AUTOMATION OF REVERSE OSMOSIS PLANTS

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Abstract

A detailed description of an automation pilot plant unit that is used for production of desalted water by reverse osmosis (R.O) methods is given. The operation parameters that influence the performance of membranes such as pressure drop, permeate flow rate, temperature, pH and total dissolved solid for permeate and reject streams can be automated and continuously monitored during the test. Measured values can be stored in a text file on a hard disk drive in regular time intervals set by user. After the test run, stored data can be displayed and used in program for further evaluation also; the results can be plotted and printed with time.

This technology enables the assessment of the performance of membranes and specifying the time of chemical cleaning for membranes due to the fouling and scaling formation that accumulated with time as a result of errors in the pretreatment section.

A visual Basic-6 is used for designing different user interface Windows and also, Delphi language was used for receiving the signal that was converted from analog to digital signal through interface.

The test was carried out in a pilot plant having a capacity $9m^3/h$ for production of desalted water by reverse osmosis membranes. The plant was provided with two types of membranes and different sensors for continuous monitoring.

The results revealed more flexibility to specify the optimum time for the chemical cleaning depending on the decline in percent recovery or increasing in the differential pressure.

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Introduction

Reverse osmosis invented in 1959, is the newest major method of water purification. It is a process, which removes both, dissolved organic, and salts by pressurized feed water flows across membranes with a portion of the feed permeating the membrane.

The principle cause of R.O system failure is membrane scaling which results from the accumulation of water formed deposits that affect the flow of fluid and increase the pressure differential across the membrane.

The fouling process is another reason affected the membrane performance by affecting both water flux and salt passage.

Under high fouling conditions the permeate flux reduces and a higher feed pressure is required to produce the design flow of permeate or percent recovery. Usually, there is a parallel increase in salt passage resulting in a higher salinity of permeates. Advanced stages of biological fouling will result in blockage of channels and increase pressure drop.

First of all, when the R.O scaling problem is discussed, the chemistry of concentrated water should be treated. Concentrated water results from the extraction of pure water (permeate water) from the saline feed water. The chemistry of concentrated water can be specified depending on feed water analysis multiplied by the concentration factor (CF).

Many researchers studied the methods that can be used to reduce the effect of scale formation and fouling on the performance of membranes and reverse osmosis membranes.

David et al [1] studied the influence of $CaSO_4$ on the performance of R.O membranes at different recovery levels.

Ahmed [2] studied the effect of adding of sodium hexametaphosphate and sulfuric acid on the scaling.

Ann and Menachem [3] investigated the effect of magnesium sulfite and calcium sulfite on the nanofiltration membranes.

An important technique for membrane regeneration is chemical cleaning of fouled membranes. Sayed et al. [4] used different agent with different concentration and specified the best agent for removal of fouling on the membranes.

It is clear that the controlling on the scaling and fouling deposited on the membranes surface governs the performance of membranes. The efficiency of membranes can be monitored depending on different parameters such as percent recovery, total dissolved solid of permeate and differential pressure. Any change in these variables out of operation limits means that there are problems in the membranes efficiency.

Loss in salt rejection and loss of permeate flow rate are the main problems encountered in R.O plant operation. It is almost importance that corrective measures are taken as early as possible.

Reverse osmosis monitoring provides the tool necessary for the detailed tracking of the performance of a R.O system. It develops an understanding of the R.O operating and performance variables including how they are calculated and applied. The monitoring of R.O plant depended on system automation. Automation refers to process control device that is used to increase productivity by monitoring the main variables affecting the membrane efficiency.

Ali and Mutaz [5] designed soft computing methodologies for desalination processes using fuzzy logic and neutral network. The authors concluded that the cost of producing desalted water can be decreased using proposed fully automate control strategy.

Imad et al. [6] discussed the controlling of desalination plants from different commercials point of view. The authors specified the advantage of process control on the reverse osmosis and multistage flash evaporation systems.

Plant Description

The only way of obtaining reliable design parameters for the production scale plant is to run pilot plant test under different operation conditions and with different membranes. Important parameters such as pressure drop, permeate flow rate, temperature and pH need to be carefully controlled and continuously monitored during test runs. This requires an automated pilot plant unit, equipped with measuring sensors capable of continuous data acquisition.

In the present work a pilot plant has a capacity of $9m^3/h$ for production of desalted water by reverse osmosis membranes are used. The plant comprised of three parallel vessels, each vessel contains five elements with 8 inch in diameter and 40 inch in length. The first vessel consists of Saehan membranes type RE8040BE of South Korean original and Koch membranes type 8822-XR of USA original is used in the second vessel. The pilot plant is used a brackish water from Tigris river having total dissolved solid (TDS)>700ppm.

The pilot plant is provided with different sensors, capable of continuous monitoring. Conductivity sensor type Conducta of Germany original is used to measure the conductivity of permeates, reject, and feed water. The sensor is connected with four solenoid valves, three valves in the input stream, and one valve in the output stream. Solenoid valves are electrically operated devices used to control the on/off or directional control flow. Solenoid valves consist of two main elements one electrical coil in the solenoid, and a valve body or pressure vessel. When the valve received an electrical signal, the plunger opens or closes a valve orifice, which gives the valve on/off.

Figure (1) shows the natural of connection between these parts. The mechanism of operation for these valves are carried out simultaneously, when the valve 1 is input the valves 2 and 3 are closed so, the value of conductivity will be measured and converted to digital signal in the PLC interface section. Measured value is transferred from interface to the personal computer and saved as data acquisition. After that the valve 4 will be opened for rejection the sample then valve 1 is closed. The other valves are operated with same way, where the time daily between each measurement about five minutes.

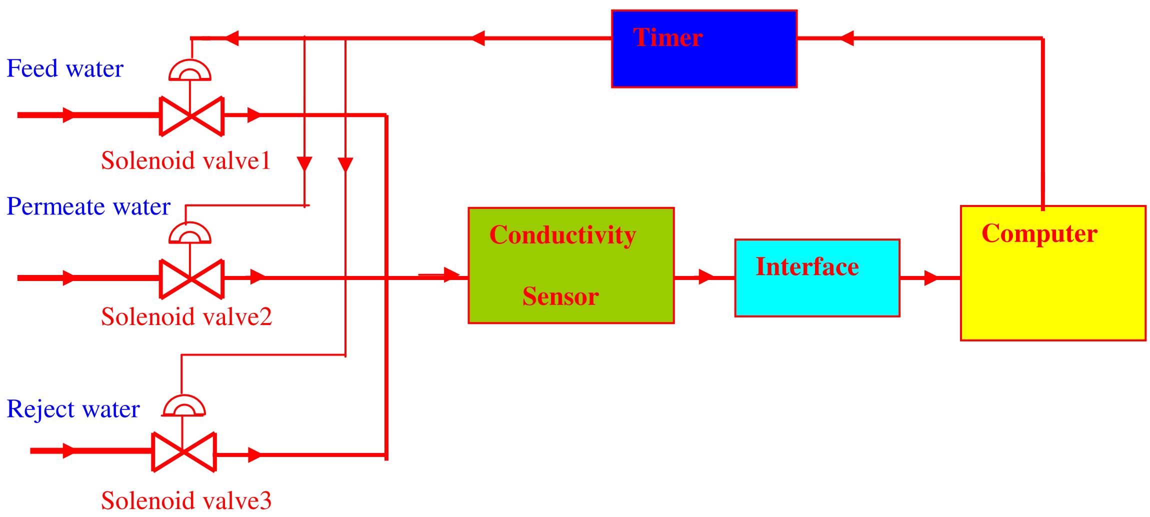

Fig. (1) Connection between valves and personal computer

The pressure drop of the permeate in the pilot plant is measured by pressure gauge where the results are saved in the hard disk for computer as data acquisition. The temperature of the feed water is measured by thermocouple while the feed, permeate, and reject flow rates are measured by rotameters and saved as a database. Fig. (2) shows the flow diagram of R.O pilot plant with production about $9m^3/h$ of desalted water.

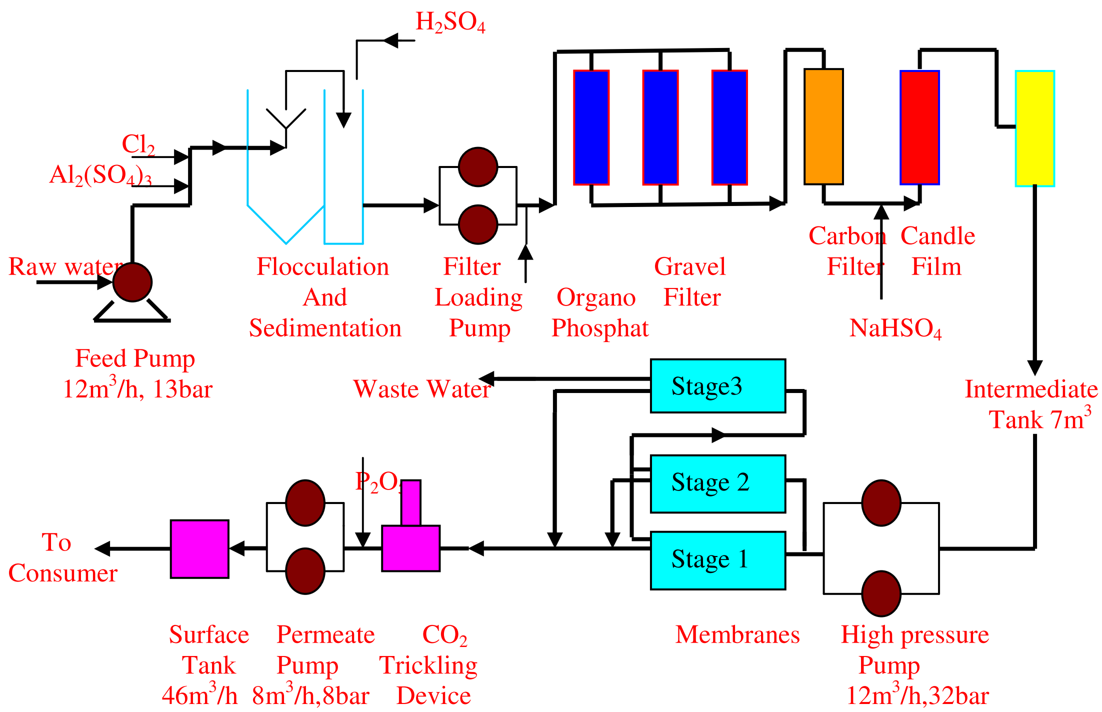

Fig.(2) Flow Diagram of R.O Pilot Plant

Results and Discussion

The performance of any R.O systems depends on controlling of scaling and fouling that is deposit on the membrane surface. The aim of the present work is to automate of reverse osmosis pilot plant. The main objective of automation is to monitoring the variables that are connected with the performance of membranes such as total dissolved solid of permeate, percentage recovery and differential pressure. Sensors are used to measure the previous variables. Measured values are transferred from the PLC to the personal computer where an ROUOB software package program is installed. In this work an original ROUOB program application is developed. A visual basic-6 is used for design of different user interface windows and saving of the values, which are measured by sensors. The PLC interface sends the sensor output to the computer where the data is displayed in real time. Data is displayed in actual form. In addition to the actual values, graphics of conductivity for each stream are displayed enabling the user to evaluate the state of the system at a glance. The display interface provides the opportunity to investigate a change in the operation condition before an alarm state is reached. Operating data is stored in the computer memory. Monitoring and data acquisition are never interrupted.

Figure (3) shows the effect of operation time for 8 months on the permeate flow rate. It is appeared that the permeate flow rate decreased with time, this may be due to the scale formation and fouling deposition on the surface of membranes which is likely to come from the inaccuracy of pretreatment system, while the jump in values of permeate flow rate occurs due to the chemical cleaning for the membranes. Cleaning therefore becomes necessary to improve the membrane performance.

Figures (4) and (5) show the effect of operation times on the differential pressure and the conductivity of permeate. The increase of pressure drop across membranes and permeate conductivity may be attributed to the membrane blocking by calcium sulfate and organic substance.

The results reveal that the performance for both types of membranes are decline after 6-8 months and the chemical cleaning must be carried out in order to removal of scaling and fouling formation on the surface of membranes.

CONCLUSION

An automation of reverse osmosis pilot plant is described. Sensors are used monitor process parameters that influence on the performance of membranes. The optimum time for chemical cleaning is specified depending on the decline of these parameters.

The pilot plant unit design enables the study of all-important variables such as differential pressure, conductivity of feed, permeates and rejects streams, pH and temperature that influence performance of membranes. Fouling and scaling can also be studied.

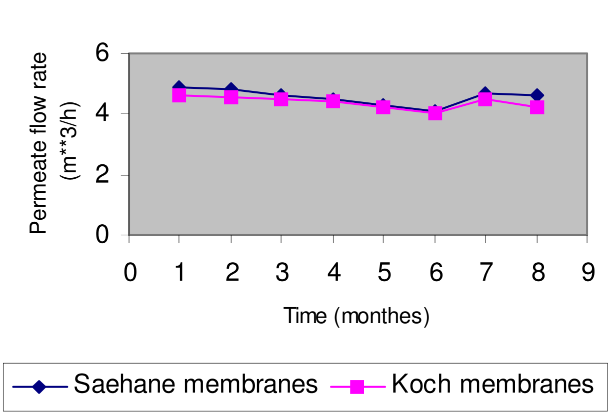

Fig.(3) Permeate flow rate for various type of membranes

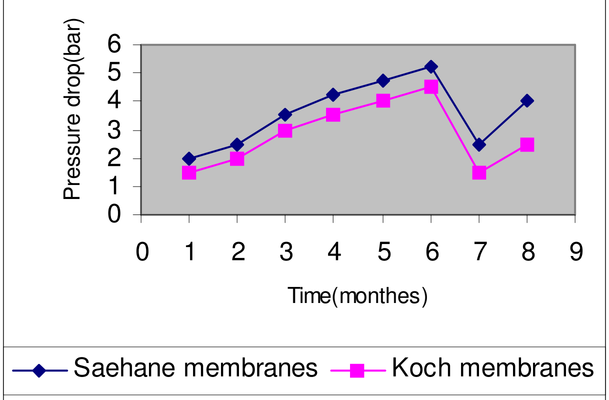

Fig.(4) pressure drop for various membranes.

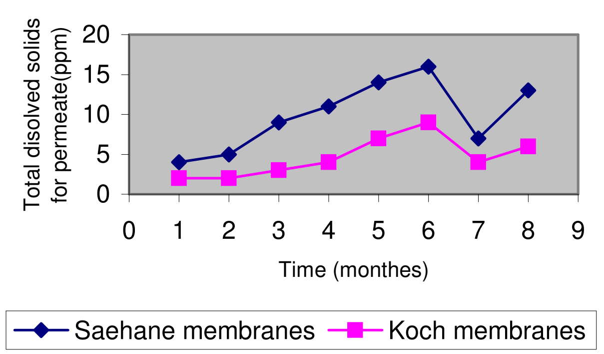

Fig.(5) Total disolved solids for permeate for various type of membranes.

References

1- David H., Alexander D. & Raphael S. "Inception of $CaSO_4$ scaling on R.O. membranes at various water recovery levels", Desalination, Vol. 139, P. 73, 2001.

2- Ahmed AL-rammah "The application of acid free antiscalant to mitigate scaling in reverse osmosis membranes", Desalination, V.2, P. 123, 2000.

3- Yann A. and Menachem E. "Calcium sulfate (gypsum) scaling in nanofiltration of a agricultural drainage water", Journal of membrane science, No.205, P.279, 2002.

4- Sayed S., Trraj M. & Mansour K., "Chemical cleaning of reverse osmosis membranes", Desalination, No.134, P. 77, 2001.

5- Ali Z. & Mutaz J. "Automation and process control of reverse osmosis plants using soft computing methodologies" Desalination, No.135, P.51, 2001.

6- Imad A., Hisham E. & Hisham D. "Process control in water desalination industry: an overview" Desalination, No.126, P.15, 1999.