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Waste Water Treatment Plant Using Distributed Control System

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Abstract: *The efficient administration and treatment of municipal and industrial waste water is crucial to sustaining community health and a clean, safe environment. Distributed Control System (DCS) is an archetype of automated control system that is distributed throughout the plant to provide commands to different parts of various machines. This paper proposes a DCS software application on waste water treatment plant model. By enhancing this technique we can interface to the process hardware, to create a comprehensive real-time application for a modern waste water operation. DCS acts as an entire framework in accordance with usual engineering practices for programming, simulating and testing the distributed network, thus enables the user to monitor and control the online processes even from a remote place.*
Keywords: *BOD, Control Valve, DCS, Reverse Osmosis, TDS*

I. Introduction

Waste water treatment is the process of removing contaminants from water, primarily from household sewage. It includes physical, chemical, and biological processes to remove these contaminants and produce safe treated water. A by-product of sewage treatment is usually a semi-solid waste or slurry, called sludge that has to undergo further treatment before being suitable for disposal or land application. The physical infrastructure used for waste water treatment is called a "Waste Water Treatment Plant" (WWTP).

The treatment of waste water deals with the management of solid waste, sewage treatment, storm water (drainage) management, and water treatment. By-products from waste water treatment plants, such as grit and sludge which is also treated in a waste water treatment plant. If the waste water is predominantly from municipal sources (households and small industries) it is called sewage and its treatment is called sewage treatment. Our project is to implement DCS in the Waste Water Treatment Plant. The production of waste water also contains a wide range of substances that cannot be easily separated from the sludge. Hence there is a strong need to automate the plant thereby avoiding these drawbacks. For that the first layout of plant is taken and stimulation is done using Yokogawa CENTUM VP. [1] [10]

The proposed system consists of four stages

- Primary Stage
- Preliminary Treatment
- Secondary Treatment
- Reverse Osmosis Treatment

II. Methodology

Conventional waste water treatment consists of a combination of physical, chemical, and biological processes and operations to remove solids, organic matter from waste water. General methods used are preliminary stage, primary treatment, secondary treatment and reverse osmosis. As per the process flow diagram depicted above gives a clear-cut idea about different stages involved in waste water treatment. This forms the basement for the development of piping & instrumentation diagram.

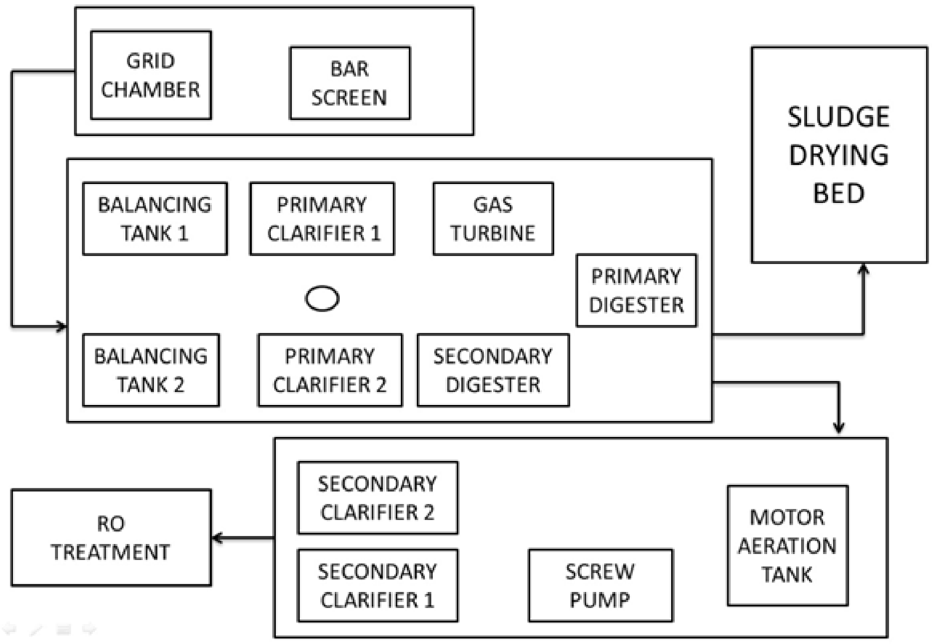

Fig. 1: Process Flow Diagram

The main stages in our project are:

1. **Preliminary Stage:** Solid materials are removed using Bar screen and Grit chamber. Bar Screen is the first stage of purification process which is used to remove the solid particles present in the sewage water. Solid particles like plastics covers, bottles, are removed with the help of Bar Screen. In Grit chamber the inorganic materials present in the sewage water is removed. The inlet flow rate to the grit chamber is should not be very high and should not be very low it should be in the normal region.
2. **Primary Treatment:** Primary treatment is the first stage in the waste water treatment process. In this stage the solid particles get settled down and this is due to the slow movement of the water. The slow movement of water is due to the gear motor which rotates at the centre of the primary clarifier. This motor will evenly spread the water slowly at the same time it will skim off the foams present at the top of the water. The sludge which settles down is pumped out for the further treatment. The sludge which comes from the primary clarifier is sent to sludge well. From sludge well the sludge is pumped to the primary digester. In the primary digester the sludge is digested for 25-30 days by maintaining the temperature and pH value. To maintain the temperature a hot steam is passed in to the digester tank. To maintain the pH value, caustic and sulphuric acid are added and mixed in the tank; Temperature controller and pH controller is used in this process. By maintaining the temperature and pH value, gas present in the sludge is separated due to micro-organism present in the sludge. [3]
3. **Secondary Treatment:** Sludge which comes out from the primary digester is sent to secondary digester for further treatment. In secondary digester the thickening process is done to thicken the sludge. In this a motor is used which is connected with the fence. When the motor rotates the fence will also rotate. The fence separates the water particles and solid particles present in the sludge. This makes the sludge thicker. Here also we have to keep this sludge in the tank for at least 25-30 days. Then the remaining sludge is sent to the sludge drying bed then it is used as manure.
4. **Reverse Osmosis Treatment:** Here the effluent which comes from the secondary clarifier is subjected to the reverse osmosis process for drinking purpose by reducing the BOD level and TDS level. It is a water purification technology that uses a semi permeable membrane to remove ions, molecules and larger particles from drinking water. In Reverse Osmosis, an applied pressure is use to overcome the osmotic pressure, a colligative property that is driven by chemical potential differences of the solvent, a thermodynamic parameter. Reverse Osmosis can remove many types of dissolved and suspended species from water including bacteria and is used in both industrial and domestic processes of the production of the potable water. [9]

Apart from these stages of treatment we have additional components which are fixed in series with main line. They are:

1. **Balancing Tank**: In morning time the incoming sewage water is more. At that time we cannot send the water directly to clarifier which may cause over flow in the tank. To avoid that we are sending water to balancing tank when the incoming flow is high. Whenever the water flow is low, the water in the balancing tank is sent to clarifier. These processes are done with the help of ON /OFF control valves. In control drawing builder ST16 block is used to design this logic. The percentage of valve opening is written in CALCU block.
2. **Aeration Tank:** The effluent coming from the primary clarifier is taken into the aeration tank. In aeration tank we maintain the pH and temperature to achieve the required BOD level of the outgoing effluent. In this process the micro-organism plays an essential role which helps to reduce the BOD level. The essential oxidation has been done by blowing the oxygen into the tank. Then this effluent is taken to the secondary clarifier for further settling process. [9]

III. Design and Implementation

3.1 Preliminary Treatment

3.1.1 Bar Screen and Grit Chamber

This chamber is designed in such a way to make the inflow water to circulate inside the chamber. By doing this process (sedimentation) the solid particles will sediment at the bottom of the tank. To achieve this process the inflow has to be controlled and maintained with the help of flow indicator FCI1 and control valve CV1. Here the flow of the water is indicated by FCI1 indicator. According to that flow the control valve undergoes action which represented below. [10]

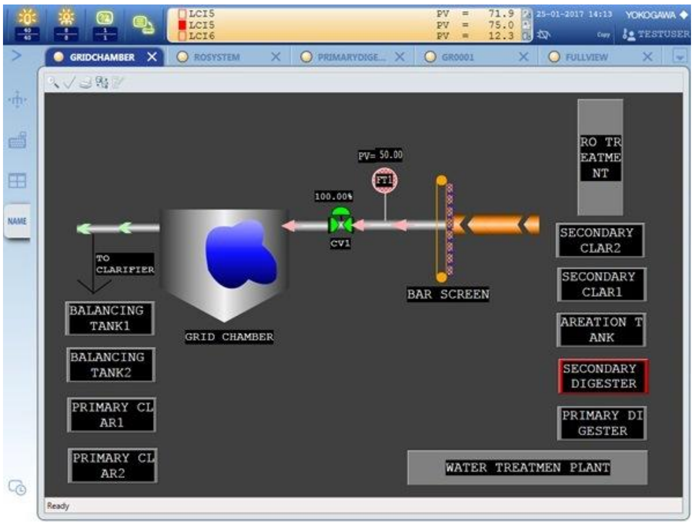

Fig. 2: Bar Screen & Grit Chamber

Table 1: Action of control valve in grit chamber based on flow

FLOW(FCI1)	OPEN	CLOSE
HH		CV1
NR	CV1	
LL		CV1

The table clearly shows the action of the control valve according to the flow which is indicated by the FCI1Accordingly if the “FCI1” indicates “HH” alarm which means the flow of the incoming water is very “high” and then the “CV1” valve will be “opened” and by this action the normal amount of water is allowed into the grit chamber. If “FCI1”indicates “LL” alarm which means the flow of the water is very low, then the CV1 valve will be closed. By this action it is clear that only a Normal flow of inlet water is allowed into the chamber. [10] [4]

3.2 Primary Treatment

3.2.1 Action of Control Valves in Primary Treatment (Based on flow condition)

In this primary treatment we are about to discuss the process of clarifier and digester. In this section totally we have 6 chambers (2 balancing tank, 2 primary clarifier and 2 primary digester). Each tank is provided with both inlet and outlet valves. According to the flow indicator FCI1 the valves are adjusted in particular way which is shown in Table II.

Table 2: Action of Control Valves in Primary Treatment based on Flow

FLOW(FC11)	OPEN	CLOSE
HH	CV2, CV3, CV4, CV5 (50%)	
NR	CV2,CV3	CV4,CV5
LL	CV2,CV3,CV6,CV7	CV4,CV5

The table clearly shows the action (open and close) of the control valves CV2, CV3, CV4, CV5, CV6 and CV7 with the help of indicator FCI1.If the FCI1 indicates HH alarm which means the flow is very high then the control valves CV2, CV3, CV4, CV5 will be opened. But according to the process description only 50% of the valves will be opened. If the FCI1 indicates "NR" alarm which means the flow is "normal" then the CV2 and CV3 valves are opened at the same time control valves CV4 and CV5 are closed. If the FCI1 indicates "LL" alarm which means the flow is very low, then CV2, CV3, CV6, CV7 valves are opened at the same time CV4, CV5 valves are closed. So by the sequence the water is equally sent to both chambers. [10]

3.2.2 Action of Control Valves in Balancing Tank (based on the level condition)

In order to avoid the overflow in balancing tank, the level indicators are placed in each tanks (LCI1, LCI2) Shown in Table III.

Table 3: Action of Control Valves in Balancing Tank Based on the Level

LEVEL (LCI1)	OPEN	CLOSE
HH	CV6, CV7	CV4, CV5
NR	CV4, CV5	CV6, CV7
LL	CV4, CV5	CV6,CV7

If the LCI1 and LCI2 indicate "HH" alarm which means the water level of the balancing tank is so "high", then the valves CV6, CV7 are opened and the valves CV4, CV5 are closed. If suppose the LTI1 and LTI2 indicates

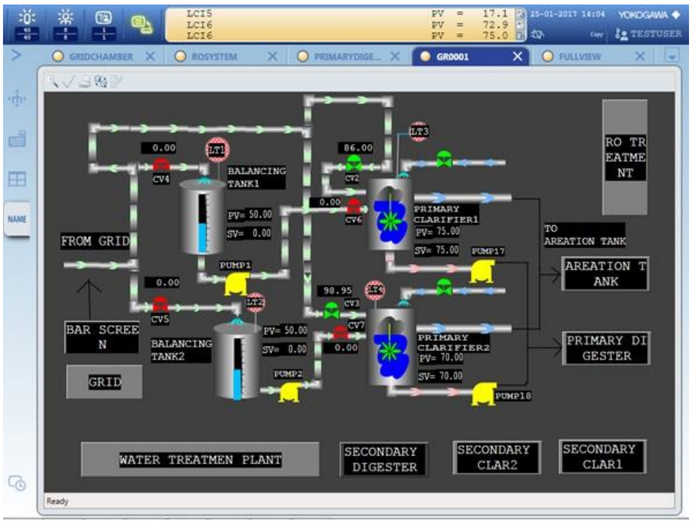

Fig. 3: Primary Clarifier with Aeration Tank

the "NR" alarm which means the water level of the tank is "normal" then the valves CV4,CV5 is opened and the valves CV6,CV7 is closed. If suppose LT1 and LT2 indicates the "LL" alarm which means the water level of the tank is "low" then the valves CV4,CV5 are opened and the valves CV6,CV7 are closed.

3.2.3 Action of Control Valves in Primary Clarifiers (Based on Level Conditions)

In order to avoid the over flow in primary clarifiers, the level indicators are placed in each tanks LCI3, LCI4 shown in Table IV. [10]

Table 4: Action of Control Valves in Primary Clarifiers based on the Level

LEVEL (LCI3,LCI4)	OPEN	CLOSE
HH	CV13, CV14	CV2, CV3, CV6, CV7
NR	CV2, CV3	
LL	CV2, CV3, CV6, CV7	

If suppose the LCI13,LCI14 indicates the "HH" alarm which means the water level of the primary tank is so "high", then the valves CV13, CV14 are opened and the valves CV2,CV3,CV6,CV7 are closed. If suppose the

LTI3 and LTI4 indicates the "NR" alarm which means the water level of the primary tank is "normal" then the valves CV2,CV3 are opened . If suppose LT3 and LT4 indicates the "LL" alarm which means the water level of the tank is "low" then the valves CV2,CV53,CV6,CV7 are opened. [10]

3.2.4 Action of control valves in primary digester (Based on level, temperature and pH condition)

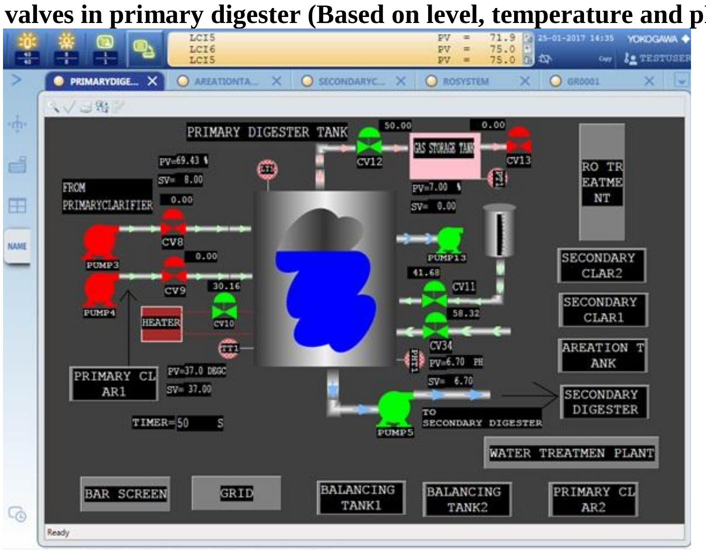

Fig. 4: Primary Digester

In the primary digester the sludge extracted from the water is taken into the tank for digesting process. The sludge from the primary tank is taken through the valves CV8, CV9 and to suck the sludge from the primary tank "pump 1" is used as shown in figure 4. In this chamber the microorganisms plays the essential role which separates the gas from the existing sludge. Then gas emitted from sludge is taken to turbine to produce electricity. In order to keep the microorganisms alive here we are maintaining the perfect temperature, pressure and pH value. To maintain perfect temperature we are applying hot steam. To pass the hot steam a feedback loop is created. With the help of "CV10" the hot steam has been controlled to maintain the temperature. To maintain the pH value same feedback loop is created and with the help of splitter block the output from the controller has been split, one is given as direct and another one is given reverse so that the direct output is given to "CV11" which control the pH base and the reverse output is given to CV34 which controls the pH acid concentration. The output gas which is created in the process tank has been controlled with the help of "CV12" and "CV13". Then the whole process is preserved for 30 days using timer block. Once the timer is reached then the output valve and "Pump 5" become ON so that the processed sludge goes to the next process called the "Secondary Digester". [5] [10]

3.2.5 Action of Control Valves in Secondary Digester (Based on Level Condition)

After the sludge from the primary digester gets into the secondary digester with the help "CV14" and "Pump6" after reaching the High level then CV14 and Pump6 will automatically switch OFF. Then the motor starts to rotate that will make the sludge separate from the water present in the sludge after the timer reaches the time then the output pumps will automatically start. The "Pump14" pumps the water and the "Pump7" pumps the treated sludge. The sludge goes to the dry bed then after drying, the sludge is used as manure and the pumped water is again sent to the primary clarifier as shown in Fig. 4. [2] [5]

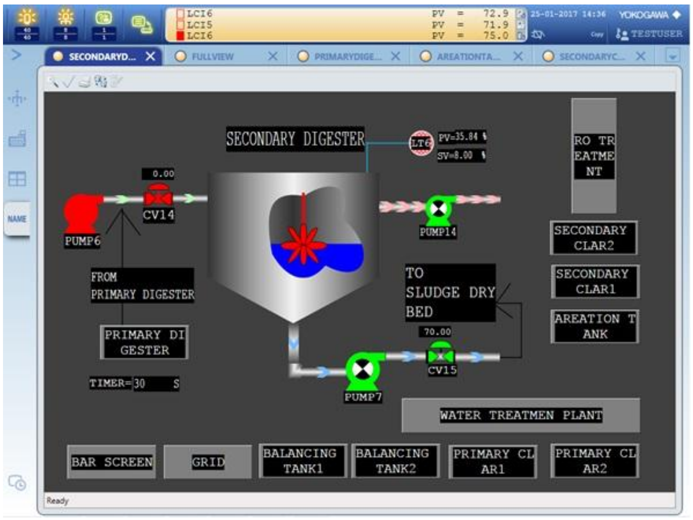

Fig. 6: Secondary Tank

3.3 Secondary Treatment

3.3.1 Action of Control Valves in Aeration Tank (Based on Level, Temperature and pH condition)

The influent which is separated from the primary clarifier comes to aeration tank. In the aeration tank the water is oxidized with the help of oxygen blower in the BOD levels of that influent has been reduced shown in Fig.6. In this tank to reduce the BOD level the microorganisms is used. To maintain the microorganisms to be alive the temperature and the pH maintained in the influent is controlled with the help of "CV16" in order to maintain the level constant. The valve "CV17" is also one of the inlet valves which give the microorganisms' influent from the secondary clarifier. The temperature is maintained with the help of cascade loop. The main control valve to maintain the temperature is "CV18" and with the help cascade loop the inlet temperature is also controlled so the "CV16" also maintain the temperature. The pH in the tank is maintained with the help of a feedback loop and the controller is designed. With the help of splitter block the output is given to two valves "CV19 and CV20". "CV19" controls the waste concentration and the "CV20" controls the acid concentration. The "CV35" is used to control the outlet influent then the treated influent goes to secondary clarifier. [9]

Fig. 6: Aeration Tank

3.3.2 Action of Control Valves in Secondary Clarifier (Based on Level Condition)

The influent from the aeration tank goes to the secondary clarifier with the help of screw pump. Then the influent has been separated into two parts and goes to two clarifiers. First tank level has been controlled with the help "CV21" and second tank level controlled with the help of "CV22". If the level goes beyond the limit then the "CV2" and "CV22" will close automatically. The motor is rotated inside the tank to make the impurities to settle. The settled impurity has been again pumped to aeration tank with the help of Pump11 and Pump12 shown in Fig. 7. Then the output influent goes to storage tank that tank level is also been controlled with the valves "CV23" and "CV24". The influent which left out from the clarifier contains 20% BOD. To reduce that BOD level we are going for RO treatment.

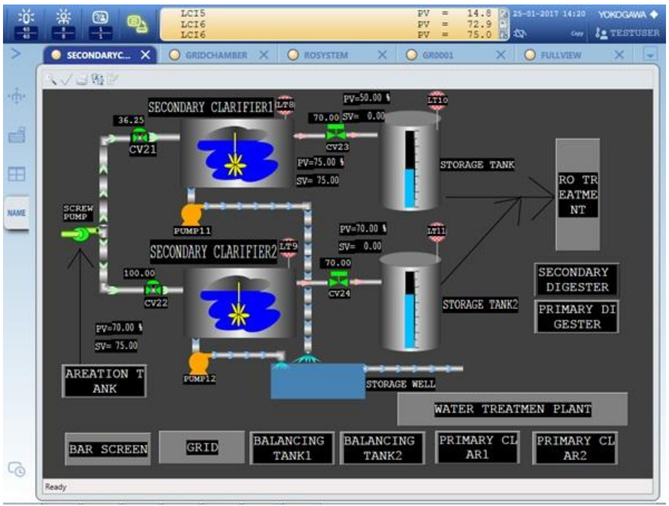

Fig. 7: Secondary Clarifier

3.4 Reverse Osmosis Process

3.4.1 Action of Control Valves in Pre-treatment Tank (Based on Level, Temperature, pH and Chlorine Condition)

The effluent from the secondary clarifier goes to RO treatment but before RO process the effluent has to be treated as shown in figure 8. The influent is first treated in pretreatment tank. In that tank, the pH, temperature, level and chlorine is controlled. The temperature is controlled with the help of cascade loop. The valve "CV28" and "CV30" are used to control the temperature. In these two valves the "CV28" is also used to control the level. The pH of the tank is maintained with a normal feedback loop and the output is split into two with the help of splitter block first output from the splitter is direct mode and another in reverse mode. The direct mode output goes to "CV25" and the reverse mode goes to 'CV26" that will maintain the pH concentration. The chlorine is used to reduce the BOD level and the chlorine is controlled with the controller and the valve "CV27" is a normal feedback loop. Then the treated influent will go to filter section. [6] [7]

3.4.2 Action of Control Valves in Pre filtration (Based on Differential Pressure)

The two main filters used in this section is carbon filter and cartridge filter. Carbon filter is used to remove carbon content present in the influent shown in figure 8. Cartridge filter is used to remove some impurities present in the influent. In this section there is only one control action. If there is any chocking happened in the filter the Pump15 will automatically turn OFF. This is done by measuring the inlet and outlet pressure from the filter using the relational block the differential pressure has been found and according to that the Pump15 works. If the pressure is normal then Pump15 is ON. If the pressure is abnormal Pump15 gets OFF shown in Fig.8 [8]

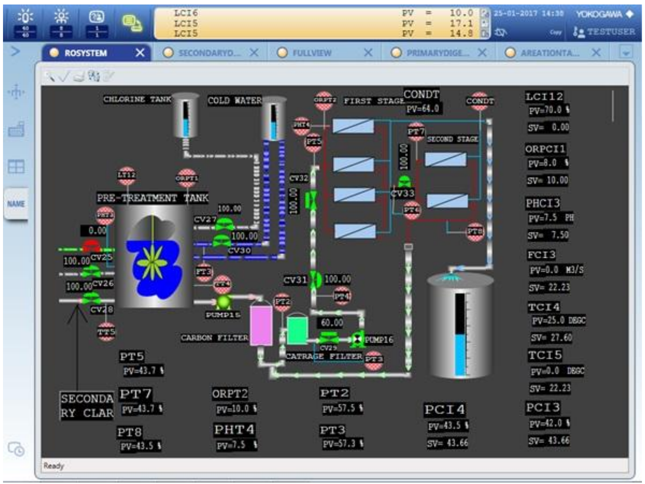

Fig. 8: Reverse Osmosis system

3.4.3 Action of Control Valves in Reverse Osmosis (Based On Differential Pressure, pH, Chlorine, Temperature)

The effluent after the pre-filter treatment goes to the RO filter membrane with the help of pressure controller and the control valve “CV31” the inlet pressure is controlled before going to the RO membrane tube. Then the pH value, temperature and the pressure of inlet influent is measured with the help of transmitters. If any one of the above parameters goes wrong then “CV29”, “CV31”, “CV32”, Pump15 and Pump16 all goes OFF position. If the temperature, pH, pressure in the influent is normal then “CV29”, “CV31”, Pump15 and Pump16 all goes to ON position. Then like the filters in the RO membrane tube, the differential pressure is maintained by keeping the pressure indicators on both the inlet and outlet tube to avoid the chocking in membrane. If there is any chocking problem in the membrane automatically all pumps and valves will goes OFF. Then the conduction meter is used to check the TDS value of the outlet influent. If the TDS value is beyond the limit then all the pumps and valves will turn OFF. Then the pure treated water goes to storage tank and the impure water goes to the RO process again. [8]

IV. Result

In this paper we have described about the implementation of DCS in Waste Water Treatment Plant where the impure water is converted in to pure water. The simulation WWTP is done in Yokogawa CENTUM VP and the simulation is done on the basis of the observations gathered from the literature survey as well as from the advice of industrial experts. All the physical parameters involved in the process are monitored and controlled automatically.

V. Conclusion & Future Enhancement

This paper conveys the idea of implementation of DCS in a WWTP. The idea proposed in this paper can be implemented in small as well as large industries. The basement works starts by the development of process flow diagram, P&ID, creation of logics, interlocks and finally creating the entire graphic display on the basis of the previous data. Thus our final objective of creating drinkable water from the water taken from industrial as well as local sewer networks has been done successfully and the plan to make the hardware model is in progress. After the proper control with the help of the DCS, the water which we get in the storage tank contains 64\% TDS (Total Dissolved Solids) and 0\% BOD (Biological Oxygen Demand). Now this water has become perfect for drinking. This water can also be used for industrial purpose like feed water to boiler, cooling tower etc. This water can be retreated with the help of Ion exchange resins to make it ultra-pure water. With proper and effective DCS we can make the water recycling process in an efficient way. The proposed idea can be implemented in all the industries in future for the betterment in production.

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