Journal of Engineering and Sustainable Development
Vol.23, No.01 January, 2019
ISSN 2520-0917
https://doi.org/10.31272/jeasd.23.1.6

CONDUCTIVITY BEHAVIOR FOR THE PERMEATE STREAM OF REVERSE OSMOSIS WATER IN THERMAL POWER STATION

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Abstract: The study deals with the conferences of the Reverse Osmosis membrane of water treatment unit in AL-Doura thermal power station in Baghdad. The study concerned the analysis of RO water by the most convenient analytical equipments. From May 2015 to May 2016 over one year samples quality of the RO water in AL-Doura thermal power plant was accomplished .The results show that the lowest conductivity average values in the 1st quarter at day and at night. The greatest conductivity average values in the 3rd quarter at day and at night. In general the operation of reverse osmosis unit in Al-Doura thermal power station are in compliance with the restriction specifications of manufactured company design manual but in some days in hot months are not in the range.

Keywords: *Reverse osmosis water; pretreatment in thermal power station.*

سلوك التوصيلية للماء الخالي من الاملاح الخارج من مرحلة التنافذ العكسي لمحطة كهرباء حرارية

الخلاصة: تعنى هذه الدراسة بعمل اغشية التنافذ العكسي في وحدة معالجة المياه التابعة لمحطة كهرباء الدورة الحرارية في بغداد حيث تعتمد الدراسة على تحليل الماء الخالي من الاملاح الخارج من مرحلة التنافذ العكسي باستخدام اكثر الاجهزة فعالية للتحليل . اخذت نماذج الماء الخالي من الاملاح الخارج من مرحلة التنافذ العكسي على مدى عام كامل من مايس/٢٠١٥ الى مايس/٢٠١٦ اشارت نتائج البحث الى ان معدل اقل قيمة توصيلية كانت في الربع الاول من السنة في النهار و في الليل . واعلى معدل قيمة توصيلية في الربع الثالث في النهار وفي الليل . بالعموم التشغيل لمرحلة التناضح العكسي في محطة كهرباء الدورة الحرارية كان ضمن محددات الشركة المصممة ما عدى بعض ايام في الاشهر الحارة .

1. Introduction

About 560 billion Liters of water daily is required to produce steam and cooling purposes for thermal power plants that burn fossil fuels or produce nuclear reactions for the generation of electricity. In order to keep these plants as efficient as possible, the quality of the water is very important.

High pressure steam generating systems needs high clarity water for makeup water for open recirculation cooling systems in thermal power station. High concentration of impurity can be elevated in makeup. The thermal power station needs stable intake of

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water to put back water lost throughout steam losses, sampling systems, and blow down and evaporation from cooling.

It is essential to have a constant source of received water, because of the continuous loss in recycling water. At the start of thermal power station cycle chemistry is treating the received water. The treatment includes demineralization that removes dissolved impurities.

The pretreatment equipment includes clarifiers, softeners and filters. By increasing basis, membrane technology and ion exchangers to get efficient demineralization treatment.

The aim of the demineralization treatment is to get high purity water using for overall feed water -condensate cycle [1].

Water treatment unit in thermal power plants is conducting to avoid troubles for example scale formation/deposition in turbine system and the boiler, carryover to the turbine component and corrosion. Early 1959, water treatment methods would develop to handle nonconformity of equipment. Water quality requirement for turbine and boiler of thermal power plant is set by the Japanese Industrial Standard is often amended; also Mitsubishi Heavy Industries has contributed. The development in water treatment ways for old plants, high operation efficiency, and improved environmental conservation have been in the plan for the recent years [2].

2. Thermal power station

2.1. Thermal power station Operation

Steam is produced by oil combustion in boiler through high pressures and temperatures, which is passed to steam turbines. Oil has economic advantages when it can be pumped from refinery through pipelines direct to the boilers of generating station. The axial-flow type of turbine is in common use with several cylinders on the same shift. The steam power station operates on the Rankine cycle.

A chemical water treatment unit (CWTP) for demi water production and a polishing plant (PP) for condensate purification are the systems for ultra pure water production. The PP is a system for the make-up of feed water and it is a part of the water steam cycle (WSC), as presented in Fig.1.

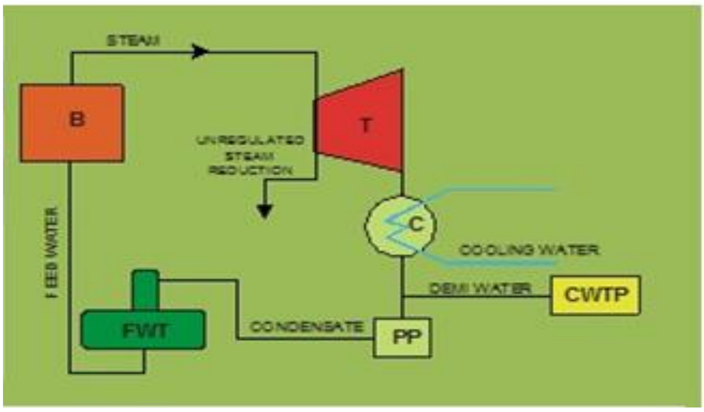

Fig. 1. water – steam cycle

2.2. Water Steam Cycle

The water steam cycle (WSC) made of: polishing plant, feed water tank, boiler, turbine and condenser. Circumstances in the WSC are severe, in the company of high temperatures, high pressures, and different other specifications of steam. Because of the loss of the condensate (brought about by leakage or evaporation) in the water steam cycle, demineralised water from feed water tank ongoing added.

Desalted water in feed water tank is the resource of steam generation produced in boiler. Steam with fixed pressure and temperature enters the turbine [3].

3. Reverse Osmosis

3.1. Main Impurities in water

1-Suspended (Micro size) – dirt, silt, sand. These have a part of turbidity to raw water.

2-Colloidal Micro size particles (1-100 nm)

3- Dissolved appearance- neutral salts, organic matter and alkaline salts.

- Alkaline salts are generally bicarbonates infrequently carbonate and hydrates of magnesium, sodium and calcium.
- Neutral salts are nitrates, chlorides and sulfates of sodium, calcium and magnesium. [4].

Advantages of use Reverse Osmosis in water treatment of thermal power station:-

1- Continuous operation .No need for regeneration.

2- No need for bulk storage of acid- alkali.

3- No effluent treatment required.

4- Operating cost mainly power cartridge filter replacement and membrane replacement (Low operating cost except cost of membrane).

5- Excellent silica removal [5].

3.2. Reverse Osmosis Work

Osmosis is a natural phenomenon. This occurring when weaker salty solutions have a tendency to transfer to a strong salty solution.

Reverse Osmosis, commonly referred to as RO, is a process where you demineralize or deionize water by pushing it under pressure through a semi-permeable Reverse Osmosis Membrane. Fig. 2 shows how osmosis and reverse osmosis working.

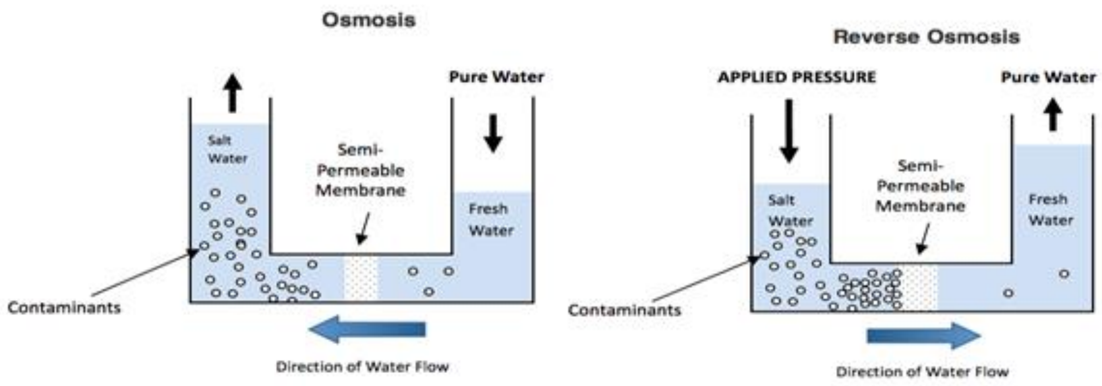

Fig.2. The Osmosis and Reverse Osmosis work

A semi-permeable membrane in a semi-permeable membrane some atoms are allowed to pass through the membrane while others are prevented. A screen door can be taken as an example in which the air molecules are allowed to pass through the holes in screen while pests and other large particles are prevented [6].

While Osmosis occur in nature with no energy consumed, to get more salty solution reverse osmosis process thus needs applying energy. Reverse osmosis membrane are semi-permeable membrane that allow the passage of water molecules while prevent bacteria, organics and dissolved salts to pass. On the other hand, applying pressure to forced water through the reverse osmosis membrane that is greater than natural happening osmotic pressure so as to desalinate (deionize or demineralize) water in the process, allowing water molecules to pass through while the contaminants are not allowed through. Exiting stream have (95% - 99%) of dissolved salts is the reject stream. While the product water (desalinated water) is called permeate stream.

The pressure required depends on salt concentration of providing water. More salty water in the feed, needs more pressure to overcome the osmotic pressure [7].
The RO process is shown in Fig. 3.

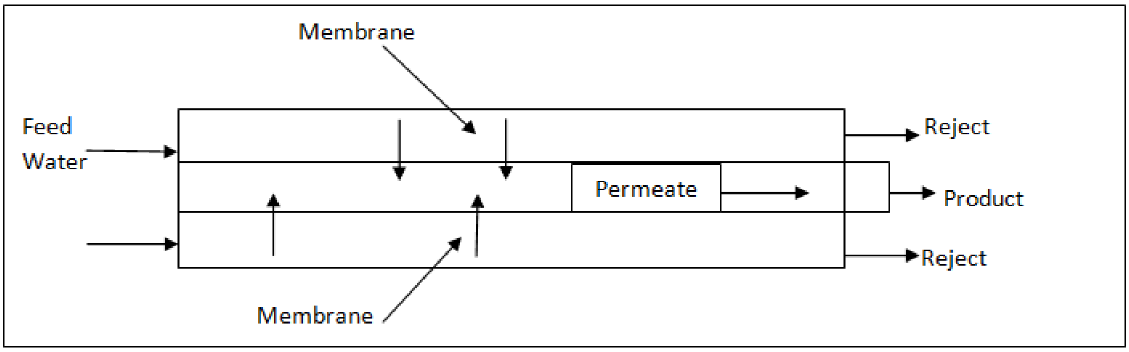

Fig.3. The Reverse Osmosis Membrane work

3.3. Reverse Osmosis Process Terminology

The RO process is rather simple in design. It included of a feed water source-pretreatment unit- high pressure pump-RO membrane and in some cases advances treatment [8].

The principal theory of fluid transport through membranes is expressed as [9]:

$$N_A = \rho_A \nu - D_{AB} \nabla\rho_A \quad (1)$$

Where
N_A = the mass flux of component A through the membrane.
ρ_A = the mass density of component A,(the mass average velocity of the fluid through the membrane).
D_{AB} = the effective diffusion coefficient of component A in the membrane.
$\nabla\rho_A$ = the mass density gradient.

In membrane where holes flows contribute considerably to flux, Darcy's Law is frequently used to distinguish the mass average velocity [9]:

$$\nu = - K/\mu\ (\nabla p - \rho g) \quad (2)$$

Where
κ = the Darcy Law constant.
μ = the fluid viscosity.
∇p= the pressure gradient
ρ = the solution density.

3.4. Water Conductivity

Pure water contain no exogenous ions it is an excellent insulator, however even deionized water is not totally free of ions. In the liquid state, Water undergo auto ionization , when one hydronium cation (H_3O^+) and one hydroxide anion (OH^-) are produced from two water molecules [10].

Water is a good solvent; therefore, it at any time has some solute (often a salt) dissolved in it. The water can conduct electricity easily even it has a little amount of an impurity.

The theoretical upper limit of electrical resistivity for water is about 182 kΩ·m at 25 °C. This agrees with what is seen on deionized ultra-pure water systems, ultra-filtered and reverse osmosis.

Responsive equipment is able to sense an extremely small electrical conductivity of 0.05501 ± 0.0001 µS/cm at 25 °C, in pure water. Also,water is capable of electrolyzing into hydrogen and oxygen gases except in the absence of dissolved ions this is a so slow process and extremely tiny current is conducted [11].

4. Case Study

This study deals with the conferences of the RO treatment in water treatment unit in AL-Doura thermal power station in Baghdad.

The station was built in 1966, bombed in 1980 in first Gulf war, building extra were added (two unit each produces 160 Mw) in 1985 by Siemens and in 1988 a second two units were built each produce 160Mw by Ansaldo.

Filtered water is delivered by the high pressure pump to three stages RO connected in series.

The brine out of the first stage is the feed solution to the second stage and the brine out of the second stage is the feed solution to the third stage. The brine out from the third stage is disposed to the RO neutralization basin.

First stage including three pressure vessels, second stage including two pressure vessels and third stage including one pressure vessel. Each pressure vessel is containing four spiral wound modules.

The product from each stage is connected to a main feeding the desalinated water storage tank.

The configuration of RO water unit in Al-Doura thermal power station is shown in fig. [4].

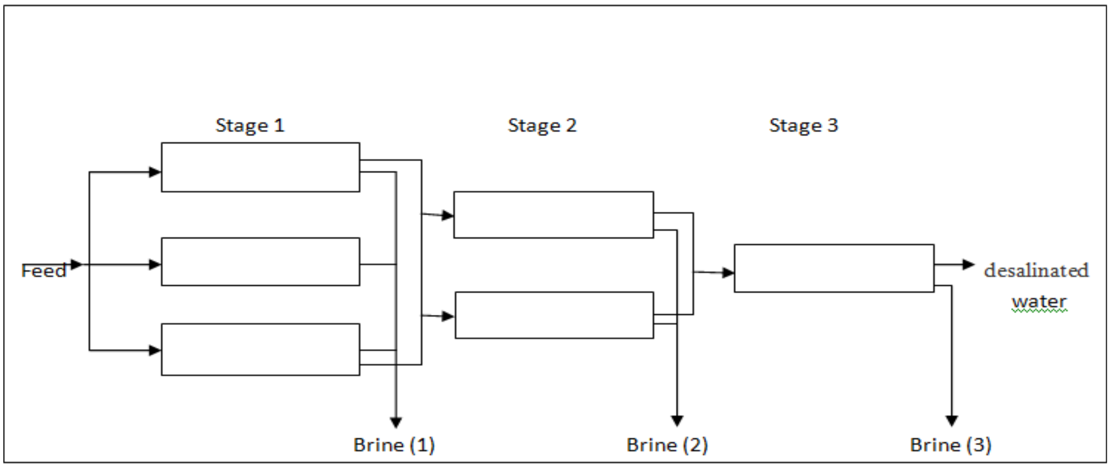

Fig. (4). The configuration of RO water unit in Al-Doura thermal power station

5. Experimental work

The measurements of conductivity of permeate stream from final stage are conducted by experimental methods.

From May 2015 to May 2016 over one year samples quality of the RO water in AL-Doura thermal power plant was accomplished samples were divided in four quarters each quarter represent three months. June 2015 represents the hot month, September represents the temperate month and December 2015 represent the cold month for day and night time.

The restriction specifications of filtered water that fed to RO system and desalinated water that produced from RO system according to the manufactured company design manual are tabled in Table[1].12]

The cell and stages of RO water treatment unit in Al-Doura Thermal Power Station is shown in fig.[5]

Fig.5: The Cell and Stages of Water Treatment Unit in Thermal Power Station

Table (1):- The restriction specifications of filtered water and desalinated water according to the manufactured company manual.

specifications	Filtered water (feed to RO)	Desalinated water (product from RO)
Ca^{+2} (ppm)	90	4
Mg^{+2} (ppm)	55	3
Na^{+} (ppm)	129	10
K^{+} (ppm)	4-9	0.5
HCO_3^{-} (ppm)	298	24
Cl^{-} (ppm)	199	12
SO_4^{-2} (ppm)	202	10
TDS (ppm)	20	1-2
Conductivity (Ms\cm)	750-1200	14-65

6. Results and Discussion

The conductivity of RO water over one year as quarters are represented in Table 2 and Table 3.

Table 2: Average Conductivity of permeate stream of RO unit in one year as quarters.

Dating	At day	At night
1st Quarter	25	21
2nd Quarter	45	33
3rd Quarter	59	43
4th Quarter	35	22

Table 3: the Conductivity of permeate stream of RO unit in one year.

Date	Conductivity (Ms\cm)		Date	Conductivity (Ms\cm)	
	At day	At night		At day	At night
1st week January	25	22	1st week July	48	31
2nd week January	21	21	2nd week July	45	30
3rd week January	23	20	3rd week July	55	37
4th week January	25	23	4th week July	62	39
1st week February	22	19	1st week August	61	42
2nd week February	30	20	2nd week August	62	56
3rd week February	29	20	3rd week August	60	59
4th week February	23	21	4th week August	63	58
1st week March	25	22	1st week Sep.	58	43
2nd week March	24	21	2nd week Sep.	66	46
3rd week March	27	23	3rd week Sep.	59	45
4th week March	29	24	4th week Sep.	61	39
1st week April	35	26	1st week Oct.	46	28
2nd week April	37	28	2nd week Oct.	45	25
3rd week April	42	30	3rd week Oct.	40	22
4th week April	44	32	4th week Oct.	36	21
1st week May	48	39	1st week Nov.	36	22
2nd week May	50	37	2nd week Nov.	36	23
3rd week May	46	35	3rd week Nov.	33	20
4th week May	57	37	4th week Nov.	33	22
1st week June	53	32	1st week Des.	32	20
2nd week June	46	30	2nd week Des.	31	17
3rd week June	40	36	3rd week Des.	30	19
4th week June	50	38	4th week Des.	30	22

In the 1st quarter the lowest conductivity value in 2nd week January was (21 Ms\cm) and the greater one in 2nd week February was (30 Ms\cm) at day.

The lowest conductivity value in 1st week February was (19 Ms\cm) and the greater one in 4th week March was (24 Ms\cm) at night Fig.6

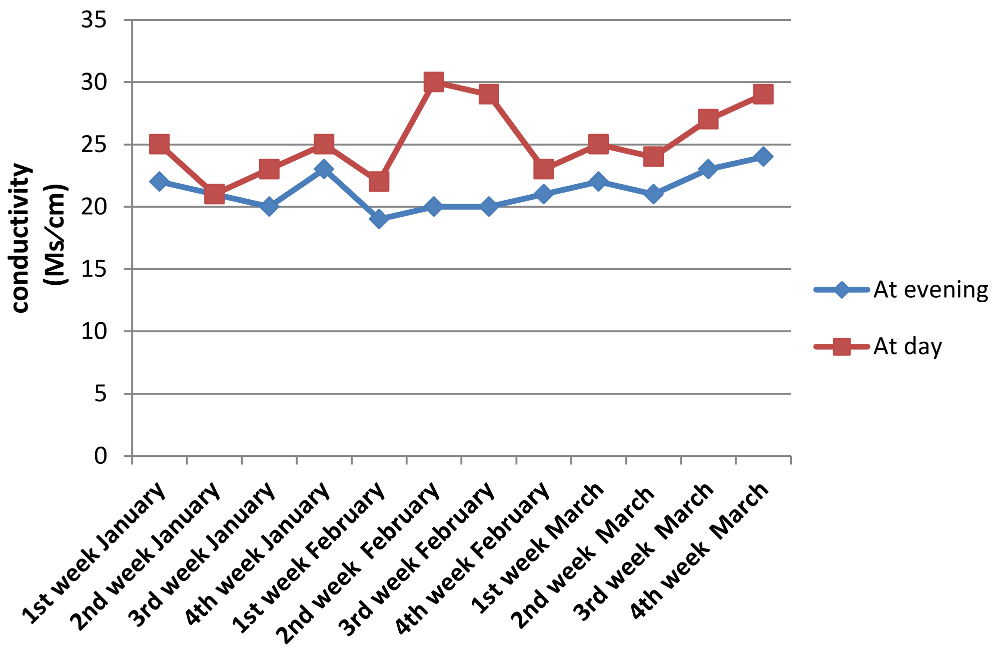

Fig.6. 1st Quarter conductivity values

In the 2nd quarter the lowest conductivity value in 1st week April was (37 Ms\cm) and the greater one in 4th week May was (57 Ms\cm) at day. The lowest conductivity value in 1st week April was (26 Ms\cm) and the greater one in 1st week May was (39 Ms\cm) at night Fig.7

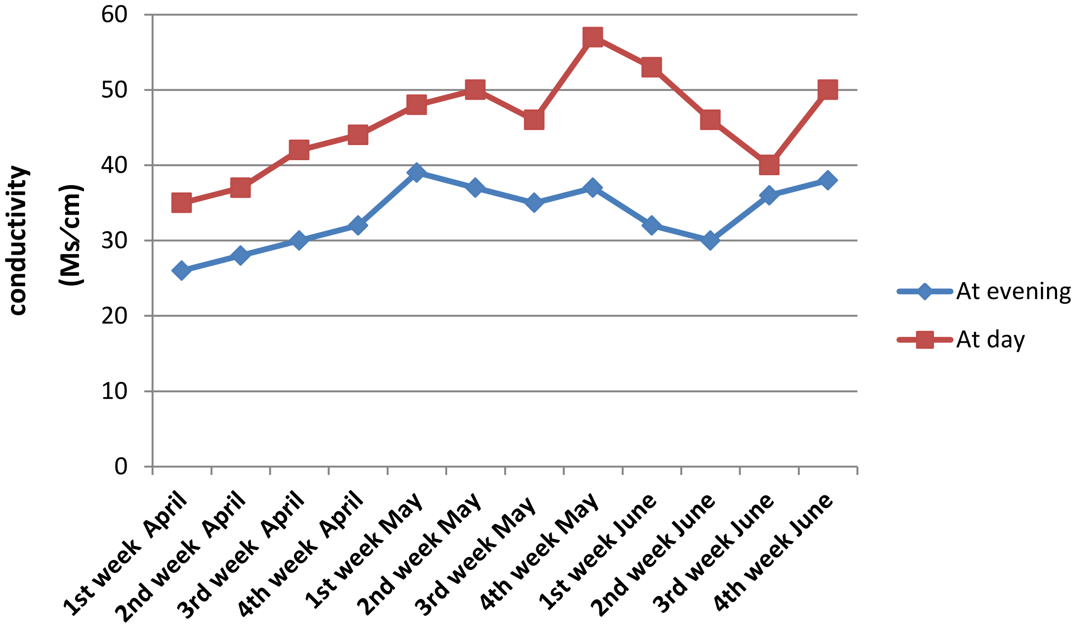

Fig.7. 2nd Quarter conductivity values

In the 3rd quarter the lowest conductivity value in 2nd week July was (45 Ms\cm) and the greater one in 2nd week September was (66 Ms\cm) at day. The lowest conductivity value in 2nd week July was (30 Ms\cm) and the greater one in 3rd week August was (59 Ms\cm) at night Fig. 8

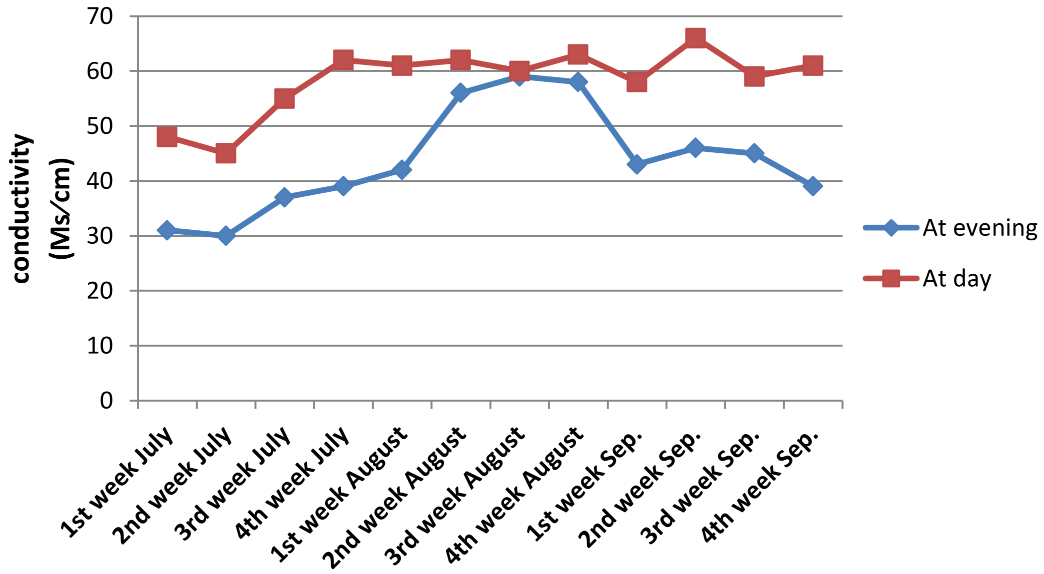

Fig.8. 3rd Quarter conductivity values

In the 4th quarter the lowest conductivity value in 3rd week December and 4th week December was (30 Ms\cm) and the greater one in 1st week October was (46 Ms\cm) at day. The lowest conductivity value in 2nd week December was (17 Ms\cm) and the greater one in 1st week October was (28 Ms\cm) at night,Fig.9

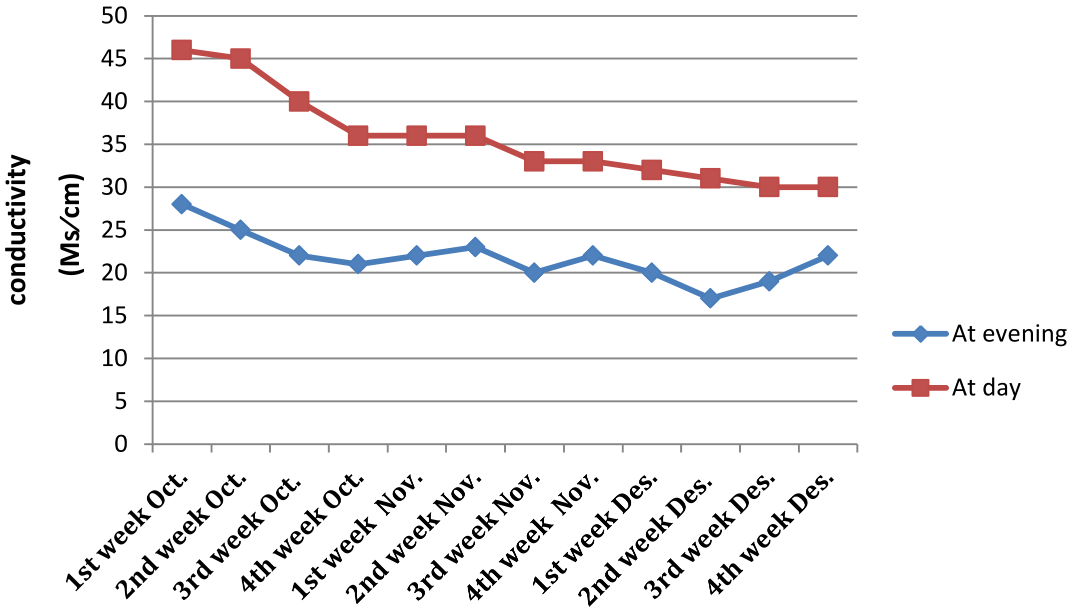

Fig.9. 4th Quarter conductivity values.

Generally the lowest conductivity average values in the 1st quarter was (25 Ms\cm) at day and (21 Ms\cm) at night. The greatest conductivity average values in the 3rd quarter was (59 Ms\cm) at day and (43 Ms\cm) at night.

In June the lowest conductivity value in 04⁄06⁄2015 was (34 Ms\cm) at night and the greater one in 26⁄06⁄2016 was (69 Ms\cm) at day,Fig.10.

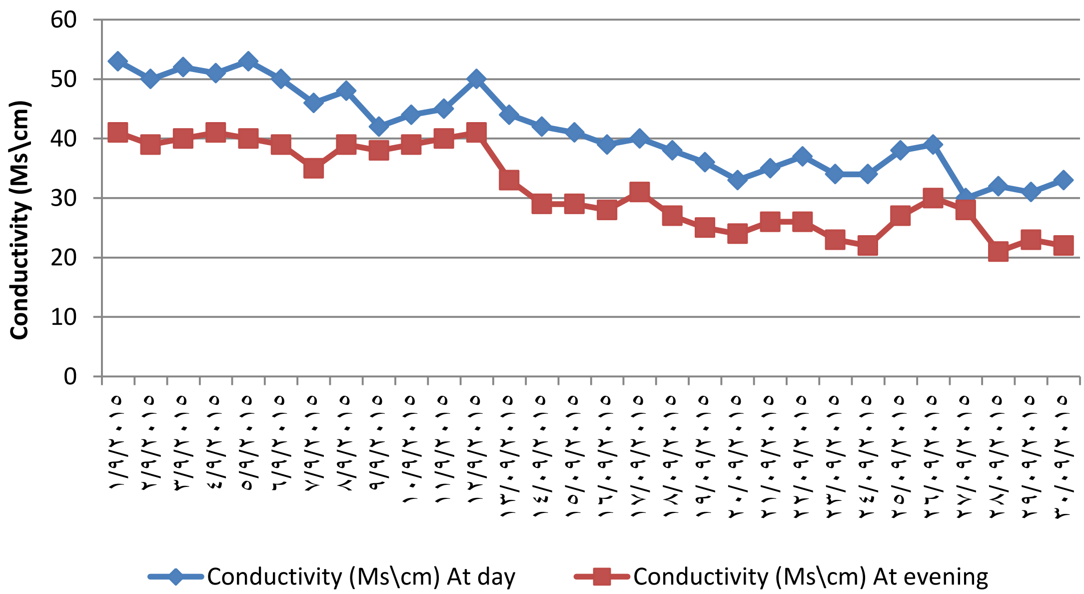

Fig.10. Conductivity values in June 2015

In September the lowest conductivity value in 28/09/2015 was (21 Ms\cm) at night and the greater one in 01/09/2015 and 05/09/2015 was (53 Ms\cm) at day.Fig.11.

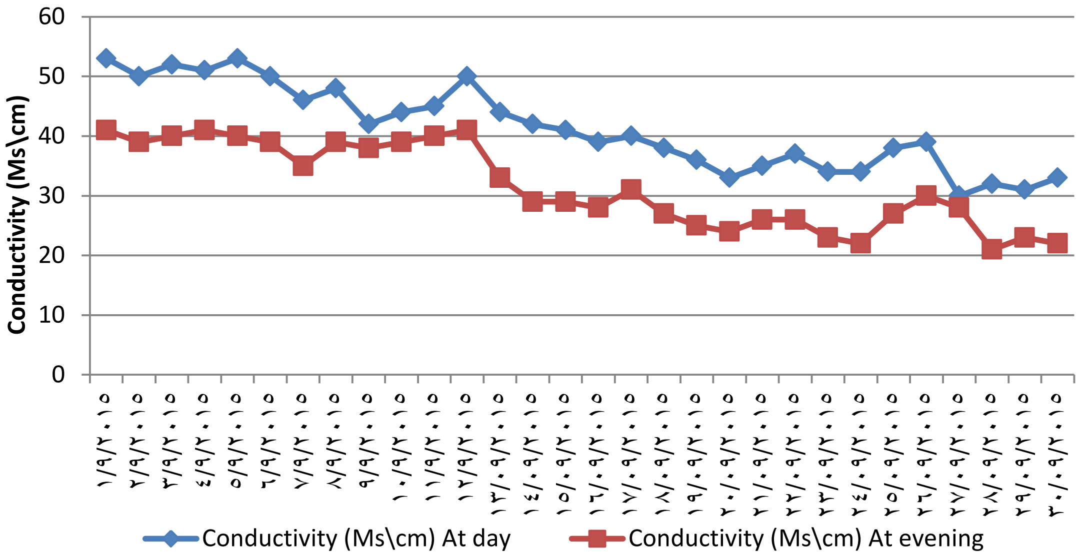

Fig.11:-Conductivity values in September 2015.

In December the lowest conductivity value in 13/12/2015 and 28/12/2015 was (18 Ms\cm) at night and the greater one in 29/12/2015 was (29 Ms\cm) at day.Fig.12.

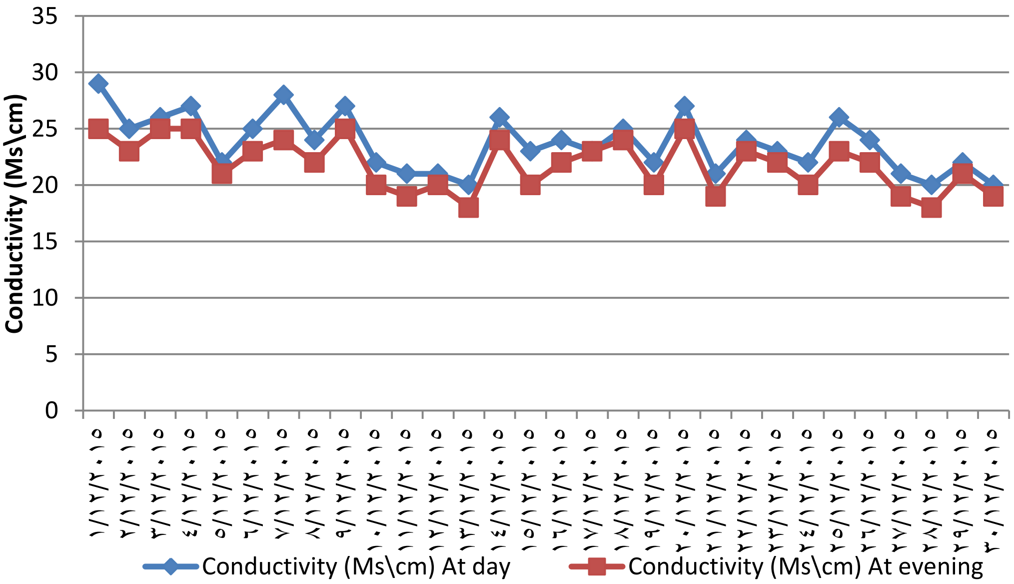

Fig.12:-Conductivity values in December 2015.

The average of conductivity in June 2015 during the day was (59.06 Ms\cm) and at the night was (48.53 Ms\cm). The average of conductivity in September 2015 during the day was (41.33 Ms\cm) and at the night was (29.06 Ms\cm). The average of conductivity in December 2015 during the day was (23.66 Ms\cm) and at the night was (21.8 Ms\cm).

There are unnatural values out of ranges in 11⁄01⁄2016 at evening (52 Ms\cm) and in 13⁄01⁄2016 at day (160 Ms\cm) because of operation problems such as the cell of RO stage need to be washed or regenerated or the membrane might be damaged.

7. Conclusions

It is found that the value of conductivity would vary during operation at day and at night and also varies between the months according to the weather of these months.

In general the lowest conductivity average values in the 1st quarter was (25 Ms\cm) at day and (21 Ms\cm) at night. The greatest conductivity average values in the 3rd quarter was (59 Ms\cm) at day and (43 Ms\cm) at night.

Generally the operation of reverse osmosis unit in Al-Doura thermal power station are in compliance with the restriction specifications of manufactured company design manual but in some days they are not in the range in hot months because of increasing the evaporating losses in hot days.

8. Recommendations

According to the study conclusions suggesting set an additional RO unit consists of one stage to the RO water treatment unit in the station that will be operating only in the days when the conductivity is out of the restrictions after the three existing stages in the hot days.

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