SCADA/HMI Development for a Multi Stage Desalination Plant

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Abstract— **The desalination plant is a project that needs to control and monitor the operation sequence This paper describes the construction of a Supervisory Control and Data Acquisition system (SCADA) and the corresponding Human-Machine Interface (HMI) for a multi-stage flash Brine Recirculation (BR) desalination plant. It consists of eight main cycles: the sea water cycle, the brine recirculation cycle, the brine heater cycle, the distillation cycle, the brine blow down cycle, the steam cycle, the condensate cycle and the pressure reduction cycle with a large number of inputs and outputs signals. The relay matrix is used to minimize the number of signals connected to the S7-3000(PLC) Siemens controller and connect it with (WINCC) software to show the application running under control. To maintain healthy system in case of main server failure we must create a redundant server connected with the main server by Ethernet and connected with the main control loop by Multi Point Interface (MPI). In this paper the SCADA/HMI main control loop is MPI because it is faster than Ethernet connection while MPI the control speed is 185kbps but the control speed in Ethernet is only 10/100kbps.**

Keywords- SCADA, Desalination Plant, HMI, Flashing Brine.

I. INTRODUCTION

SCADA and a corresponding HMI are used in many large and medium systems so as well as many types of software in SCADA development. They are proprietary and PLC dependent [1] [2].The multi stage desalination plant is a large application that requires S7, 300 PLC of the Siemens family, with WINCC, MPI control loop to connect the server with PLC while the Ethernet control loop to connect the Operator PC (OPC) client consoles. Engineering Work Station (EWS) connectors are joined with the main loop by using Ethernet router [3] [4] [5].

Usually Ethernet is used to connect the operator pc OPC to the server; it is also used to connect the server to the plant as shown in Figure (1).

This paper presents a solution for the data transfer rate encountered in medium and large scale plants since huge number of input and out points must be considered. Ethernet connection is used to connect the client OPC to the OPC server from one side this latter to the plant from the other side [6].

This connection offers data transfer rate of 10/100 kps. MPI connection is suggested to connect the OPC server to the plant with superior data transfer rate of 185 kps. This reduce considerable the scanning time increases the availability of data at the client OPC.

The proposed NPI connection is connected with only one OPC server. In many plants hot redundancy provided with a second OPC server. This problem is not addressed in this paper and remains to be solved.

Figure (1) shows the desalination plant which includes:

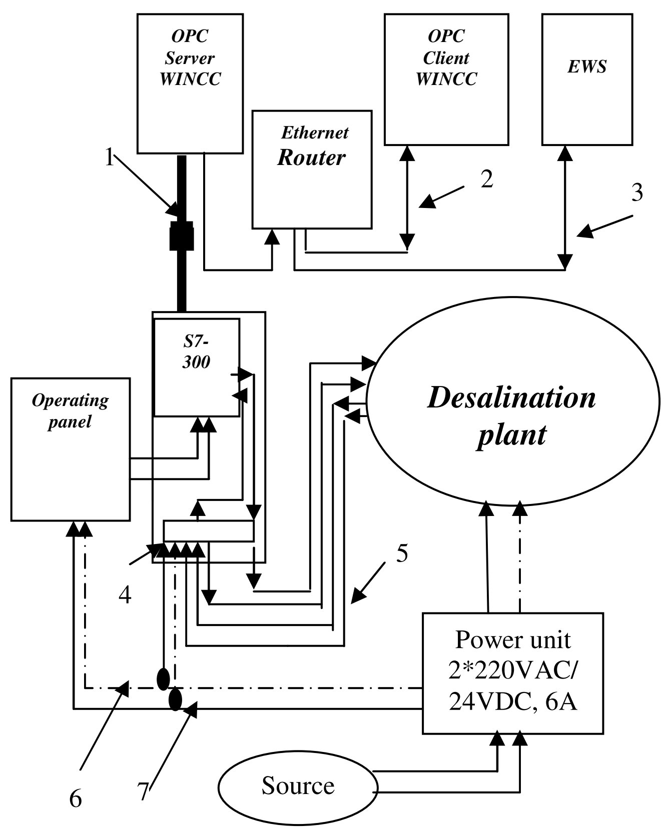

Figure (1) The desalination plant with SCADA system

1- Main control loop MPI (Multi Point Interface) with speed connection 185kbps.

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2- OPC client connector.
3- Engineering Work Station (EWS) connector.
4- Terminal blokes.
5- Hard wire connection.
6- Ground.
7- Power supply.

The paper started by introducing the SCADA/HMI system follows by a description of the brine desalination plant is given. The operation sequence of the desalination plant is detailed. This is followed by the results and conclusions.

II. REL ATED WORK

Many large scale plants were designed and implemented by system integrators. In these systems the OPC are connected to the servers from one side and the servers are connected to the plant from the other side using Ethernet [6]. These last connections hinder the high speed transfer data between the servers and the plant. In this paper the connection is made using MPI which raise the speed of data transfer from 10/100 kps to 185 kps.

III. THE SCADA/HMI SYSTEM

Control and supervision tasks of industrial plants distributed over wide areas are characterized by many sensing and actuation points in the order of hundreds or even thousands of units as petrol chemical plants, paper factories, newspaper rotary printing presses, plants for extraction and bottling of alimentary juices, etc…, This require the use of sophisticated automation schemes that must be able to grant access to production data and field variables at large distances, even in the order of kilometers and from various levels of factory automation field, control, and supervision .Many of the networking technologies have already been available for a long time in industrial automation control level buses.

Great improvements have been noticed in the last few years, which have been progressively integrated by new introduced connectivity solutions like industrial Ethernet, wireless LAN. They have greatly contributed to the technological renewal of a large number of automation solutions in already existing plants. Obviously, even the software technologies involved in the corresponding data exchange processes have been greatly improved. Today it is possible to use a common personal computer in order to implement even complex remote supervisory tasks of simple as well as highly sophisticated industrial plants. Until recently, the operator's interfaces, i.e., the equipment that grants the interaction between a human operator and a single machine or an entire plant, were built by means of electric and electromechanical components in the form of often greatly complicated and cumbersome synoptic panels with pushbuttons, switches, signaling lamps, etc.

In the last few years, these panels have been progressively substituted by greatly sophisticated "virtual" interfaces displayed on CRT or LCD monitors, in the form of interactive graphical panels. These facilities are known as Human Machine Interfaces HMI systems. Moreover, today it is also possible to access and to exchange great amounts of production data between various levels of factory automation. As an example, in the presence of adequate network architecture, an operator at the administrative level of a facility can gain access to field and/or control level data. This data can be used in some kind of in-line processing procedure to generate, as an example, real-time trend diagrams, useful to predict the amount of supplies required to face a definite production period. Obviously, this data can also be stored in a historical database, ready to be used for successive post processing analysis procedures [7][8].

These kinds of systems are known as SCADA Systems which represent the interfaces between an operator and the machine (desalination planet), and the design of a graphic representation by using a WINCC and a powerful (HMI) System are used depending on the Microsoft windows 2000 or windows XP. The actual control over the process is performed by the automation system. WINCC communicates with both operator and the automation system [9] [10].

IV. DESCRIPTION OF THE SYSTEM

The Multi stage flashing BR tank desalination plant is a major type of implementation and produces 5000 Ton per day (T/day). The performance ratio of the evaporator is designed to be 8 kg of distillate per 1 kg of heating steam into the main brine heater. The steam is reduced to suitable pressure by reducing valves and supplied to brine heater and steam ejectors [11] [12].

A. Plant specification:

- The number of unit one (1)
- Type Multi-stage flash B.R
- Scale prevention high temperature additive
- Capacity 5000 Ton per day
- Performance ratio 8 kg distillate per 1kg of steam
- Number of stages 20
- Sea water temperature 27 C°
- Maximum brine temperature 11 C°
- Recirculation brine flow rate 1847 T/Hr
- Cooling sea water flow rate 1570 T/Hr
- Concentration of sea water salt 43900 ppm
- Concentration of recirculation brine salt 63000 ppm
- Concentration of distillate salt 25 ppm [13] [14].

B. Multi-stage flashing BR tank desalination plant consists of eight main cycles:

- The sea water cycle.
- The BR cycle .
- The brine heater cycle.
- The distillation cycle.
- The brine blow down cycle.
- The steam cycle.
- The condensate cycle.
- The pressure reduction cycle.

Figure (2) displays the Graphical User Interface (GUI) of the desalination plant.

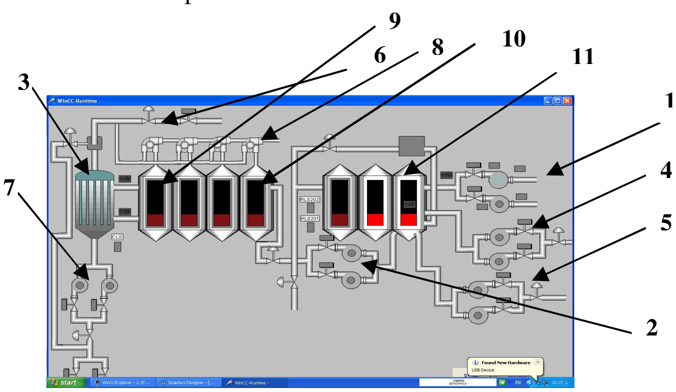

Figure (2) The Graphical User Interface (GUI) of the desalination plant

Where:

1- The sea water cycle
2- The brine recirculation cycle
3- The brine heater cycle
4- The distillate cycle
5- The brine blow down cycle
6- The steam cycle
7- The condensate cycle
8- The pressure reduction cycle
9- The desalination stages no. 1
10- The desalination stages no. 17
11- The desalination stages no. 20

B.1 The sea water cycle:

It is responsible for dragging the sea water using two 6 kV centrifugal pumps (sea water pumps) where one pump is in operation while the second is in standby. It pushes sea water through the desalination stages (20, 19, and 18) and the deaerator that nourishes the desalination stage floor [13] [14].

B.2 The brine recirculation cycle:

It is responsible for dragging the brine water by two 6 kV centrifugal pumps (Brine Recirculation Pumps) where one pump is in operation and the other in standby. It drives the brine water in the water pipes of the desalination stages from 1 to 17. It consists of 2 shut off valves in outlet of the two pumps and one control valve [13] [14].

B.3 The brine heater:

It heats the sea water in the pipes using the steam line and controls the temperature of the water using temperature control valve [13] [14].

B.4 The distillate cycle:

It drags the distillated water in the collected distillate small tank in stage 20 and pushes it to the desalination tank. It consists of two centrifugal pumps and an outlet control valve [13] [14].

B.5 The brine blow down cycle:

After desalination plant runs the brine water, high concentration of salt will be found in the stage floor and the brine blow down is responsible for dragging the salt water in the stage floor and pushes it to the sea through the discharge pipe line. It consists of two centrifugal pumps and two shut off valves and an outlet control valve [13] [14].

B.6 The steam cycle:

The steam line is used to heat sea water, which comes from the boiler at high temperature and high pressure. the ejector is used to reduce the steam pressure; this step is necessary to reduce the boiler temperature [13] [14].

B.7 The condensate cycle:

It consists of two pumps and two shut off valves in the outlet of each pump and conductivity analyzer, where the steam line passes through the brine heater at high temperature. Heat transfer is made between the steam line and the water coming from the sea water system, as part of the steam cools down and condensates in the condensation area of the brine heater .The conductivity of condensates water is tested. If the conductivity is approved, the condensate system drags the water to the desalination tank; Otherwise the condensate system drags the water to the new cycles in stage 20 [13] [14].

B.8 The pressure reduction cycle:

Four ejectors are used to reduce the steam pressure in order to enhance the water vaporization under low pressure and at lower temperature. The first ejector is always on and the others are started one by one to decrease the pressure if required. [13] [14].

V. OPERATION SEQUENCE OF THE DESALINATION PLANT

The multi-stage BR, flashing tank desalination plant yields 5000 T/day. At start up, sea water pump must be started No.1or No.2. Each of them can pump 1830 T/Hr at a pressure of 4-5bar in the header line. Pressure switches are used to maintain the pressure in the header line between 1.5 and 6.5 bars. A flow transmitter is used to transmit the real value of the water flow which must be about 1500 /Hr and not less than 1100 T/Hr.

The sea water flows from the pump to the stage 20 and then to the stages 19 and 18 by the water box. At the outlet of stage 18 the water is divided into two parts: The first part goes to the deaerator, which is used to separate gases and the water to the floor of stage 20; the second part goes to the sea and divides the two control valve in two parts. The control valve which is before the deaerator depends on the water level in stage 20 and the open percentages of distillate water valve. The control valve in the discharging line depends on the control valve before the deaerator in the reverse direction.

The water flow of the stage 20 reaches the level (2400mm) and uses the level transmitter to transmit the level in the stage 20 which gives alarm when it goes to low level (1550 mm). When the level in stage 20 reach to 22400 mm, the brine recirculation pump number 1 or number 2 can start to drag the water in stage 20 to stage 17, 16, 15… 1. This pump will pump the water with pressure 7.5bar and flow of 1400 T/Hr. The shut off valve is used after every pump, for starting the pump. The recirculation valve must be open 10 sec and the shut off valve is closed to keep the pressure after the pump. At the end of the starting the recirculation valve is closed and the shut off valve is open. This sequence is followed for every pump in the system. The water goes through the brine heater and the brine heater makes the heat transfer between the steam coming from the boiler and the water. The inlet water temperature is 19.5 C° and it grows to 94 C° when starting and the outlet going to stage 1 reaches 104 C°.

The water is vaporized under low pressure and condenses on the water pipes in the stage and collects in the collection box in the stage 20. Then the distillate water pump number 1 or number 2 starts to drag the distillate water in stage 20 and pumps it to the tank. The distillate pump and the distillate control valve at the out let of the pump line depend on the water level between the stage 20.at steady state, the desalination plant, the conductivity of the brine water in the floor of the stage increases and the brine blow down pump No 1or No 2 circulates the brine water to the discharge line in the sea. The control valve in the discharge line depends on the water level in the stages. The steam line pressure is 7.5 bars at temperature of 180 C° and the steam going to shut off valve. The valve is opened only if the sea water pump and the brine recirculation pump run. The steam line is divided into two parts; the first part goes to the ejectors. These require steam at high pressure and high speed to absorb the air in the stage and make the vacuum. then starting up the system, the main ejector is operated to reach -0.88 bar (vacuum) and then the first and second ejector are started one by one to reach -1 bar.

VI. Results

The Desalination Plant with SCADA control system is designed and the communication of this SCADA with PLC step7 is implemented.

According to this communication between SCADA control system and PLC the HMI is able to interface with field and control it. Therefore at anytime the valve can be opened or closed, and start or stop any pump using HMI according to the operation instruction**.** Figures (3-6) are the HMI representation of the BR desalination plant

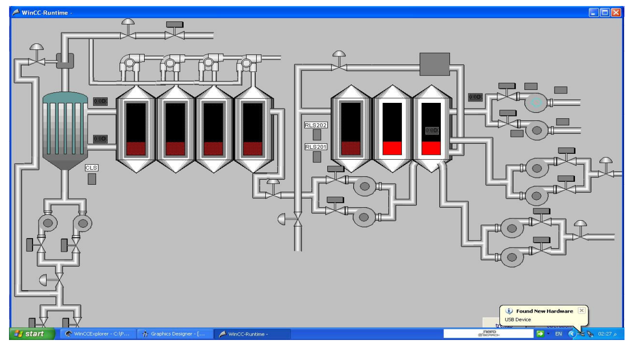

Figure (3) The desalination plant out of service

Figure (4) represents the plant with Sea water pump running.

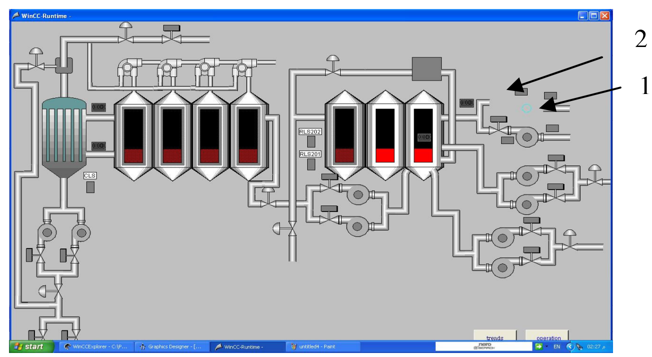

Figure (4) Sea water pump is running

Where:

1- The blinking pump gives an indication that the pump is running.

2- The blinking valve gives an indication that the valve is opening.

Figure (5) displays the desalination room water level operating.

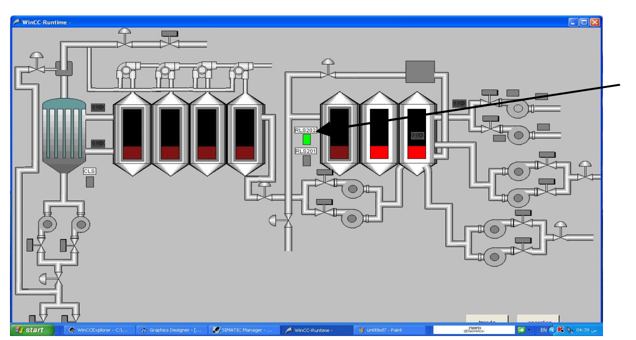

Figure (5) The desalination room water level is operating

Where:

3- The blinking alarm gives an indication that the water level in the desalination room is operating.

Figure (6) shows the desalination plant in service

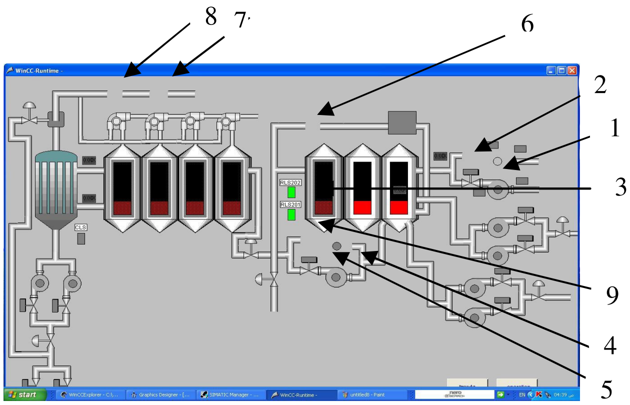

Figure (6) The desalination plant in service

Where:

1- The blinking sea water pump gives an indication that the pump is running.

2- The blinking valve gives an indication that the valve is opening.

3- The blinking alarm gives an indication that the water level in the desalination room is operating.

4- The blinking brine recirculation pump gives an indication that the pump is running.

5- The blinking valve gives an indication that the valve is opening.

6- The blinking valve gives an indication that the level control valve is opening.

7- The blinking valve gives an indication that the shut off steam valve is opening.

8- The blinking valve gives an indication that the pressure control valve is opening.

9- The blinking alarm gives an indication that the distillate water level is operating.

VII. CONCLUSION

1- SCADA/HMI system is used to collect the data from a long distance and to control it by sending, and receiving signal from and to this system.

2-In this system the WINCC is used to design the graphic that is used as an interface between the human (operator) and the machine (desalination planet).

3-The most important benefit from using SCADA system is decreasing the operation time.

4- Making the matching between the hardware which is used to control the system and the software of SCADA. The large number of (input/output) signals, which are used to control it and limit the number of PLC channels.

5- Using the MPI connection in main control loop instead of Ethernet connection because MPI speed is 185kbps and Ethernet connection speed is 10/100kbps.

In this work, three ways of connections are used; the first way is a hardware connection between the instrumentation and PLC. The second way is a multi point interface (MPI) between PLC and WINCC in the main OPC (server). The third connection is an Ethernet loop connection between the main OPC (server) and, the other OPC (Clint) and Engineering Work Station (EWS).

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