PLC & SCADA Based Automation of Industrial Reverse Osmosis Desalination Plants

Mehul S. Prajapati
Department of Instrumentation & Control,
Dhrmsinh Desai University, Nadiad,
Gujarat,India

Prof. Ashish G. Patel
Department of Instrumentation & Control,
Dhrmsinh Desai University, Nadiad,
Gujarat,India

Abstract— Reverse osmosis (RO) is proved to be the most reliable, cost effective, and energy efficient in producing fresh water compared to other desalination technologies. Today's Reverse Osmosis plants are a widely used application of water treatment engineering all over the world, applied for water conservancy projects, emerged by the technology of automation control system is to ensure safe, continues, high quality water supply to municipal and for multi-purpose usage in Industries. This paper represents a locally developed customized monitoring and controlling system for a typical generalised Reverse Osmosis Desalination plant which mostly used in industries. This work illustrates an integrated automation system which can facilitate monitoring and controlling of entire Reverse Osmosis plant from one PC. This paper describes how automation of Industrial Reverse Osmosis plant is done using PLC & SCADA.

Keywords— ***Reverse osmosis; PLCs (Programmable Logic Controllers); SCADA; Automation***

I. INTRODUCTION

Making products under the control of computers and programmable controllers is known as Industrial Automation. Manufacturing assembly lines as well as standalone machine tools (CNC machines) and robotic devices fall into this category. Automation is assignment of human control functions to technical equipment for increasing productivity, better quality, increasing safety in working conditions reducing manpower & cost.

PLCs (programmable logic controllers) are the industrial control hubs for a wide variety of automated systems and processes. PLCs system is used to monitor inputs, and depending upon its state make decisions based on its program or logic, to control (turn on/off) its outputs to automate machines or electromechanical processes. They contain multiple inputs and outputs that use transistors and other circuitry to simulate switches and relays to control equipment. They are programmable via software interfaced via standard computer interfaces and proprietary languages and network options.

Inputs and outputs of programmable logic control are in the form of digital and analog both. Inputs for PLCs include DC, AC, analog, thermocouple, RTD, frequency or pulse, transistor, and interrupt inputs. Outputs for PLCs include DC, AC, relay, analog, frequency or pulse, transistor, and triac.

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. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs), or other commercial hardware modules. SCADA systems used to run on DOS, VMS and UNIX; in recent years all SCADA vendors have moved to NT and some also to Linux. They are used in distribution systems such as water distribution and wastewater collection systems, oil and gas pipelines, electrical power grids, and railway transportation systems. A SCADA control center performs centralized monitoring and control for field sites over long-distance communications networks, including monitoring alarms and processing status data. Based on information received from remote stations, automated or operator-driven supervisory commands can be pushed to remote station control devices, which are often referred to as field devices. Field devices control local operations such as opening and closing valves and breakers, collecting data from sensor systems, and monitoring the local environment for alarm conditions.

The SCADA System would be used for data acquisition, logging and control of the plant variables. The system should be easy to use and implemented on normal PCs in order to make the control and data acquisition more easy and cheap.

Benefits offered by PLCs:

- Easy to program, operate, maintain and repair.
- More durable and less expensive for controlling complex systems.
- allows for fast and easy online changes in relay ladder logic to meet the changing needs of the process.
- Extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact.
- Flexible and can be reapplied to control other systems quickly and easily.
- Easy to trouble shoot, so the programming becomes easier and reduce downtime.

II. LITERATURE REVIEW

Reverse osmosis is a separation process that is used to remove a large majority of contaminants from water by pushing the water under high pressure through a semi-permeable membrane . Reverse osmosis works by using a high pressure pump to increase the pressure on the salt side of the RO and force the water across the semi-permeable RO membrane, leaving almost all (around 95% to 99%) of dissolved salts and solid particles behind in the reject stream. The amount of pressure required depends on the salt concentration of the feed water. The more concentrated the feed water, the more pressure is required to overcome the osmotic pressure. Osmosis is natural phenomena explained as water moving from low concentration solution to high concentration solution until equilibrium is achieved by natural osmotic pressure. So reverse osmosis is a osmosis process in reverse. Whereas Osmosis occurs naturally without energy required, to reverse the process of osmosis you need to apply energy to the more saline solution. A reverse osmosis membrane is a semi permeable membrane that allows the passage of water molecules but not the majority of dissolved salts, organics, bacteria and pyroxenes. (As illustrated in Figure 1)

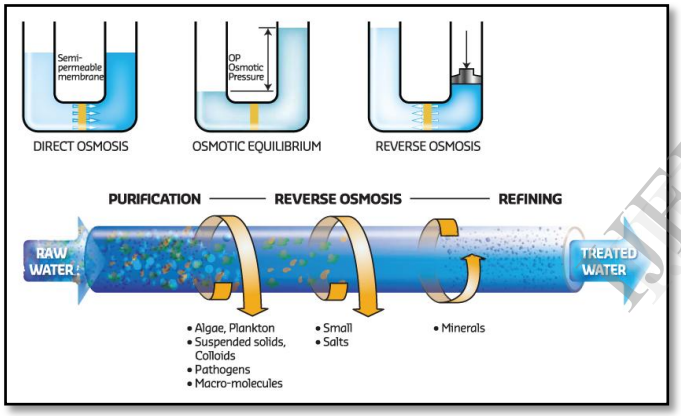


Figure 1 : Reverse Osmosis Process [7]

III. PLANT BACKGROUND

Now days, Reverse Osmosis Plant play important role in Water treatment technology. It becomes main requirement of water intensive sectors like textile industry, pulp and paper industry, machining operation, metal plating, chemical industry, fruit and vegetable processing, mining, copper industry, petroleum industry, power sector, pharmaceutical industry and etc.

Here, the Reverse Osmosis Plant output capacity is approximately 15-16 MLD. The Plant is designed such way that we get fresh dematerialize or demonize water in two different output streams. Each stream has separate Micron cartridge filter, RO membrane system. But at a time only one stream can be running and other is remain stand by because of when somehow one of MCF filters, membrane systems needs replacement or require chemical cleaning or any instrument needs maintance. So whole plant can't be shutdown it will affect on the production of plant. So simply plant would switch to one output stream to another at regular interval. It increases lifetime of plant and continuously maintain production 24 hours a day.

When one Water shall be either taken through gravity or shall be pumped from the intake pump house at Sea or River on which an intake tank is constructed. Intake Chamber raw water flows to reverse osmosis plant through Raw water Gate valve. In manual mode operator has to give Open command to this valve through SCADA while in Auto (Normal) mode it gets Open command after a specified time of getting ON Feedback from at least any one pump of Intake Pump House. Operator can give this lead-time from SCADA.

Reverse osmosis plant Section involves

1. Turbidity Measurement and Chlorination Dosing
2. Dechlorination (SMBS) Dosing and Antiscalant Dosing
3. Two Micron cartridge Filters (MCF)
4. ORP measurement
5. PH measurement
6. Two R.O. membrane systems
7. Conductivity measurement
8. Chemical Cleaning Section

IV. SYSTEM CONFIGURATION

In this project for Online Graphical Interfacing, in the plant section MMI (Panel View Terminal or PC) is used. To communicate the PC or MMI of Reverse osmosis plant, Ethernet IP protocol is established. Here, the PLC, IO modules and SCADA-PC are communicated by Ethernet IP network protocol. EtherNet/IP is an application layer protocol that is transferred inside a TCP/IP Packet. That means that EtherNet/IP is simply the way data is organized in a TCP or UDP packet. All devices on an EtherNet/IP network present their data to the network as a series of data values called attributes grouped with other similar data values into sets of attributes called Objects. EtherNet/IP is part of CIP, the Common Industrial Protocol. CIP defines the Object structure and specifies the message transfer. So to established communication of these devices Advance interface converters are used in system configuration.
Printer is connected to PC, which scatters the facility to print the online parameters printouts (Daily, Monthly, and Yearly Report) of the plant as per operator's requirement.

Reverse osmosis plant Section involves:

1. Programmable Logic Controller (CompactLogix L23E QB1B)
2. Racks for modules
3. Power Supply for CompactLogix
4. Digital Input Modules
5. Digital Output Modules
6. Analog Input Modules
7. Basic Module
8. Ethernet IP Static switch

9. Ethernet IP Point I/O Adapter Module
10. Network Interface Module
11. Graphical User interface (Panel View Terminal)
12. PC for SCADA
13. Cables

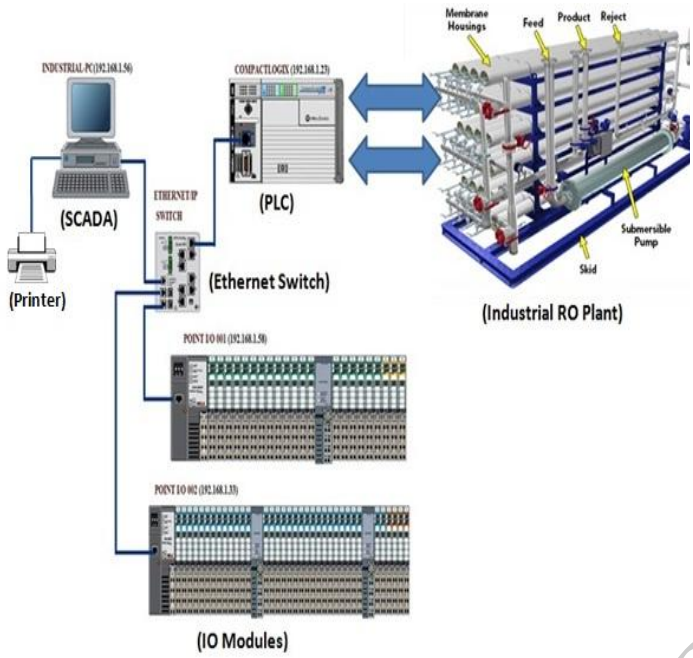


Figure 2 : System Configuration and Illustration

V. OPERATION PHILOSOPHY

The Plant can be operated in three different modes.

- Service (Auto) Mode
- Manual Mode
- Shutdown Mode

The mode and the output stream can be selected through SCADA. In Service (Auto) mode, according to PLC programming, first faulty conditions like low level in Inlet storage tank, SMBS dosing tank and Antiscalant tank are checked. If one of them is not healthy then alarms will be displayed in SCADA display and the plant will be shutdown. When all the faulty conditions are healthy, then the plant can be run in Service mode. In Service mode, ORP would be continuously checked across the respective Micron cartridge filter and also PH, Conductivity can be continuously checked across RO membrane systems. If somehow one or more parameters are gone out of its set ranges then the plant will be tripped and shutdown step by step. There are three high pressure pumps (two working, one stand by at a time) which used to build up proper pressure for reverse osmosis operation and overcome the osmotic pressure. The pumps can be selected through SCADA display. Chemical cleaning cycle can be operated between particular time intervals and it will be necessary when the pressure across at the inlet of RO plant would be low.

Maintance mode is design for manual / calibration / testing operation. So no other mode is running during maintance mode. In this mode all the Digital Outputs can be operated for the just 2 minutes and after 2 minutes it should be automatically stopped. This mantaintace time duration can be changed through SCADA

There are three levels of operator right provided for the operation of system. The operator can operate the service and backwash/regeneration, chemical cycle, but cannot access the maintenance mode and set parameters. The supervisor can operate all the modes and can only view the set parameters but cannot change. The administrator has full access to all modes and set parameters. There is interlock between all three modes. So when one mode is running, no other mode will start.

Digital Inputs list, Digital outputs list, Analog inputs list, Instruments used in the plant are represented in respective Table 1 , Table 2, Table 3 and Table 4. (*Refer page no.5 and page no. 6)

VI. ANALYSIS AND RESULTS :

USER LOGIN SCREEN*:*

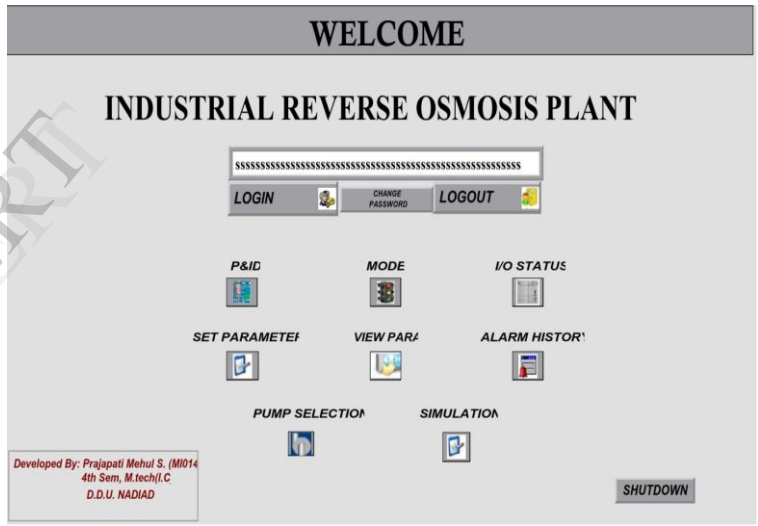


Figure 3 : SCADA User Login Screen

SCADA User Login Screen is shown in Figure: 3.It provides user's utility and security. One of the users from Operator, Supervisor, and Administrator can be access the plant by login in the Welcome screen. User can be directly access the different screens like Process and Instrumentation Diagram (P&ID) of plant, Mode Screen, Input output Status, Set parameter Display, Alarms History, Pump Selection Screen, Simulation Screen by simply clicking.

MAIN P&ID SCREEN*:*

It is the main screen of plant which shows the Process and Instrumentation Diagram of reverse osmosis plant. Operator can able to view status of each & every valve, pump as well as blower i.e. ON/OFF or Open/Close by color animation or rotating animation. In bottom of the SCADA P&ID screen alarm summary, local message summary displayed, which is showing details of any alarm occurred in the process. Operator can acknowledge any alarm by clicking on the ACK button at the corner of the window. It is shown in Figure 4.

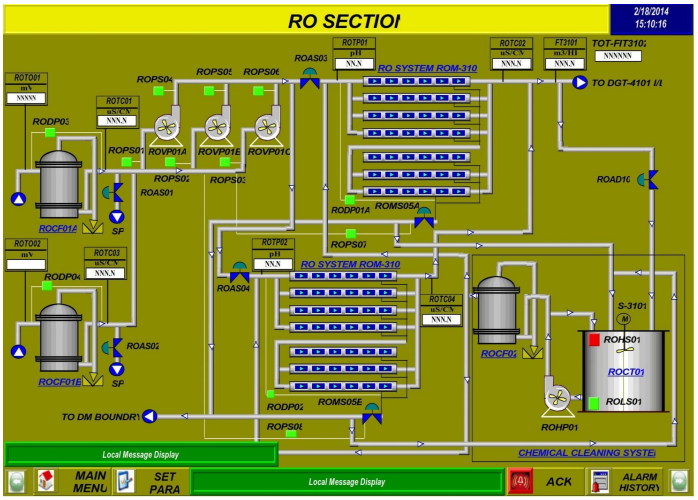


Figure 4 : Process and Instrumentation Diagram (*Refer page no.6 for Enlarged view)

MODE SELECTION SCREEN:

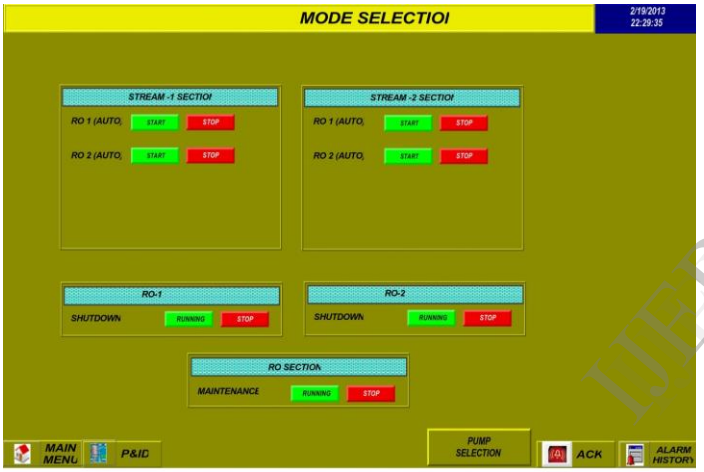


Figure 5 : Mode Selection Screen (*Refer page no.7 for Enlarged view)

Mode Selection Display is shown in Figure: 5. Operator can easily select the operation mode and the output stream of plant by clicking Start-Stop buttons.

ANALOG PARAMETERS SCREEN:

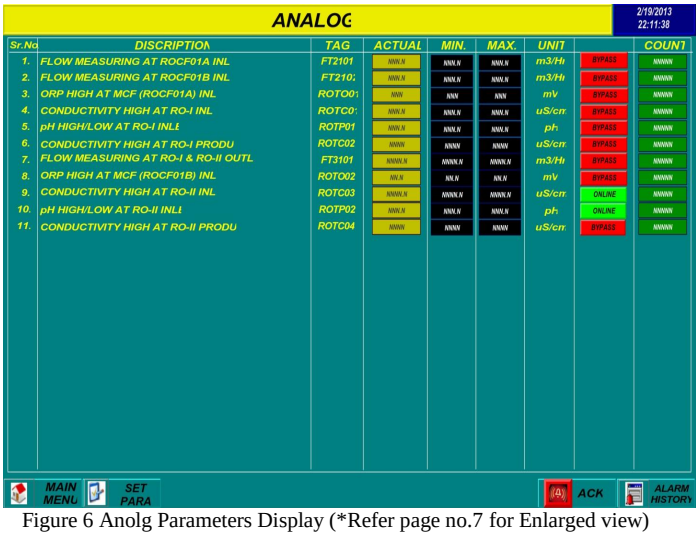


Figure 6 Anolg Parameters Display (*Refer page no.7 for Enlarged view)

Analog Parameters Display is shown in Figure: 6. It continuously shows the status of Analog variables of plant. Operator can able to view the status of Actual data's, Min-Max Set ranges and Digital count values of Analog process variables like PH, Conductivity, ORP, Total flow in each streams etc.

VII. CONCLUSION

In this paper we have presented a PLC-SCADA based automation of Industrial Reverse Plant which is main requirement of water intensive sectors. The trend in automated Reverse Osmosis plants is to use SCADA systems based on PLCs, advanced communication systems, and PC-based software. This system is just an example to give an idea of how SCADA and PLC would be a perfect choice for feeding water supply specially in remote areas and industrial plants where the manufacturing processes , production continues for 24 hours a day. 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. The SCADA proves its advantages through the project comparing it to other conventional control systems.

ACKNOWLEDGEMENT

The authors would like to thank Department of Instrumentation and Control (Dharmsinh Desai University) for supporting this work.

REFERENCES

[1] Madhuchhanda Mitra & Samarjit Sen Gupta, Programmable Logical Controllers & industrial Automation; 2nd Edition,Penram Intrnational Publishing Pvt.Ltd.

[2] Boyer, Stuart, A. SCADA: Supervisory Control and Data Acquisition, Instrument Society of America, Research Triangle, NC. 1993.

[3] L.A.Brayan & E.A.Brayan, Programmable Controllers Theory & Implementation; 2nd Edition, (1997-01).

[4] http://www.ab.com/linked/networks/ethernet/faq.html

[5] http://literature.rockwellautomation.com/idc/groups/public/documents/webassets/browse_category.hcst.

[6] http://www.rockwellautomation.com/rockwellsoftware/performance/view/viewstudio.html

[7] http://www.degremont-technologies.com/IMG/png/ro-diagram.png

[8] http://www.puretecwater.com/resources/basics-of-reverse-osmosis.html

[9] Omar Mohamed Torky, Irraivan Elamvazuthi and Noor Hazrin Hany Binti Mohd Hanif, Paper on "PC based SCADA system for reverse osmosis desalination plants", IEEE digital library.

[10] Archana B.Yadav, Paper on "PLC & SCADA based automation of Filter House, a section of Water Treatment Plant", IEEE digital library.

Table 1: PLC/DIGITAL INPUTS DETAILS

DIGITAL INPUT SR.NO.	DESCRIPTION	PLC TAG	DRIVE TYPE	CONTACT TYPE
DI:01	Low Suction Pressure at HPP (ROVP01A) inlet	ROPS01	FIELD	NO
DI:02	High Discharge pressure at HPP (ROVP01A) outlet	ROPS04	FIELD	NC
DI:03	Low Suction Pressure at HPP (ROVP01B) inlet	ROPS02	FIELD	NO
DI:04	High Discharge pressure at HPP (ROVP01B) outlet	ROPS05	FIELD	NC
DI:05	Low Suction Pressure at HPP (ROVP01C) inlet	ROPS03	FIELD	NO
DI:06	High Discharge pressure at HPP (ROVP01C) outlet	ROPS06	FIELD	NC
DI:07	Differential Pressure High At RO-1	RODP01	FIELD	NC
DI:08	High pressure at RO-I Reject Recirculation	ROPS07	FIELD	NC
DI:09	High pressure pump-A	ROVP01A	ON Indication	NO
DI:10	High pressure pump-B	ROVP01B	ON Indication	NO
DI:11	High pressure pump-C	ROVP01C	ON Indication	NO
DI:12	Differential Pressure High At RO-2	RODP02	FIELD	NC
DI:13	High pressure at RO-II Reject Recirculation	ROPS08	FIELD	NC
DI:14	Differential Pressure High at ROCF01A	RODP03	FIELD	NC
DI:15	Differential Pressure High at ROCF01B	RODP04	FIELD	NC
DI:16	Chemical Cleaning Pump	ROHP01	ON Indication	NO
DI:17	Chemical Cleaning Agitator (ROCT01)	S-3101	ON Indication	NO
DI:18	Low Level at Chemical Cleaning Tank	ROLS01	FIELD	NO
DI:19	High Level at Chemical Cleaning Tank	ROLS02	FIELD	NC
DI:20	Auto ORP Dump Valve at RO-I	ROAS01	Open Indication	NO
DI:21	Auto ORP Dump Valve at RO-I	ROAS01	Close Indication	NC
DI:22	Auto ORP Dump Valve at RO-II	ROAS02	Open Indication	NO
DI:23	Auto ORP Dump Valve at RO-II	ROAS02	Close Indication	NC
DI:24	Auto Valve at RO-I Inlet	ROAS03	Open Indication	NO
DI:25	Auto Valve at RO-I Inlet	ROAS03	Close Indication	NC
DI:26	Auto Valve at RO-II Inlet	ROAS04	Open Indication	NO
DI:27	Auto Valve at RO-II Inlet	ROAS04	Close Indication	NC
DI:28	Auto Valve at RO-I Reject	ROMS03A	Open Indication	NO
DI:29	Auto Valve at RO-I Reject	ROMS03A	Close Indication	NC
DI:30	Auto Valve at RO-II Reject	ROMS03B	Open Indication	NO
DI:31	Auto Valve at RO-II Reject	ROMS03B	Close Indication	NC
DI:32	Auto Valve at Chemical Cleaning Tank Inlet	ROAD10	On/Off Command	NO

Table 2: PLC/DIGITAL OUTPUTS DETAILS

DIGITAL INPUT SR.NO.	DESCRIPTION	PLC TAG	DRIVE TYPE	CONTACT TYPE
DO:01	Auto ORP Dump Valve at RO-I	ROAS01	On/Off Command	NO
DO:02	Auto Valve at RO-I Inlet	ROAS03	On/Off Command	NO
DO:03	Auto Valve at RO-I Reject	ROMS03A	On/Off Command	NO
DO:04	High pressure pump-A	ROVP01A	Start/Stop Command	NO
DO:05	High pressure pump-B	ROVP01B	Start/Stop Command	NO
DO:06	High pressure pump-C	ROVP01C	Start/Stop Command	NO
DO:07	Auto ORP Dump Valve at RO-II	ROAS02	On/Off Command	NO
DO:08	Auto Valve at RO-II Inlet	ROAS04	On/Off Command	NO
DO:09	Auto Valve at RO-II Reject	ROMS03B	On/Off Command	NO
DO:10	Auto Valve at Chemical Cleaning Tank Inlet	ROAD10	On/Off Command	NO
DO:11	Chemical Cleaning Pump	ROHP01	Start/Stop Command	NO

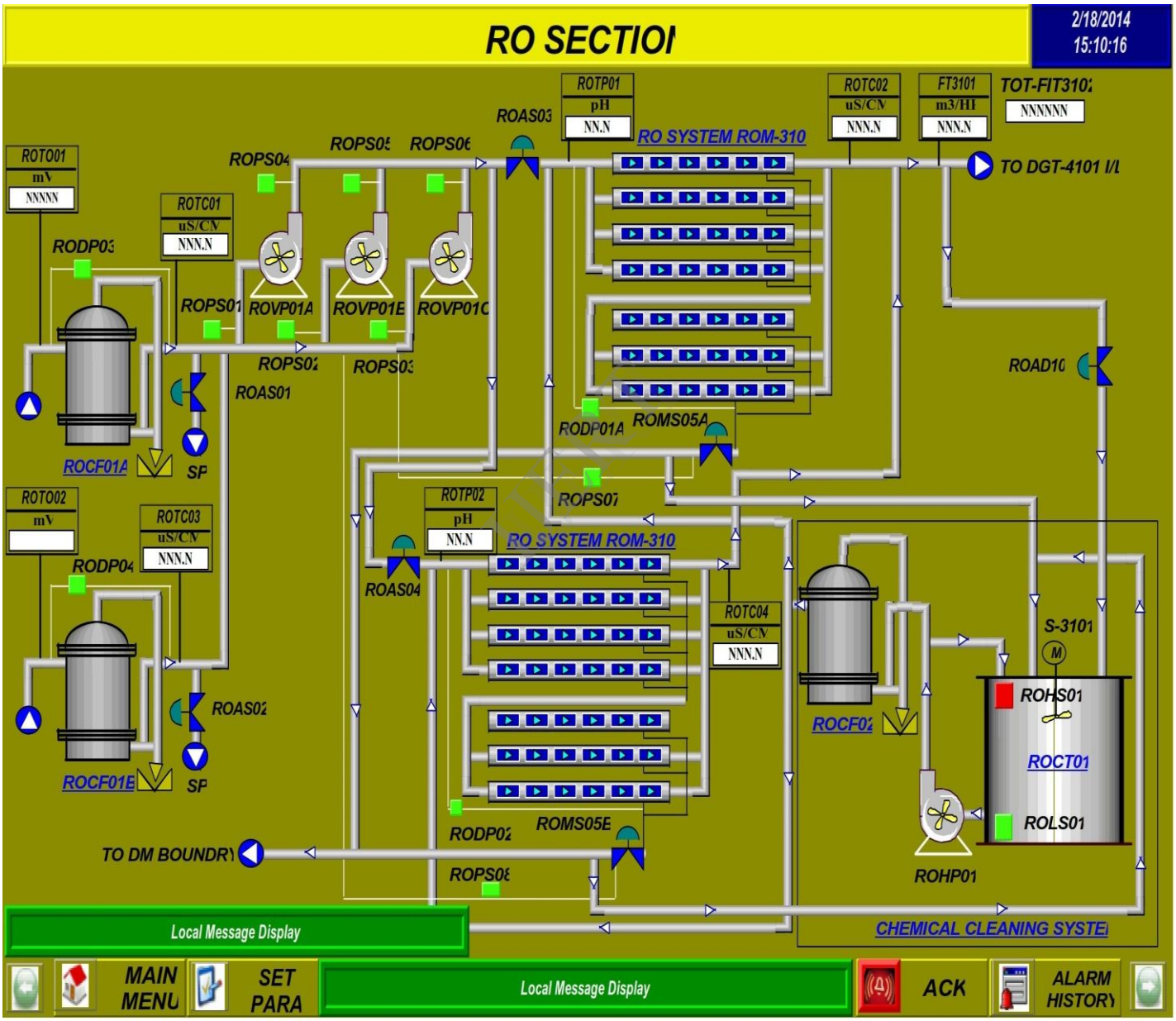
NO = Normally Open Contact, NC=Normally Closed Contact

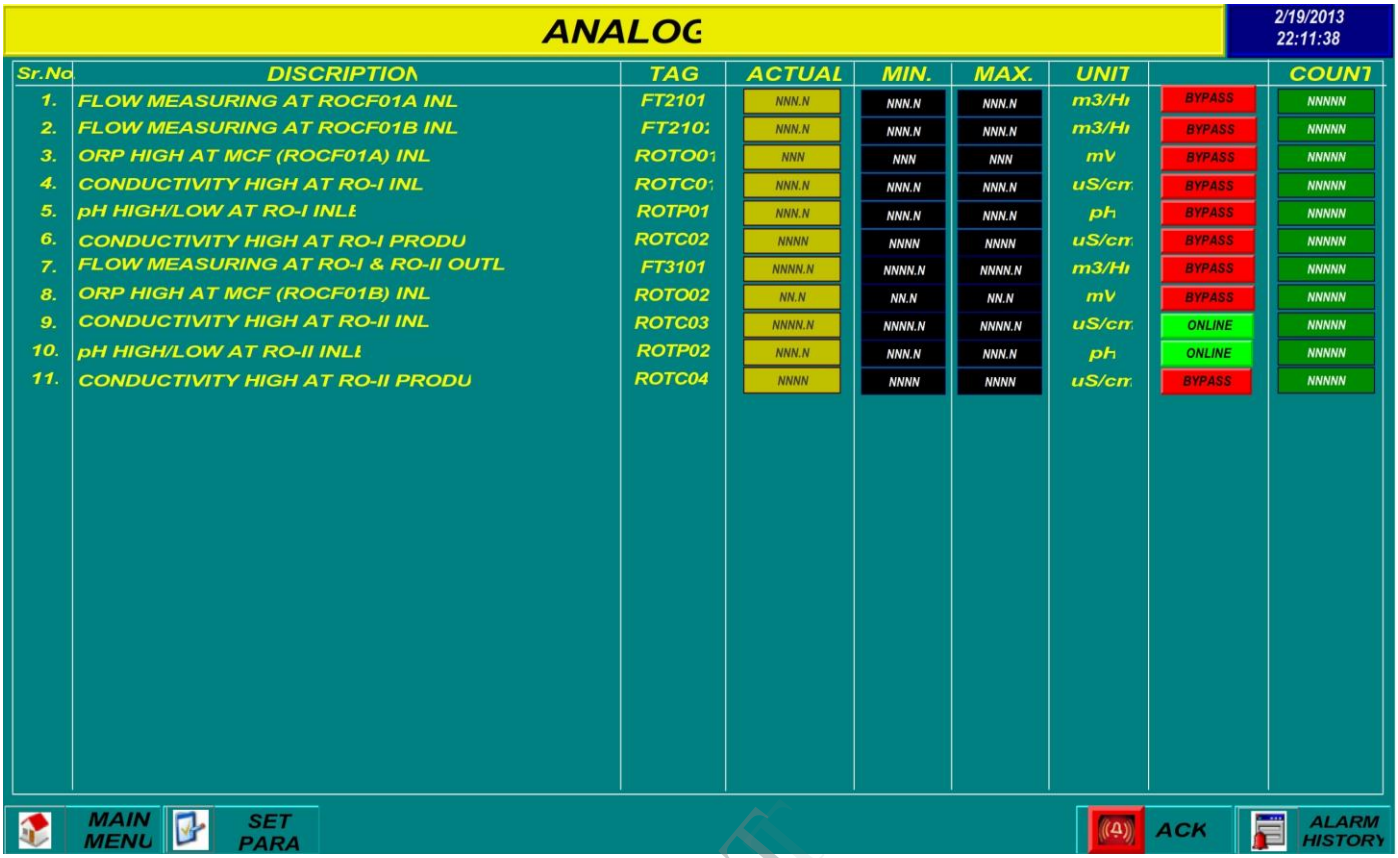
Table 3: PLC/ANALOG INPUTS DETAILS

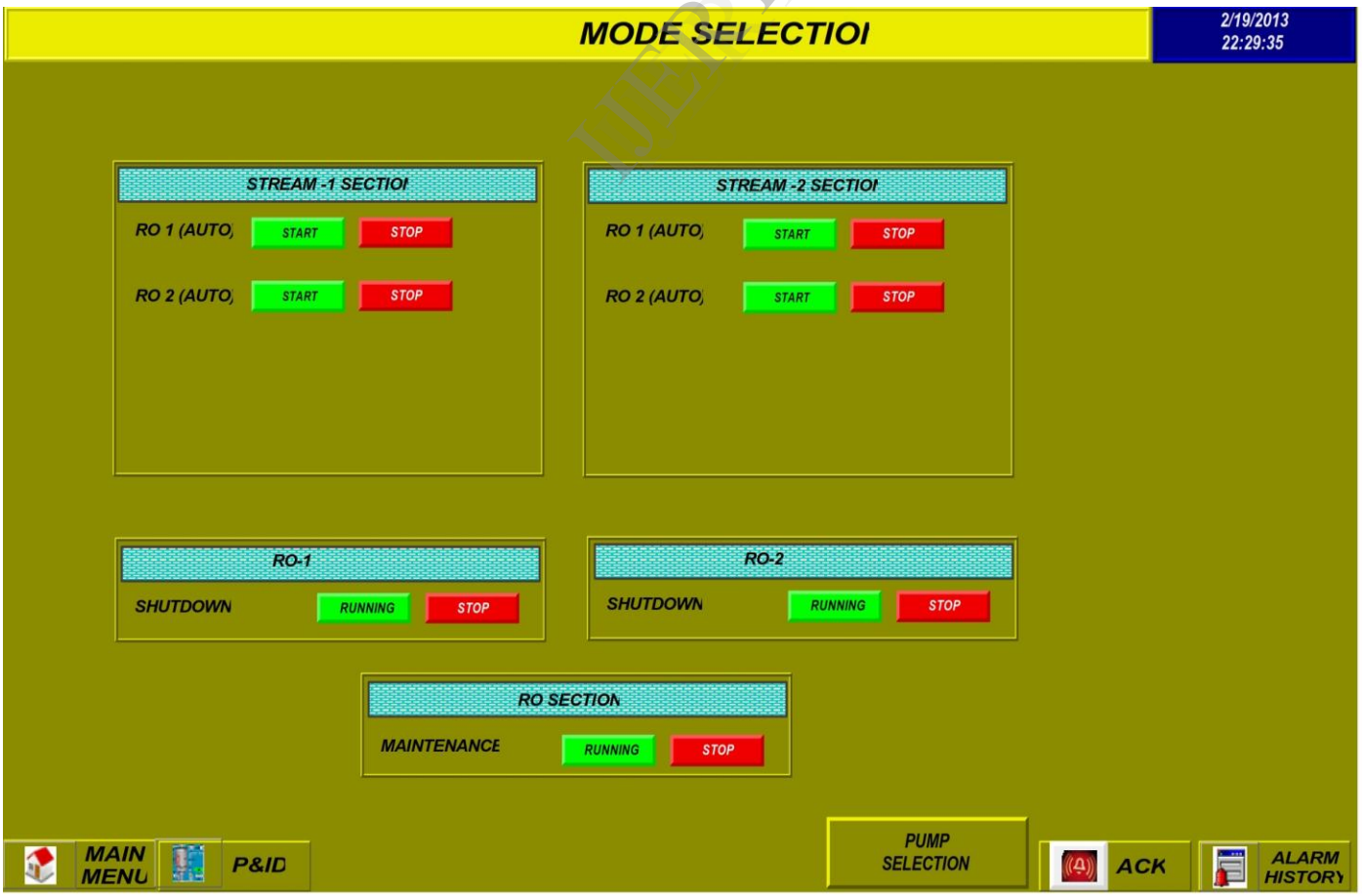
ANALOG INPUT SR.NO.	DESCRIPTION	PLC TAG	DESTINATION
AI:01	ORP High at Microne Cartridge Filter (ROCF01A) Inlet (4-Wire)	ROTO01	Panel
AI:02	Conductivity High at RO-I Inlet (4-Wire)	ROTC01	Panel
AI:03	pH High/low at RO-I Inlet (4-Wire)	ROTP01	Panel
AI:04	Conductivity High at RO-I Product (4-Wire)	ROTC02	Panel
AI:05	Flow Measuring at RO-I & RO-II Outlet (2-Wire)	FT-3101	Field
AI:06	ORP High at Microne Cartridge Filter (ROCF01B) Inlet (4-Wire)	ROTO02	Panel
AI:07	Conductivity High at RO-II Inlet (4-Wire)	ROTC03	Panel
AI:08	pH High/low at RO-II Inlet (4-Wire)	ROTP02	Panel
AI:09	Conductivity High at RO-II Product (4-Wire)	ROTC04	Panel

Table 4: INSTRUMENT LIST

INSTRUMENT TAG	DESCRIPTION	QUANTITY
ROLS	Level Switch	01
ROLI	Level Indicator	01
TA	Differential Pressure Switch	04
FT	Flow Transmitter	01
ROSP	pH Sensor	02
ROFI	Flow Indicator	6
ROPG	Pressure Gauge	14
ROTC	Conductivity Transmitter	02
ROTO	ORP SENSOR	02




ANALOG
2/19/2013
22:11:38
Sr.No
DISCRIPTION
TAG
ACTUAL
MIN.
MAX.
UNIT
COUNT
1. FLOW MEASURING AT ROCF01A INL FT2101 NNN.N NNN.N NNN.N m3/Hr BYPASS NNNNN
2. FLOW MEASURING AT ROCF01B INL FT210: NNN.N NNN.N NNN.N m3/Hr BYPASS NNNNN
3. ORP HIGH AT MCF (ROCF01A) INL ROTO01 NNN NNN NNN mV BYPASS NNNNN
4. CONDUCTIVITY HIGH AT RO-I INL ROTC01 NNN.N NNN.N NNN.N uS/cm BYPASS NNNNN
5. pH HIGH/LOW AT RO-I INLE ROTP01 NNN.N NNN.N NNN.N ph BYPASS NNNNN
6. CONDUCTIVITY HIGH AT RO-I PRODU ROTC02 NNNN NNNN NNNN uS/cm BYPASS NNNNN
7. FLOW MEASURING AT RO-I & RO-II OUTL FT3101 NNNN.N NNNN.N NNNN.N m3/Hr BYPASS NNNNN
8. ORP HIGH AT MCF (ROCF01B) INL ROTO02 NN.N NN.N NN.N mV BYPASS NNNNN
9. CONDUCTIVITY HIGH AT RO-II INL ROTC03 NNNN.N NNNN.N NNNN.N uS/cm ONLINE NNNNN
10. pH HIGH/LOW AT RO-II INLE ROTP02 NNN.N NNN.N NNN.N ph ONLINE NNNNN
11. CONDUCTIVITY HIGH AT RO-II PRODU ROTC04 NNNN NNNN NNNN uS/cm BYPASS NNNNN
MAIN MENU
SET PARA
ACK
ALARM HISTORY


MODE SELECTIOI
2/19/2013
22:29:35
STREAM -1 SECTIOI
RO 1 (AUTO) START STOP
RO 2 (AUTO) START STOP
STREAM -2 SECTIOI
RO 1 (AUTO) START STOP
RO 2 (AUTO) START STOP
RO-1
SHUTDOWN RUNNING STOP
RO-2
SHUTDOWN RUNNING STOP
RO SECTION
MAINTENANCE RUNNING STOP
MAIN MENU
P&ID
PUMP SELECTION
ACK
ALARM HISTORY