Automation and Monitoring of Reverse Osmosis Water Treatment Plant

Bharat Lal, Sandeep Sagar, Misbah Arain, Burhan Aslam Arain, Farrukh Shaikh

Abstract: ***The world is suffering from an eminent water crisis. Safe and pure drinking water is the necessity and right of everyone. The use of reverse osmosis-based water treatment plants has become a common method for providing clean water in many areas as the global demand for water increases. Automation and monitoring is an important task for such plants at remote distance. A system is needed to prevent difficulties when one needs to control and monitor important parameters such as Total Dissolved Solids (TDS), Water Level, Flow rate manually. Manually operated RO plants have failed due to lack of proper monitoring and maintenance. Designed system in this article is equipped with Arduino microcontroller which controls the operation of system, water level sensors for water level monitoring in particular tank, water flow sensors to measure the flow rate of water during run, pH sensor for product water quality monitoring and a wireless connectivity module, which is used to establish communication between user/operator and the RO system at remote areas. The system not only allows user to monitor the important parameters of RO plant which influence the performance, but also allow to control the plant at remote distance. The system gives the measurement report upon a request message and also alerts the user automatically if any critical situation occurs at plant site. The system can be placed at any location where GSM based wireless connectivity is available and can be controlled from a single location.***

Index Terms**: *Reverse Osmosis, Water quality, Remote Monitoring, Wireless GSM Control.***

I. INTRODUCTION

The demand of pure and clean drinking water is increasing day by day due to the lack of water purification resources, especially in less-developed countries [1]. People are finding newresources of drinking water to cope with the demandbut cost of water is the most critical factor for taking decisionsto use new resources of water.Reverse Osmosis water treatment plants are an attractive desalination methodin respect of the cost [2]. However, automation and continuous monitoring atfrequent intervals is required for such plantsin order to maintain the quality water and continuous supply.

The Reverse Osmosis is the process which removes water contaminants by passing it through a semi-permeable membrane [3]. This happens by increasing the pressure on the RO plant's salt side by means of a high-pressure pump and forcing the water through the semi-permeable membrane. The designed RO System consists ofa High Pressure (HP) booster pump, semi-permeable membrane, sediment filter, carbon activated filter, 5-micron filter, raw water tank and product water tank.

Aurdino microcontrollershave been an extensively used tool in industrial applications of automation and control [4]. There are many parts in the RO system where pressure and water level control need to performed simultaneously and it becomes tedious job to handle the productmanually due to the possible human handling errorand thus this might not give expected results [5]. Therefore, there is strong potential to automate this plant to ensure and smooth operation.

Reverse Osmosis has proven to be an effective technology for producing water for use in industries that require demineralized or deionized water. Moreover, post RO system treatment can increase the quality of the water even further making it suitable for even more demanding applications [6]. The main reasons of failure in RO systems islack of proper automation and monitoring, membranescaling and fouling resulting from water contaminant accumulation on membrane that hinder the water flow thus increasing the differential pressure across the membrane. It's necessary to establish water quality guidelines [7].

Automation of RO involves the use of devices in order to monitor and control the main variables affecting membrane performance with a goal of increasing productivity [8]. The automation of RO plants can be provided by continuously monitoring the important parameters of RO system which effect the membrane and specify the time of chemical cleaning.

RO technology mostly used in rural areas, more than seven hundred smaller RO plants has installed at Tharparkar district lies in the south-east of Pakistan but most of them failed due to false operation and maintenance [9]. Asia's largest (capacity-wise) RO plant is also implemented at Tharparkar which aimed to provide two million gallons water per day but now a day it's only providing 0.5 million gallons water per day due to the lack of proper monitoring and mis operation [10]. Author [11] has collected ground water samples of 33 different villages of Tharparkar district which has averagely TDS 3967 and according to WHO standard [12] it should be less than 1000. Most of RO plant do not meet the standard provided in [12].

Therefore, it is required to optimize system performance and preventing the above problems. Researchers have provided different methods for automation of RO plants and also to alleviate the negative impact of fouling and scale formation on RO membrane performance by monitoring relevant parameters. Thus, automation is of much needed in RO plant. The main aim of this work is to design a smart RO system that can determine important parameters of RO plant automatically uponrequest and it can also send the measurement result as a SMS to the user's cell phone every time information is requested.

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Bharat Lal, Department of Electronics Engineering, Mehran UET Jamshoro, Pakistan.

Sandeep Sagar, Department of Electronics Engineering, Mehran UET Jamshoro, Pakistan.

Misbah Arain, Department of Electronics Engineering, NED University, Karachi, Pakistan.

Burhan Aslam Arain, Department of Electronics Engineering, Mehran UET Jamshoro, Pakistan.

Farrukh Shaikh, Department of Electrical Engineering, Isra University Hyderabad, Pakistan.

II. SYSTEM DESIGN

The whole system consists of two parts, a command center and automated RO Plant at a remote distance.

A. Command Center

The command center consists of a computer or cell phone to send the specific command through SMS (Short Message Service), GSM module at the plant will receive that SMS and transfers the received information to microcontrollerto make the decision accordingly. GSM based communication allows for controlling the plant from wherever cellular connectivity is possible. We can also use mobile connected with computer for ease of data reorganization, where data can be seen graphically by using a suitable software like LabVIEW. With this proposed system one can easily monitor and control the plant at remote distance.

B. Automated RO System

The designed system in the laboratory is a scaled model of a full-size RO based water treatment plant. The Reverse Osmosis plant consists of a Diaphragm pump, Sediment filter, Carbon Activated Filter, 5-micron filter, RO membrane, water storage tanks and connections as shown in the block diagram in Fig. 1.

The smart RO system is further equipped with an Arduino Microcontroller interfaced with a GSM SIM900D Module [13], 4 Relays for controlling purpose whose input is connected with PWM pins of Arduino and the outputs and

The Feed water control system consists of feed water motor, feed water storage tank, water level sensor. The sensor senses the level of water in tank (feed water storage tank) upon requested SMS from command center and motor will be turned on if level is below the set point (Empty) and when the water level reaches the set point (Full), the system will automatically turn off the motor. In both conditions SMS is sent to the cellphone/command center. Feed water control system block diagram shown in Fig. 2.

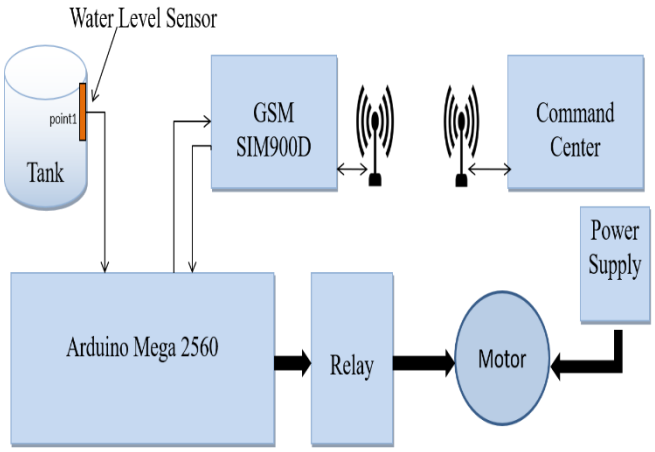

Fig. 2.Feed Water Control System Block Diagram

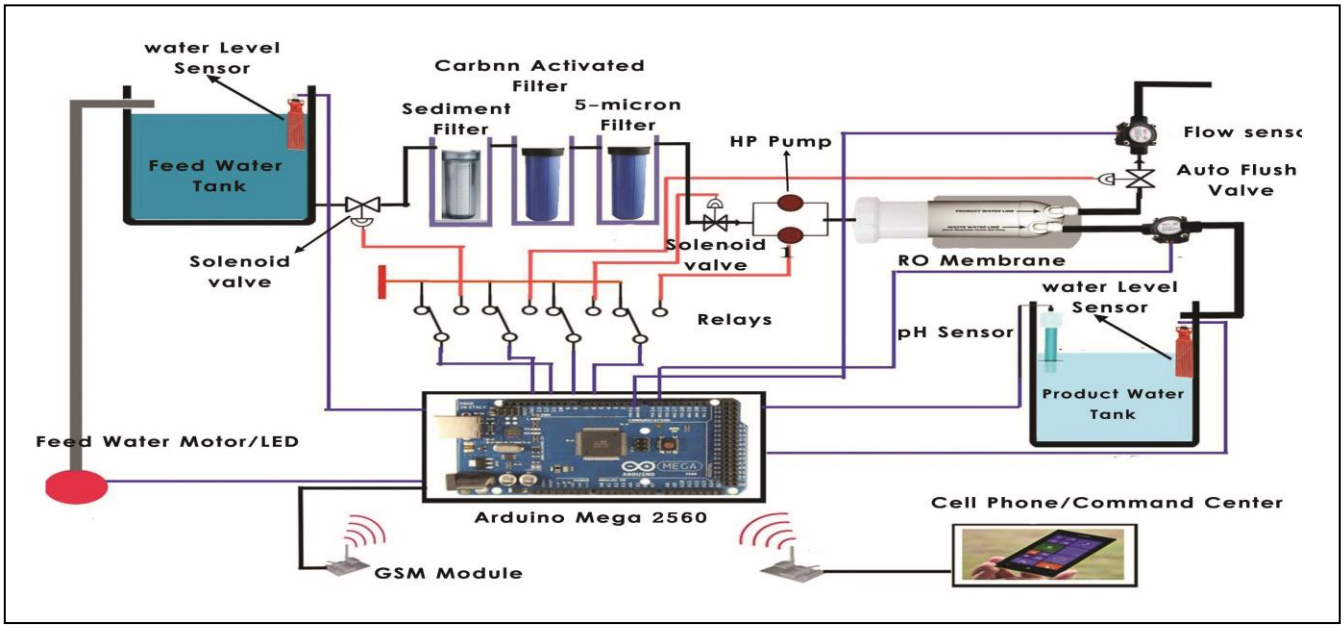

Fig. 1. RO System Block Diagram

The Auto Flush Valve. The three most important parameters to monitor in the RO plant are water level, water flow and the quality of theproduct water, therefore two water level sensors are mounted on the feed water tank and product water tank to check the water level in tanks, two flow sensors are also used to measure the flow of product water and reject water and a pH sensor is used which measures the quality of product water. Sensors are connected to Arduino as shown in above Fig. 1.

1) Feed Water Control System

2) High Pressure Motor Control System

The High Pressure (HP) control system is shown in Fig. 3 consist of HP motor, relays and water level sensors. In this case HP motor is used to increase the pressure of existing fluid flowacross semipermeable membrane. Water level sensors senses the level of water in Tank1 (feed water storage tank) and Tank 2 (product water storage tank) upon a request by SMS from user.

Sensor give the total readings from 0 to 500 and we set the threshold point1 equal to 300. If sensor value >= point1 tank will be considered as full else if sensor value < point1, tank will be considered as empty. HP motor will be controlled according to the conditions given in Table 1. In all conditions the system will report the result to user cell phone/command center.

TABLE I. HP MOTOR CONTROL CONDITIONS

	Tank1	Tank2	Result
User Command for turn on	Full = 1	Empty = 0	HP Motor = on & Feed Water motor = off
	Full = 1	Full = 1	HP Motor = off & Feed Water motor = off
	Empty = 0	Empty = 0	HP Motor = off & Feed Water motor = on
	Empty = 0	Full = 1	HP Motor = off & Feed Water motor = on

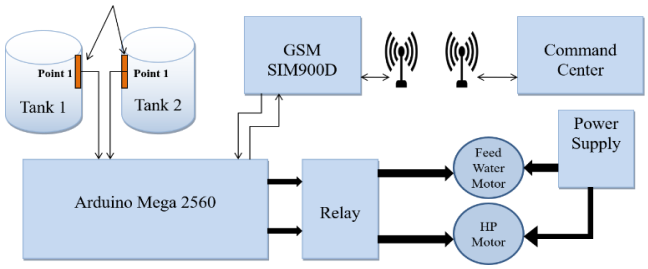

Fig. 3.HP Motor Control System

3) Water level Measurement and Control

Water level control and measurement system has water level sensor, a water pump, solenoid valves of Tank 1 (feed water storage tank) and Tank 2 (product water storage tank) as shown in Fig. 4. The water level sensors sense the level of water in both tanks and give measurement upon request via SMS.

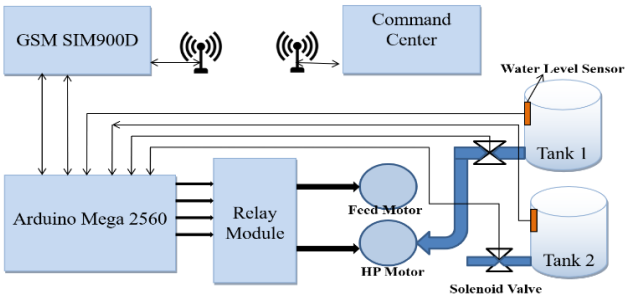

Fig. 4.Water Level Control System

4) Water Flow Rate Measurement

There are two water flow sensors used in the RO system which can measure flow rate of both product water (clean water) and reject water (waste water) in LPM (Litter Per Minute) as shown in Fig. 5. Sensors mounted on the pipe which sense water flow after system has started and once report the measurement results to user through SMS. Efficiency of the RO membrane can be measured by flow rate and quality of product water, hence with this measurement we can easily check the efficiency at a remote distance and specify the time of chemical cleaning of membrane further described in results and discussion section.

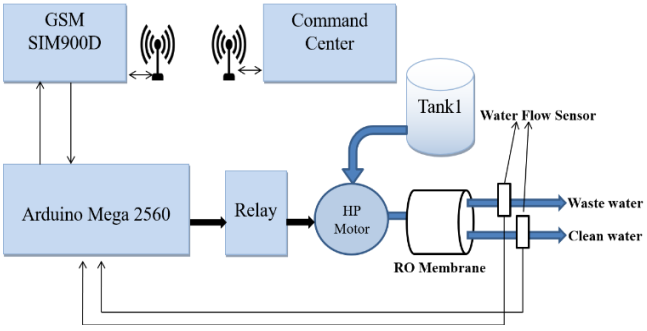

Fig. 5.Water Flow Measurement System

5) Water Quality Measurement System

Two parameters are used to measure the quality of product water i.e pH and TDS (Total Dissolved Solids). In this system we used only pH sensor to check the quality of product water. As shown in Fig. 6, the sensor is fixed in Tank2 and senses the pH of clean water when system receives SMS from user for pH measurement and reports the measurement result to user cell phone via SMS.

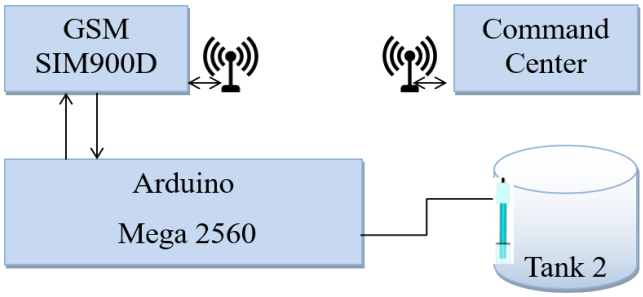

Fig. 6.Water Quality Measurement

III. SYSTEM OPERATION

A flowchart of complete system operation is shown in Fig. 7. The system waits for a request from the command center. The first two conditions will be checked for water level measurements in raw water tank 1 and product/cleam water tank 2, to determine that either tank is full or not upon receipt of an SMS.

If system receive request for runing feed water motor, water level in tank 1 will be checked first and if it is found to be greater then the set threshold value (discussed in 2 section) than it will not turn on the feed motor. However, if its below the threshold, the feed motor will remain on until the tank becomes full (Sensor value grater then set threshold).

Whenever system receives command for turn on system then water level in product water tank 2 will be checked first and ifit is greater than the threshold value, the High Pressure motor will not be started and if it falls below the set threshold value, than HP motor will be start and notification will be sent to the user. After waiting for 10 seconds measurement of the values of water flow of product water and waste water is started and reported to the user. Moreover, the user is reported automatically if flow rate increases or decreases by 5 LPM. Furthermore, the motor will automatically turn off when product water tank is full. Lastly, when system receives command requesting for pH value than pH value of product

will be measured by pH sensor and reported to user via SMS. For any other type of command, it will notify the user of an incorrect command.

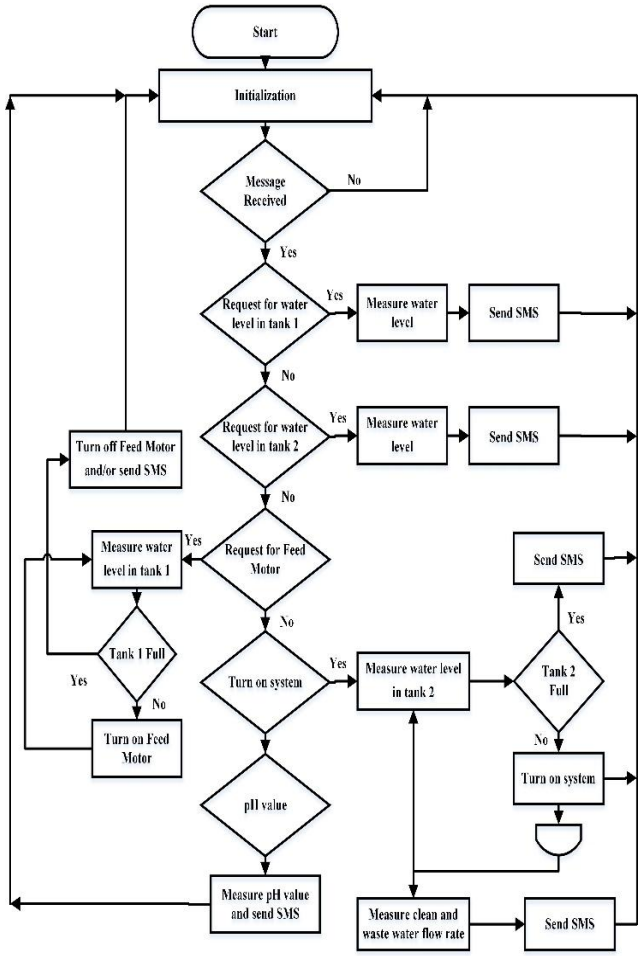

Fig. 7.Complete System Flow Chart

IV. RESULTS AND DISCUSSIONS

To ensure proper performance of RO system, the scaling and fouling deposit on the surface of the membrane needs to the brought under control. This work presents an implementation of a smart Reverse Osmosis plant. It presents an automation scheme for RO plants while providing monitoring of the variables related to its performance including water flow rate, water level, and pH etc. GSM communication has been used to transfer these measurements to a command center upon request. Where message can be received on mobile or computer to analyze the data. In this system, we use only mobile to receive the data. Furthermore, measured values are saved in computer database where data is displayed in real time graphically. Graph of pH and flow rate enables the user to monitor the condition of the system, which also helps to examine system state before an alarm condition is reached.

The monitoring results for Product water flow rate and pH are shown in Fig. 8 and Fig. 9 respectively.Fig. 8 shows the product water flow rate in LPM (Litters Per Minute) for 10 days where impurities are added in raw water in order to get proper results. From Fig. 8 it can be seen that the product water flow rate decreases with time, it may be due to scale formation and fouling deposition on membrane's surface. The jump in value of product water flow rate compared to original position is due to chemical cleaning of membrane. Fig. 9 shows the pH value for the same time duration.

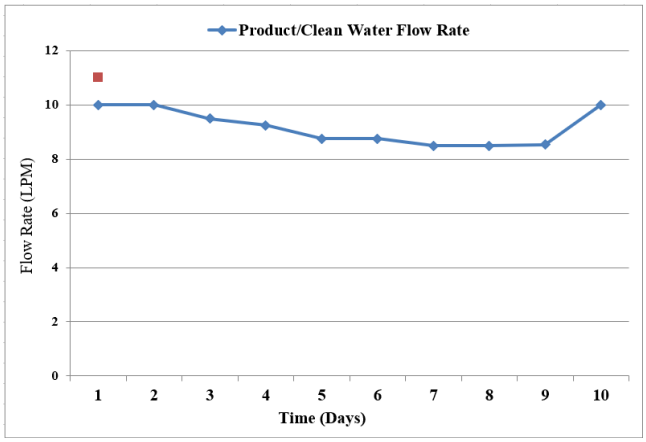

Fig. 8.Product Water Data on Day Basis

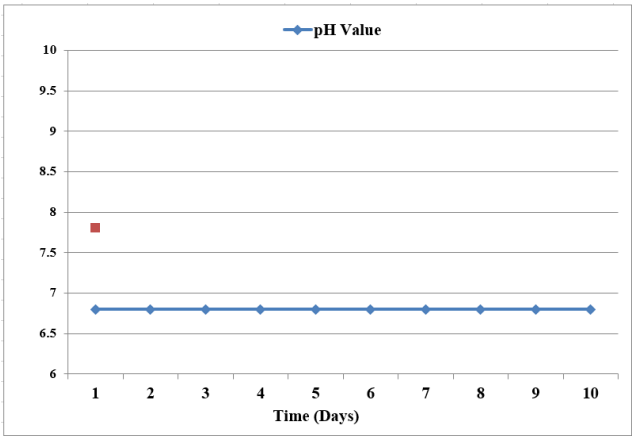

Fig. 9.pH Value of Product Water on Day Basis

V. CONCLUSION

In this project, we have designed a scheme fora smart Reverse Osmosis Plant in which automation and remote monitoring of RO plant is performed. This system has proved to be capable of monitoring the targeted parameters and system is controlled accordingly. Based on output data and depreciation of flow rate of water through membrane, it also indicates the optimum time for cleaning of membrane, which decides when to start the cleaning process for improving the sustainable yield of product water. Importance of remote monitoring and controlling of RO plants at remote distance, Fouling and scaling is also discussed. The proposed system is capable of increasing the operational efficiency of the RO Plant and reduce operational/service cost. Real time status parameters of all RO Plants anywhere in a remote locality can be monitored from a single location.

VI. FUTURE RECOMMENDATIONS

This system provides a working methodology for automating RO plant. This project can be commercialized by including measurement of TDS (total dissolved salts), fluoride content, chlorine content, dissolved oxygen, hardness of water and other variables which are necessary to monitor and check for portable water of water supply scheme for public. Another improvement that can be made is to add a solar powered supply.

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AUTHORS PROFILE

Engr. Bharat Lal have done Master of Engineering in Automation and Control and Bachelor of Engineering in Electronics Engineering with two years of teaching experience at undergraduate level. His area of interest includes automation and robotics and embedded system. He has more than three research publications in international journals related to field. Currently he is working as a Instrumentation and Control Engineer in I&C maintenance department, China Huadian Power Plant Operation Co. Ltd at Engro powergen thar Ltd. Pakistan.

Sandeep Sagaris an Electronics Engineer have done Bachelor of Engineering in Electronics Engineering his area of interest is Modern control systems and embedded systems. Currently he is working as a Sub Engineer electrical in Railway department.

Misbah Arain is an electronics engineer and have master's degree in industrial electronics and bachelor of engineering in electronics engineering. His area of interest is industrial electronics and embedded systems.

Burhan Aslam Arainis an electronics engineer and have done bachelor of engineering in electronics engineering and Masters in Automation and Control engineering. His area of interest is industrial automation and embedded systems design. Currently he is working as a Lab Lecturer at Mehran UET Jamshoro, Pakistan

Farrukh Shaikh is an Electronic Engineer with threeyearsof experience in teaching at Undergraduate level. His area of interest is Control Engineering and Robotics. Currently, he is working as a Lecturer in Electrical EngineeringDepartment at ISRA University Hyderabad, Sindh, Pakistan