connected to the RTU. This is usually at a fast rate. The central host will scan the PTUs, the data is processed to detect alarm conditions, and if an alarm is present, it will be displayed on special alarm lists. Its function is to control process equipment at the remote site, acquire data from the equipment, and transfer the data back to the central SCADA system.

Proficy software enables you to configure a system environment that provides: Supervisory control, batch processing, data acquisition, continuous control, and

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statistical process control for industrial applications.

E. Flowchart

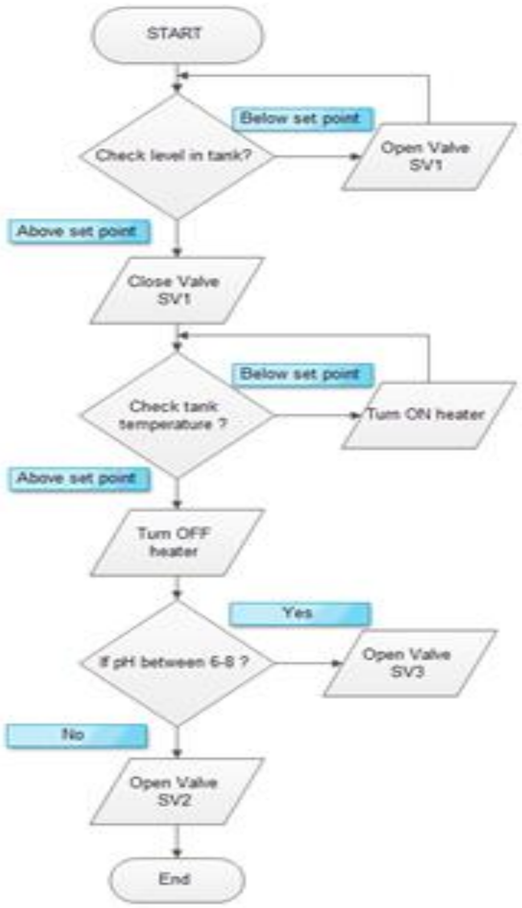

Fig. 3. Flow Chart

V. SEQUENCE OF OPERATION

Is it necessary to describe the proper sequence of events or operations which helps to run the control system in successful manner. The sequence of events can be described using narrative statements. These statements describe in brief what must happen in the system and in what way to achieve the required result. The steps involved in this project are as follows:

1) Enter security password and ID to enter the Main screen
2) Press START button on the control panel of the SCADA Main screen
3) As the inlet water starts flowing, it passes the filtrations bed
4) The water then enters the distillation column and the level in the tank is sensed
5) As the water level reaches the high set point, the valve SV1 closes and the heater is switched ON
6) The feed pump and valve SV1 are operated according to the level sensed in the column using level switches.
7) The heater is controlled by the PLC using an RTD to regulate the required temperature in the distillation column
8) The water evaporates and passes through a condenser unit to cool the vapour into droplets of water and recollects in the sampling tank after percolation
9) Here the pH of the water sample is measured and recorded
10) If the pH of the water sample is within the acceptable range, it is passed into the product water tank through the valve SV2
11) If the pH of the water sample is not within the acceptable range, it is passed into the drain water tank through the valve SV3
12) Corrective measures in the process loop or alarm con- ditions are generated respectively using the SCADA interface

VI. RESULT ANALYSIS

A. Main screen

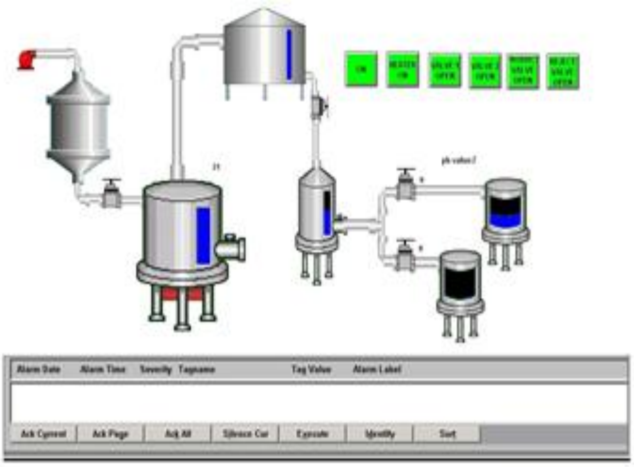

Fig. 4. SCADA main screen

SCADA Main screen is shown in Figure 4. The operator can be able to view status of each & every valve, pump as well as heater i.e. ON/OFF or Open/Close by color animation. In the bottom portion of the SCADA main screen alarm summary is also displayed, which is showing details of any alarm occurred in the process. The operator can acknowledge any alarm from this window.

The PLC system was tested for acquisition of analog and digital sensor values. In the process of capturing digital sensor values all the signals were obtained as relay outputs. In referring to analog signals which comes as a 4-20mA loop, system was tested for two analog sensor values.

Automatic execution & control of distillation tank is carried out successfully. The various loops involved give us the desired results. The values of heating time & input flow rate calculated are approximately equal to the ones practically observed. With the use of PLC-SCADA, the

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system is working satisfactory.

VII. CONCLUSION

The solution has provided a low cost custom built monitor- ing and controlling system especially for a desalination plant. However as far as the industrial applications are concerned this can be viewed as a low cost, customized SCADA system. Thus this solution can be customized to suit any other industrial requirement related to monitoring and controlling provided industrial sensors are in use.

In this paper we have presented a PLC-SCADA based automation of Desalination Plant. The trend in automated water treatment plants is to use SCADA systems based on PLCs, advanced communication systems, and PC-based software. PLC has been widely used and played an important role in the automation industry today. Due to advantages of low cost and high reliability, many automation machine manufactures still prefer to use PLC at the time being. The SCADA provides multipurpose utility management and operating flexibility for the monitoring system.

Distillation process based on programmable logic controller has got faster execution time and is more efficient in working along with safety measures to give the desired results and ease in operation. Due to relay contactor logic, more hardware is required as well as wiring is more complex which has now been overcome by present PLC machine. The present system is superior in both performance and is more flexible in operation. Moreover the running time has got shortened. Thus desired requirement of industry has been fulfilled by this automation.

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