ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Model Reference Adaptive Controller (MRAC) for Reverse Osmosis (RO) desalination system using MIT rule.

Asuntha [1*], Indrajit Jana[2], Selvam K [3], Brindha A[1], and Andy Srinivasan[4].

[1] Assistant Professor, Dept. of EIE, SRM University, Chennai, Tamil Nadu.
[2] PG student [ECE] Dept. of ICE, SRM University, Chennai, Tamil Nadu.
[3] Assistant Professor, Dept. of Chemical Engineering, SRM University, Chennai, Tamil Nadu.
[4] Professor, Dept. of E&I, Valliammai Engineering college, Chennai, Tamil Nadu.

ABSTRACT

Reverse Osmosis (RO) desalination system is a method for produces fresh drinking water. Here desalinating the sea water or brackish ground water and output produces the fresh water. Reverse Osmosis (RO) desalination unit model is considered as multi-input multi-output (MIMO) process. The relationship between the input and output variables are defined as a transfer matrix form. Reverse Osmosis (RO) desalination process, mainly power is given by using Photo-Voltaic (PV) panels. For better control performance, RO desalination system is controlled by Model Reference Adaptive Controller (MRAC) using MIT rule. Model Reference Adaptive Controller (MRAC) reduces the complexity and increase the efficiency of the desalination system.
Keywords: Model Reference Adaptive Controller (MRAC), MIT rule, Feed-forward gain.

**Corresponding author*

INTRODUCTION

Motivation:

The demand of fresh water is very important for humans, animals life and industry applications. But increasing the world population day by day, the demand of fresh water makes great problem. To solve this problem, Reverse Osmosis (RO) desalination system is an one of the method for providing sufficient amount of fresh water [1].

The main source of water is brackish ground water and sea water. RO desalination process is a very complex method, for this reason it is need to reduce the complexity and increase the efficiency of work performance. The Model Reference Adaptive Controller (MRAC) using MIT rule is used for better control performance [2].

Model Reference Adaptive Controller (MRAC) always deals with non-linear systems and overcome the various problems. Model Reference Adaptive Controller (MRAC) also known as Model Reference Adaptive Systems (MRAS), which makes the closed loop controller using system parameters and it depends on the system response changes. The system output is always compared to the reference models desired response. All controller parameters are changed based on the error values, so main target is to cover the parameters values according to an idea values. Because it is necessary match the plant model response with reference model response.

Background and literature:

H.M. Colquhoun (2010)- Reverse Osmosis (RO) desalination is a process where desalinating the sea water or brackish ground water and produces the fresh water. Reverse Osmosis (RO) desalination process consists of polyamide membrane, where mounted on porous polysulfone layer. It is used to remove the ions, particles and molecules from the fresh drinking water. Another way it is to remove many chemicals from source water, because chemicals can effect the RO desalination membrane. It is very important to clean the Reverse Osmosis (RO) membrane periodically because high pressure of flow is needed for continue the flow rate in a RO membrane.

S.R. Wenham (2007)-Photo-Voltaic (PV) cell is used for producing the more electrical power supply in Reverse Osmosis (RO) desalination systems. According to PV cell characteristics, decrease the temperature increase the output electrical power. So it is important to cool the Photo-Voltaic (PV) cell by using the heat exchanger.

G. Mittelman (2009)- To get the more power from Photo-Voltaic (PV) panels, according to the panels characteristics, it need to be cool the Photo-Voltaic (PV) panels. There are many methods used to cool the Photo-Voltaic (PV) panels. Such as water cooling method, air cooling method etc. Mainly heat exchanger is used to cool the Photo-Voltaic (PV) panels.

K. Benjelloun (1993)- Adaptive control is a technique, where systems parameters are controlled according to the environmental conditions. It is one of the process where automatically and continuously measures the plant behavior and compare with desired output values. The characteristics of adaptation mechanism is controlled by the system performance, depends upon the adaptation gain. The Model Reference Adaptive Controller (MRAC) with MIT rule is introduced in different values of adaptation gain. It is used for non-linear dynamic systems, to control the non-linear plants with unknown parameters. This is one of the techniques which gives the sufficient conditions of system performance.

K.J. Astrom (2001)- Many times some feedback controllers are not working properly, because of some disturbances effect of the systems, different changes in process dynamics and suddenly changes in environmental conditions. So adaptive control techniques are used to overcome these problems, where actual plant outputs tracks the reference model output with the constant reference input values. Model Reference Adaptive Controller (MRAC) is one of the adaptive control feed-forward techniques, where easily adjust the controller parameters. The difference between the plant and model output is defined as error. According to the error, controller parameters are adjusted, with the constant reference values.

P. Swarnkar (2010)- Adaptation control is one of the important technique, to modify the control law and control the systems parameters values according to the environmental condition. This technique mainly depends on

ISSN: 0975-8585

characteristics of adaptation gain. Adaptive control is a control performance, which deals with time- variant process. Model Reference Adaptive Controller (MRAC) with MIT rule is used to solved the desired performance, which is define in terms of reference model and it gives desired response according to the command signal.

P. Swarnkar (2011)- A control law is involve in adaptive control technique, where system parameters are controlled according to the environmental condition changes. It is automatically and continuously measure the dynamic characteristics of plant and compare the desired output values. Adaptive control technique generates the actuating signal, so optimal performance is measured depends upon the system changes. Model Reference Adaptive Controller (MRAC) scheme with MIT rule is used to control the system performance with different adaptation gain values.

In this paper, design of Model Reference Adaptive Controller (MRAC) using MIT rule for control the Reverse Osmosis (RO) desalination system. In last section, system performance are shown by using MATLAB simulations and experimental results are discussed.

MODEL REFERENCE ADAPTIVE CONTROLLER (MRAC)

The important adaptive controller is Model Reference Adaptive Controller (MRAC), where desired performance is calculate in terms of reference model and express the desired response in terms of command signal. The block diagram of the Model Reference Adaptive Controller (MRAC) is shown in Fig.1.

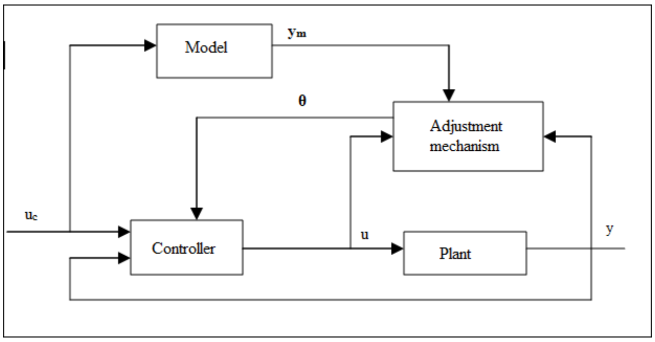

Fig.1 Block diagram of Model Reference Adaptive Controller.

Where,
θ is the controller parameter.
y_m is the model output.
y is the process output.
u is the control signal.
u_c is the command signal.
Here controller parameters are changes based on the controller and other feedback loop. These changes parameters are depend on the error values.
Where, $e= y-y_m$.

'e' is the error. It is difference between the process output and model output. The MRAC have mainly two loops. One is inner loop, which is basic feedback loop and another one is outer loop, which can adjust the system parameters. MRAC is expressed in terms of continuous time systems. Here performance specifications are expressed in terms of reference model. But the main problem of MRAC is determine the adjustment mechanism, which gives zero error value. So MIT rule is introduced in the Model Reference Adaptive Controller (MRAC) solve this problem.

MIT RULE

The MIT rule is derived for Model Reference Adaptive Controller (MRAC). It was first developed in 1960 at Massachusetts Institute of Technology (MIT). MIT rule is used to design the Model Reference Adaptive Controller (MRAC).

Here cost function is defined as, $J(\Theta)=\frac{e^2}{2}$

Where 'e' is the error between the process output and model output. θ is the adjustable parameter and J is small and system parameters are changed to the negative gradient of J. so,

$$\frac{d\theta}{dt} = -\gamma \frac{\partial J}{\partial \theta}$$
$$\frac{d\theta}{dt} = -\gamma e \frac{\partial e}{\partial \theta}$$

Where, $\frac{\partial e}{\partial \theta}$ is the sensitivity derivative of the system.

This is called MIT rule.

FEED-FORWARD ADAPTATION GAIN USING MRAC WITH MIT RULE

The main work of feed-forward adaptation gain is adjusting the feed-forward gain. Let us assume that, process transfer function is kG(s), where k is the unknown parameters and G(s) is the known value. Reference model transfer function is $G_m(s)=k_0G(s)$,where k_0 is the known parameters. Here feed-forward controller is u= θ u_c . u is the control signal and u_c is the command signal. The output transfer function from command signal is θkG(s), which is same as $G_m(s)$ and θ is defined. $\theta=\frac{k_0}{k}$

The block diagram of feed-forward gain adaptation using MRAC with MIT rule is shown in Fig.2.

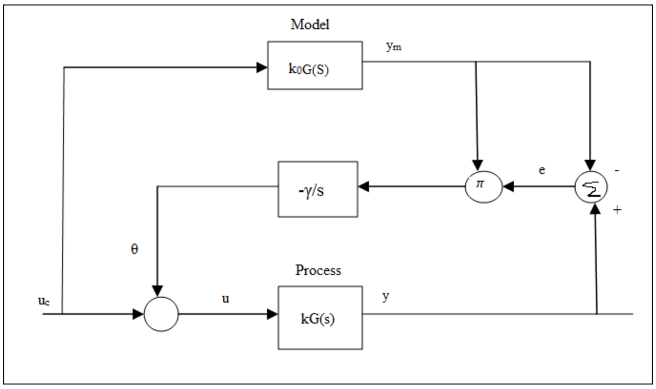

Fig.2 Block diagram of feed-forward gain adaptation.

Here error (e) is defined as $e=y-y_m$.

$$= kG(p)\theta u_c - k_0G(p)u_c.$$

Where, u_c is the command signal. y_m is the model output. y is the process output. θ is the adjustable parameters and p is defined as $p=\frac{d}{dt}$

The sensitivity derivative defined as, $\frac{\partial e}{\partial \theta}=kG(p)u_c=\frac{k}{k_0}y_m$.

The MIT rule is given, $\frac{d\theta}{dt}=-\gamma' \frac{k}{k_0} y_m e$

$$= -\gamma y_m e.$$

Where put the, $\gamma = \gamma' \frac{k}{k_0}$

From this block diagram, the properties of system is shown by MATLAB simulations, the system transfer function is given by,

$$G(s)=\frac{1}{(s+1)}$$

Consider the values of input command signal (u_c) with frequency 1rad/s. and u_c is the sinusoidal signal. So parameters value are considered as k=1 and k_0=2.

REVERSE OSMOSIS (RO) DESALINATION SYSTEMS

Reverse Osmosis (RO) desalination system is a process, which remove the salts, minerals and small particles from saline water or brackish water and make the fresh water. The basic block diagram of RO desalination system with PV panel is shown in Fig.3.

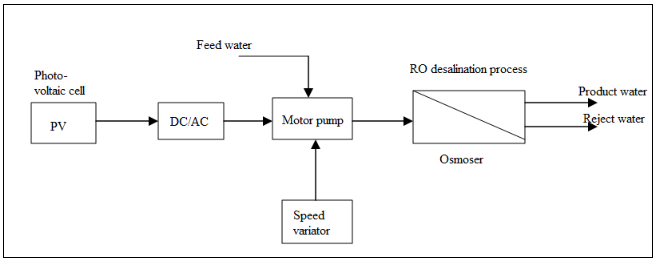

Fig.3: Block diagram of RO desalination system with PV panel.

Here desalination unit model is purify the feed water in 3000ppm. RO desalination unit model is Multi-Input Multi-Output (MIMO) system. The unit static model of desalination is shown in Fig.4.

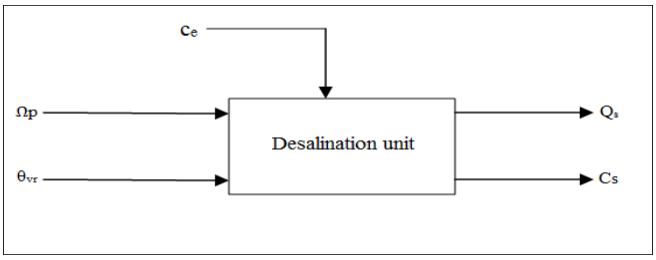

Fig.4: Desalination unit static model.

Where,
Q_s is the output product water flow.
C_s is the output product water salinity.
Ωp is the the motor pump angular speed.
θ_{vr} is the aperture reject brine valve.
C_e is the salinity feed water.

Here consider the salinity feed-water C_e=3000ppm.[ppm= parts per million] and model parameters values are shown in Table 1.

Table1: Model parameters values at C_e=3000ppm

Parameters	Values at C_e=3g/L
K_{11}	3.00
τ_{11}	1.10
K_{22}	-0.16
τ_{22}	1.10
K_{12}	-0.28
ω_{01}	1.20
ξ_1	0.30
K_{21}	-0.20
ω_{02}	1.72
ξ_2	0.45

The state equations of desalination process is,

$\dot{X}$=AX+BU
Y=CX

Where, $\dot{X}$= state vector and U= control vector.

$$X=\begin{pmatrix} Q_s \\ \dot{Q}_s \\ C_s \\ \dot{C}_s \end{pmatrix}$$

$$U=\begin{bmatrix} \Omega_p \\ \theta_{vr} \end{bmatrix}$$

The values of ABC are obtained from state-space analysis method.

$$\begin{pmatrix} -\frac{1}{\tau_{11}} & 1 & 0 & 0 \\ -\omega_{01}^2 & -2\xi_1\,\omega_{01} & 0 & 0 \\ 0 & 0 & -\frac{1}{\tau_{22}} & 1 \\ 0 & 0 & -\omega_{02}^2 & -2\xi_2\omega_{02} \end{pmatrix}$$

$$B=\begin{pmatrix} \frac{K_{11}}{\tau_{11}} & 0 \\ 0 & K_{22}\omega_{01}^2 \\ 0 & \frac{K_{22}}{\tau_{22}} \\ K_{11}\omega_{02}^2 & 0 \end{pmatrix}$$

Consider the salinity feed water C_e=3000ppm and calculate the values from the given Table1.

$$A=\begin{pmatrix} -0.91 & 1 & 0 & 0 \\ -1.44 & -0.72 & 0 & 0 \\ 0 & 0 & -0.91 & 1 \\ 0 & 0 & -2.96 & -1.55 \end{pmatrix}$$

$$B=\begin{pmatrix} 2.73 & 0 \\ 0 & -0.40 \\ 0 & -0.15 \\ -0.59 & 0 \end{pmatrix}$$

$$C=\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

ISSN: 0975-8585

SIMULINK DIAGRAM OF MRAC USING MIT RULE

The simulink diagram of Model Reference Adaptive Controller with MIT rule is shown in Fig.5.

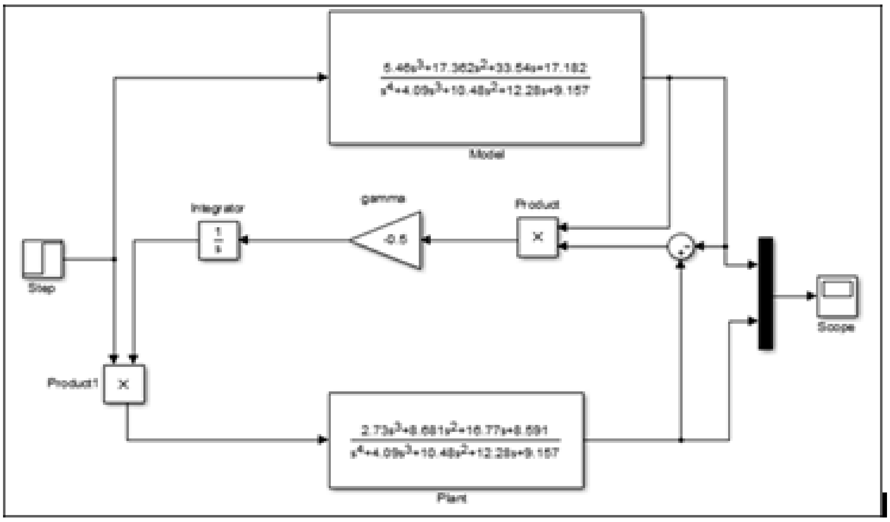

Fig.5: Simulink diagram of Model Reference Adaptive Controller with MIT rule.

The plant response is depend upon the values of adaptation gain(γ). Sometimes the larger values of γ can makes the instability of systems. But always adaptation gain (γ) value is negative. By changing the adaptation gain values, the reference and plant output model response are obtained.

DIFFERENT ADAPTATION GAIN PARAMETERS VALUE

Different adaptation gain parameters values are shown in Table 2.

Table 2: Different adaptation gain parameters value

Adaptation gain(γ)	Peak Time		Peak Overshoot		Settling Time	
	Model	Plant	Model	Plant	Model	Plant
0.5	1.222	2	59	78	7.816	10.584
1	1.23	1.62	57	101	5.894	10.998
2	1.206	1.222	57	105	5.86	11.44
3	1.205	1.206	59	100	5.864	10.23
4	1.19	1.205	58	74	5.818	10.922
5	1.206	0.836	59	77	5.8	10.98
6	1.222	0.835	25	44	5.802	10.138
7	1.25	0.822	58	84	5.832	10.522
8	1.206	0.825	59	82	5.772	10.15
9	1.19	0.805	61	79	5.832	10.98

DISCUSSION AND RESULTS

In this paper, the simulation results of Model Reference Adaptive Controller (MRAC) using MIT rule is shown in Fig.1-15. From Table 2 the different adaptation gain parameters values according to the different time domain is given. It is clear that when adaptation gain (γ) values is increased then system overshoots is high and increase the system response also. Another way when adaptation gain (γ) value is decreased then system overshoots is small and decrease the system response. Here adaptation gain (γ) is taken the range from 0.5-9 for better control performance.

Fig.6,7,8,9,10,11,12,13,14,15 shows the actual response of plant and reference model, for different adaptation gain(γ) values.

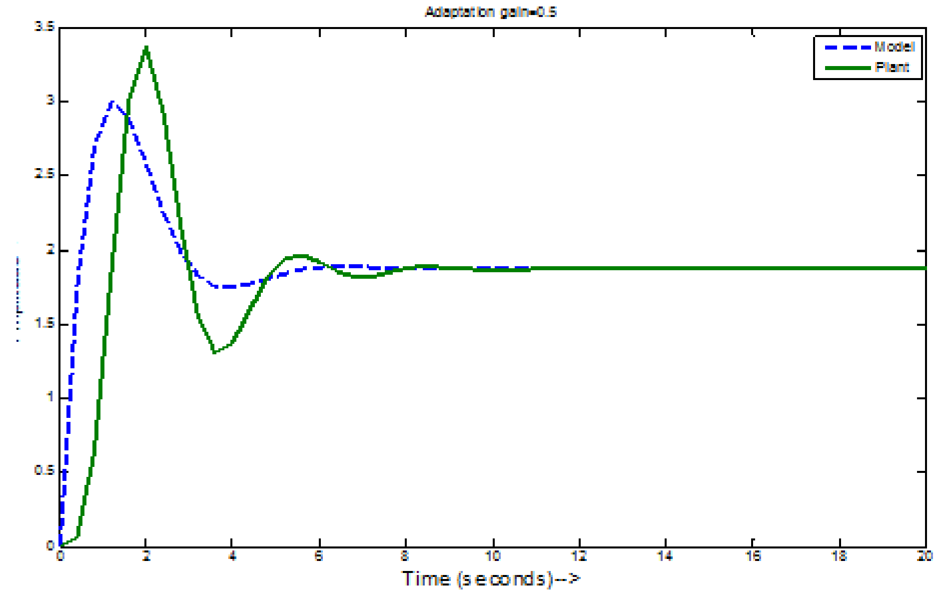

Fig.6: Simulation results of MRAC with MIT rule for adaptation gain value is 0.5.

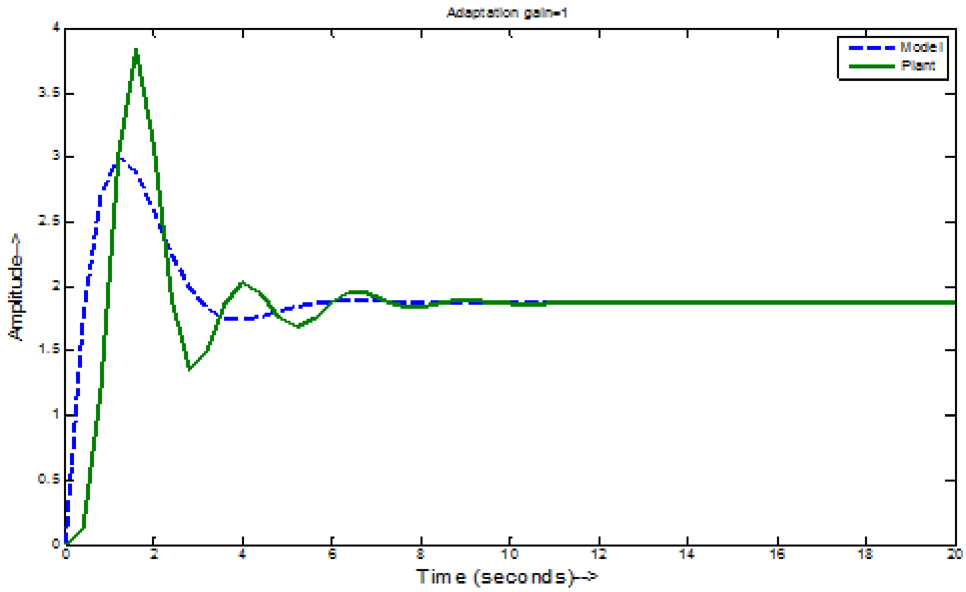

Fig.7: Simulation results of MRAC with MIT rule for adaptation gain value is 1.

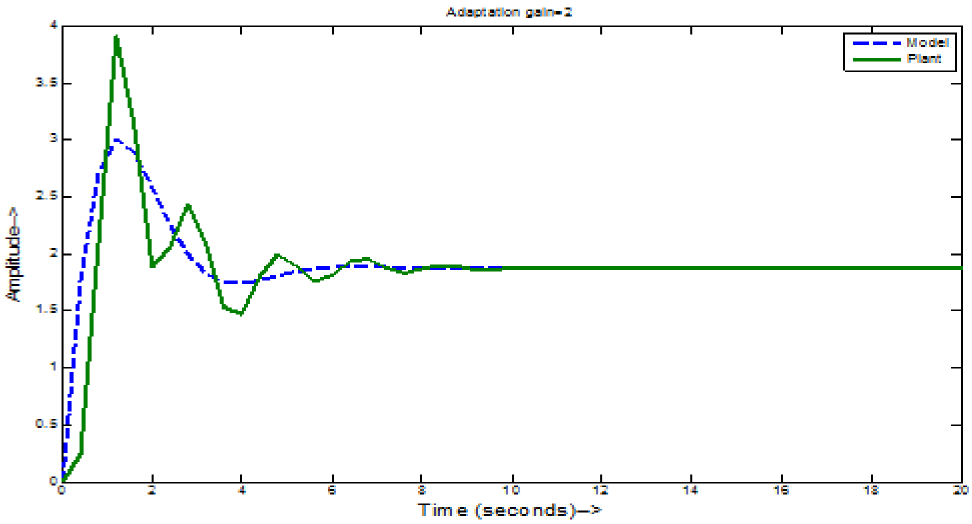

Fig.8: Simulation results of MRAC with MIT rule for adaptation gain value is 2.

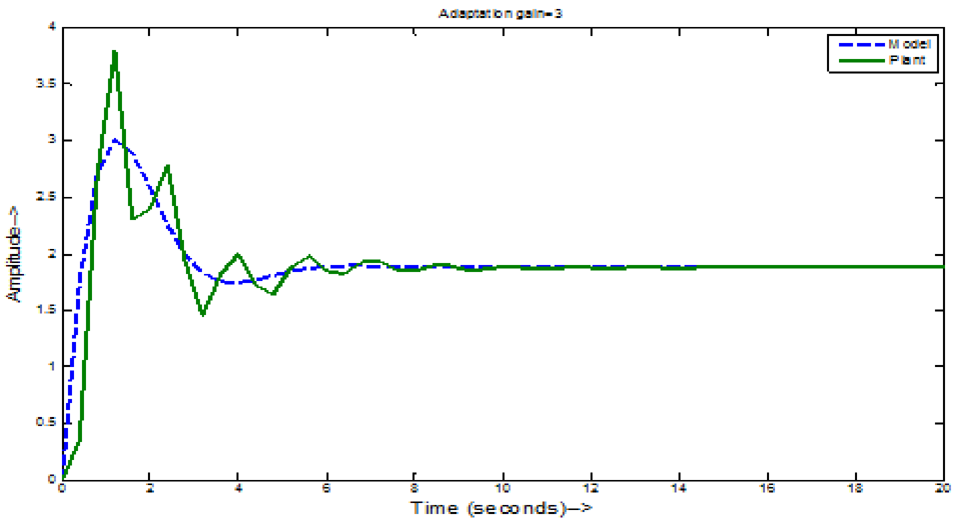

Fig.9: Simulation results of MRAC with MIT rule for adaptation gain value is 3.

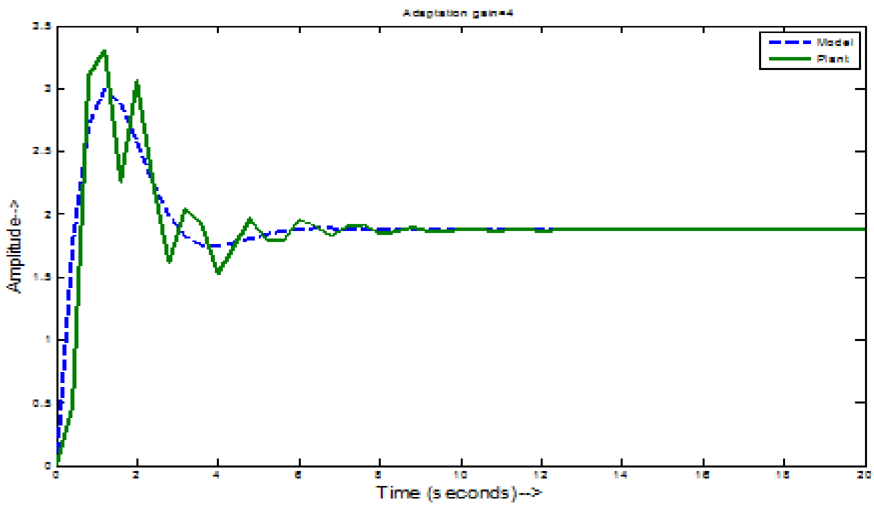

Fig.10: Simulation results of MRAC with MIT rule for adaptation gain value is 4.

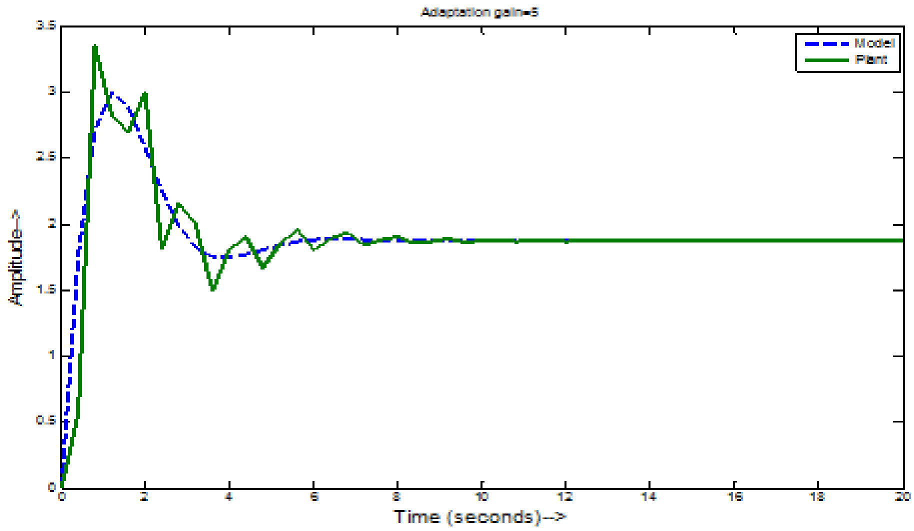

Fig.11: Simulation results of MRAC with MIT rule for adaptation gain value is 5.

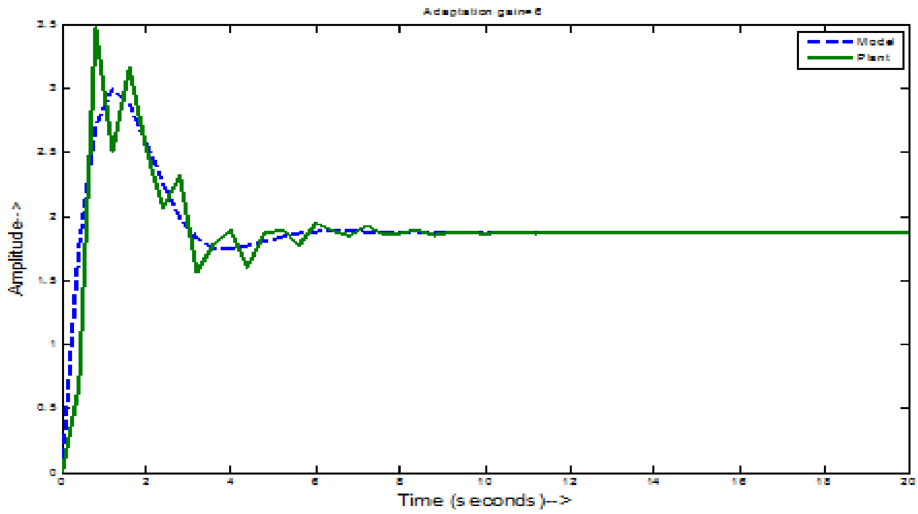

Fig.12: Simulation results of MRAC with MIT rule for adaptation gain value is 6.

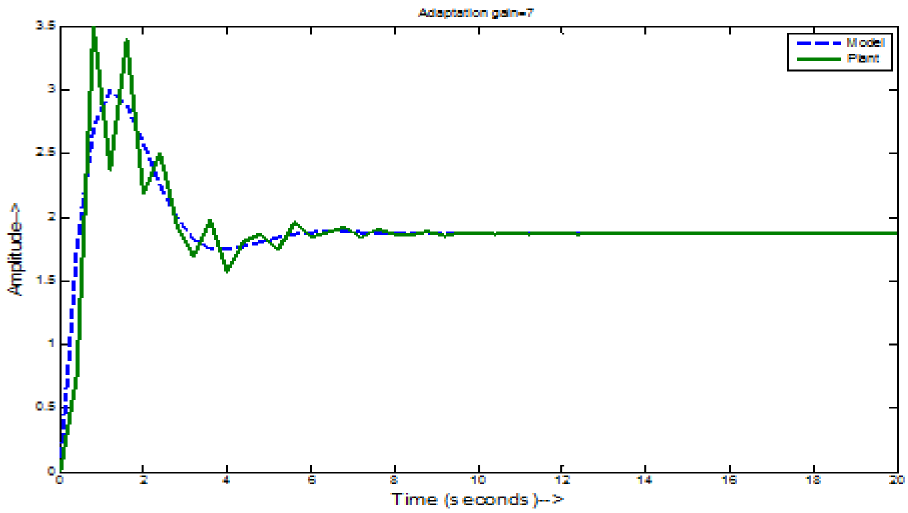

Fig.13: Simulation results of MRAC with MIT rule for adaptation gain value is 7.

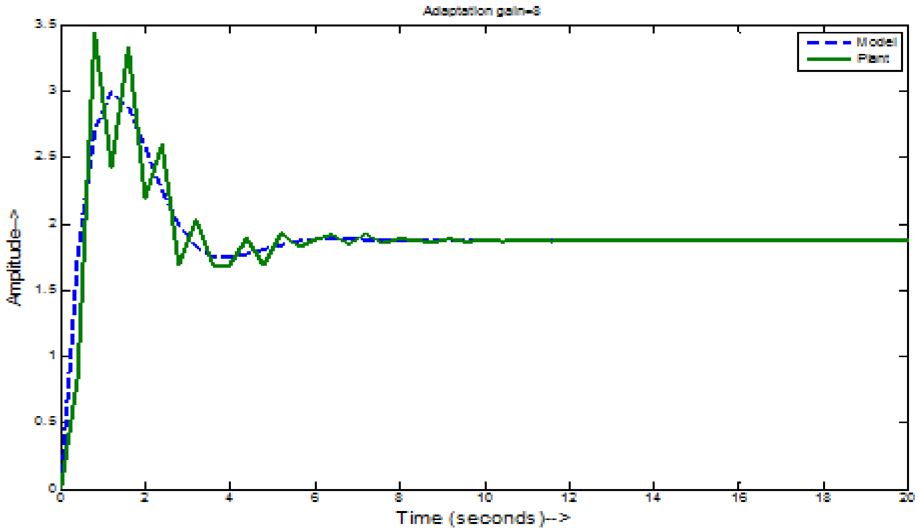

Fig.14: Simulation results of MRAC with MIT rule for adaptation gain value is 8.

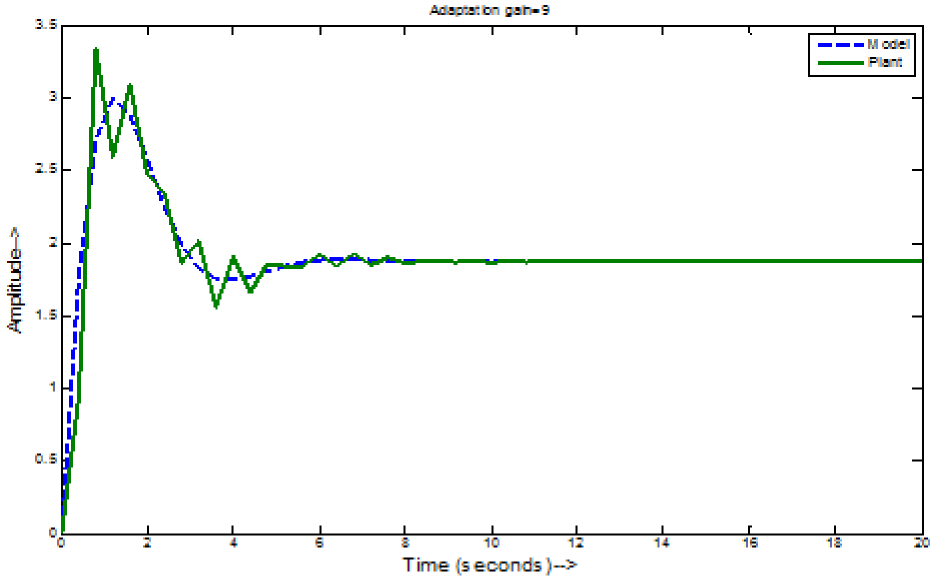

Fig.15: Simulation results of MRAC with MIT rule for adaptation gain value is 9

CONCLUSION

Model Reference Adaptive Controller (MRAC) for Reverse Osmosis (RO) desalination systems using MIT rule is completed in this paper and gives the actual performance by using MATLAB simulink. According to the Table.2, the different time domain results are obtain from different adaptation gain(γ) values. Here system responses are improved with increasing the adaptation gain values but beyond limit the system performance is very poor. In future , Reverse Osmosis (RO) desalination system using Model Reference Adaptive Controller (MRAC) with modified MIT rule for better control performance.

REFERENCES

[1] A.M. Bilton, R. Wiesman, A.F.M. Arif, S.M. Zubair, S. Dubowsky, On the feasibility of community-scale photovoltaic-powered reverse osmosis desalination systems for remote locations, Renew. Energy 36 (2011) 3246–3256.

[2] E. Tzen , R. Morris, Renewable energy sources for desalination, sol. Energy 75 (2003) 375-379.

[3] H. M. Colquhoun, D. Chappell, A. L. Lewis, D. F. Lewis, G. T. Finlan, and P. J. Williams, "Chlorine tolerant, multilayer reverse-osmosis membranes with high permeate flux and high salt rejection," Journal ofMaterials Chemistry, vol. 20, pp. 4629-4634,2010.

[4] S. R. Wenham, M. A. Green, M. E. Watt, and R. Corkish, Applied Photovoltaics.London: Earthscan, 2007.

[5] G. Mittelman, A. Alshare, and J. H. Davidson, "A model and heat transfer correlation for rooftop integrated photovoltaics with a passive air cooling channel," Solar Energy, vol. 83, pp. 1150-1160, 2009.

[6] K. Benjelloun, H. Mechlih and E. K. Boukas (1993), A Modified ModelReference Adaptive Control Algorithm for DC Servomotor, Second IEEE Conference on Control Applications, 2, Vancouver, Canada, pp. 941 –946.

[7] K. J. Astrom and B. Wittenmark (2001), Adaptive control, 2nd ed., Dover Publications, New York.

[8] P. Swarnkar, S. K. Jain and R. K. Nema (2010), Effect of adaptation gain on system performance for model reference adaptive control scheme using MIT rule. International Conference of World Academy of Science, Engineering and Technology, Paris, pp. 70-75.

[9] P. Swarnkar, S. K. Jain and R. K. Nema (2011), Comparative Analysis of MIT Rule and Lyapunov Rule in Model Reference Adaptive Control Scheme, Innovative Systems Design and Engineering,2, 4, pp 154-162