Analysis and Design of Controller for Level Process Control without Sensor

Eng. Zaid Abed Aljasim Muhasain
Ministry of science and technology
Directorate of water treatment technology
E-mail:zaid_logic@yahoo.com

Eng. Saif Abed Aljasim Muhasain
Computer Eng. department,
Nahrain University
E-mail:safe_aljibouri@yahoo.com

Abstract:

This paper deals with process control, generalized definition and modeling design of flow systems and control it based on compare to constant as principle of operation approach. After reviewing the operation of the plant, a compare system between water level and desire level is formulated to control flow rate. The scheme is then designed and tested by Matlab and Simulink Toolbox. Simulation is presented and shown that on/off switch with constraint is better and more versatile compare with conventional approach.

Keywords: Process; controller; flow.

Notation:

R is the Resistivity which represent a parameter due to pipe resistance, s/m^2
Q is the Volume flow rate, m^3/s
C is the Cross sectional area of the tank, m^2
q_i is the inflow rate, m^3/s
q_o is the outflow rate, m^3/s
H   is the water level in the tank, m

1. Introduction

The liquid level control systems have been of good interest to engineers for along time. In the development this system has increased because of studies expansion, methods multitude and easier to implement this system in digital computer. These simulations in the fluid system with two tanks need a sensor to measure the water level and control it. In the simple model of this system, it consists of valve, tank or more tank, float, transducer and controller [1]. The water will go to the two tanks interactive (in the simple model) and its level will be measured by float or any sensor and transducer in the

conventional state [2,3] and then compare with desired level to control input signal(inflow) as shown in fig.(1):

Figure (1) Fluid system with two tank using transducer to measure level.
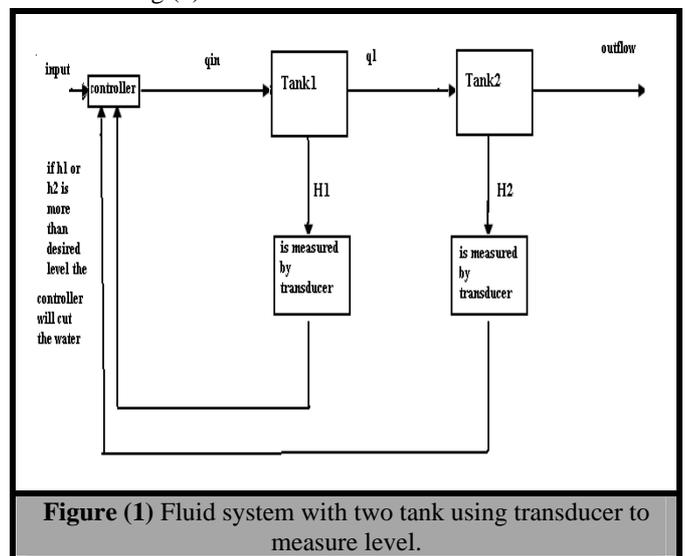
In this paper, it designs a new scheme of two tanks system. The purpose of it to present a new approach is similar to the previous without using any float or sensor if knowing the parameter of pipe resistance (Resistivity) and cross section area of the two tanks. Use a generalized definition for modeling in designing it [4, 5]. It can be designed and implemented by using Matlab program simulation. Show that this method is better and easier compared with conventional approach. This approach of simulation by Matlab allows us to solve more complicate problems and developing the measuring states to make better modeling and analyzing of system and control allow more in the designs [6].

 The design of a two tanks fluid system can control it according to the level without using any transducer. And the effect of Resistivity is observed on the level of the two tanks and

controller designs, and show that the controller affects to the system performance. All simulation is performed using Matlab / simulink. These results are achieved for research and future study.

2. Modeling of the Liquid System

The fluid flow system are very common in the process control .It can be modeled by using generalized definition and modeling of hydraulic system [7].

2.1 Single Tank

For a single tank liquid level system is illustrated in fig. (2). It must be known that, how to simplify the design in the equation. This type of the system consists of source inflow rate q_i into the tank. A drain valve in this to regulate the water out flow rate (q_o):
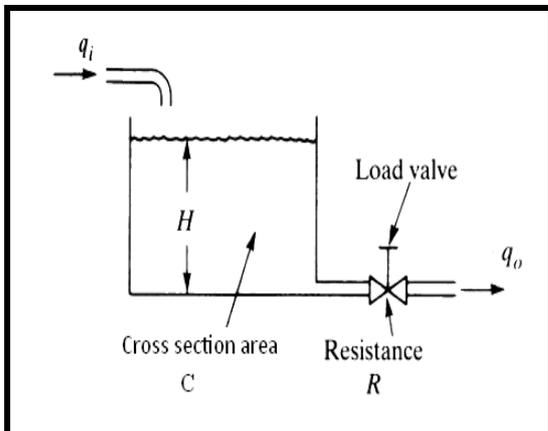
For the liquid level system in Fig.(2). It can be obtained a Mathematical Model to get the relationship between q_i and q_o or between q_i and **H**.[8].

The turbulent flow resistance can be determined by the following relationship:

$$R = \frac{Change \quad the \quad level}{Change \quad in \quad the \quad flow \quad rate}$$

$$= \frac{dh}{dq}$$

in the steady state
It will use this equation

$$R = \frac{H}{Q} \quad \text{if the relationship is linear}$$

The system is modeled by using physical principles .The physical equation governing the accumulation water in the tank (ACC) or change in liquid store [3, 9].

Accumulation water in the tank (ACC) = input - output

$$\text{Cross section area}(C) = \frac{Accumulation\ water\ in\ tank}{Change\ in\ the\ height}$$

$$C = \frac{Acc}{\dfrac{dh}{dt}} \quad \Rightarrow \quad Acc = c.\frac{dh}{dt}$$

C is constant

So that .Applied the balance equation

$$\text{Acc= I/P - O/P} = C.\frac{dh}{dt}$$

2.2 Two Tanks

Now design a hydraulic system with two tanks as interaction network and use this equation in the two tanks .It consists of source, two tanks and pipe between them. **q** may represent a water from motor to tank 1 as show in fig (3) :
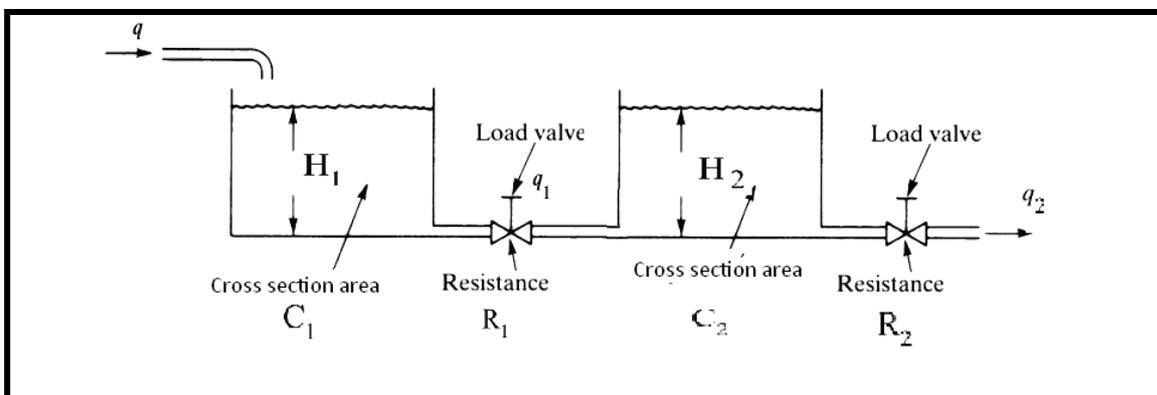
q: input flow rate to tank1
q₁: output flow rate from tank 1
q2: output flow rate from tank 2
H1: water level in tank1
H2: water level in tank1
R1: Resistivity in valve 1
R2: Resistivity in valve 2
C1: cross section area in tank 1
C2: cross section area in tank 2

In the tank 1

From fig (3), the accumulation water in tank 1(Acc_1) is the difference between the input flow rate to tank1 (q) and output flow rate from tank 1 (q1)

$$Acc_1 = In - Out = q - q_1 \qquad \boxed{1}$$

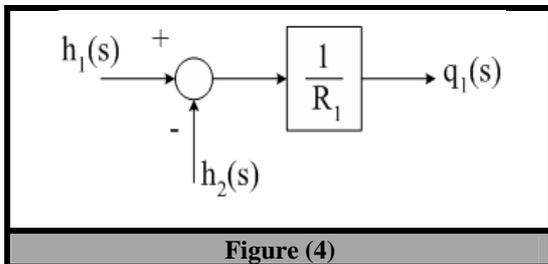$$R = \frac{Change \quad the \quad level}{Change \quad in \quad the \quad flow \quad rate}$$

In the steady state

$$R_1 = \frac{h_1 - h_2}{q_1} \implies q_1 = \frac{h_1 - h_2}{r_1} \qquad \boxed{2}$$

The Laplace domain can be used to solve this equation:

$$Q_1(S) = \frac{H_1(S) - H_2(S)}{R_1} \qquad \boxed{3}$$

Modeling of system requires us to determine the relationship between (h1-h2) and divided by R1 as show in the block diagram fig. (4):

Figure (4)

Cross section area $(C) = \dfrac{Acc}{\dfrac{dh}{dt}}$
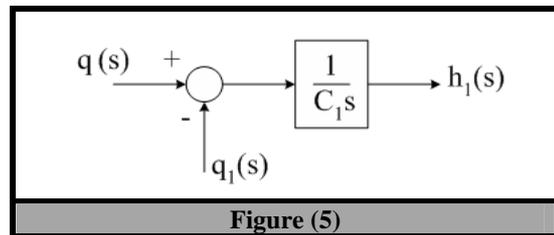
$$\implies Acc = c.\frac{dh}{dt}$$

From equation 1

$$q - q_1 = c_1.\frac{dh_1}{dt}$$

Take Laplace domain yield

$$Q_{(S)} - Q_{1(S)} = C_1 S H_1 \qquad \boxed{4}$$

$$H1(S) = \frac{Q(S) - Q1(S)}{C_1 S}$$

From the previous equation draw the second block diagram by subtract $Q - Q_1$ and divided by $C_1 S$ as shown in fig. (5).

Figure (5)

The liquid inflow q(s) and q1 as the flow out from tank1 to tank2

In tank2

$$R = \frac{dh_2}{dq_2} \qquad \text{in the steady state}$$

$$R = \frac{H_2}{Q_2}$$

The third block diagram from dividing H_2 by R_2
From fig(3), the accumulation water in tank 2 is the difference between the input flow rate to tank 2(q1) and output flow rate from tank 2 (q2)
Acc_2 (accumulation water in tank 2) = in − Out = q1-q2

Cross section area of tank 2

$$(C2) = \frac{Acc_2}{\dfrac{dh_2}{dt}} \implies Acc_2 = C_2 . \frac{dh_2}{dt}$$

In Laplace domain Acc2=C_2SH_2
Applying these equations obtain

$Q_1(s) - Q_2(s) = C_2SH_2$	5

$$H_2 = \frac{q_1(s) - q_2(s)}{C_2 S}$$

This equation can be modeled by block diagram by subtract $Q_1(s) - Q_2(s) =$ and divided by C_2s and yield $h_2(s)$ as o/p
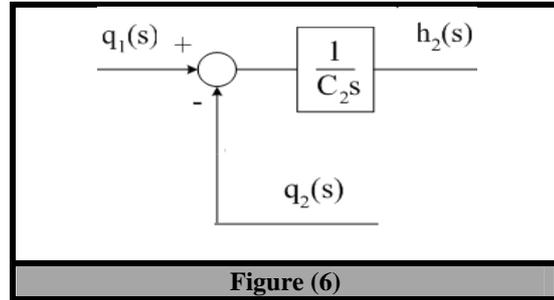
Figure (6)

It can obtain the produce block diagram by getting the component block diagram from the previous shape, and putting all form pieces to make the final block as show in fig. (7) Diagram. It must determine what the input and output for the block

It can obtain the produce block diagram by getting the component block diagram from the previous shape, and putting all form pieces to make the final block as show in fig. (7) Diagram. It must determine what the input and output for the block
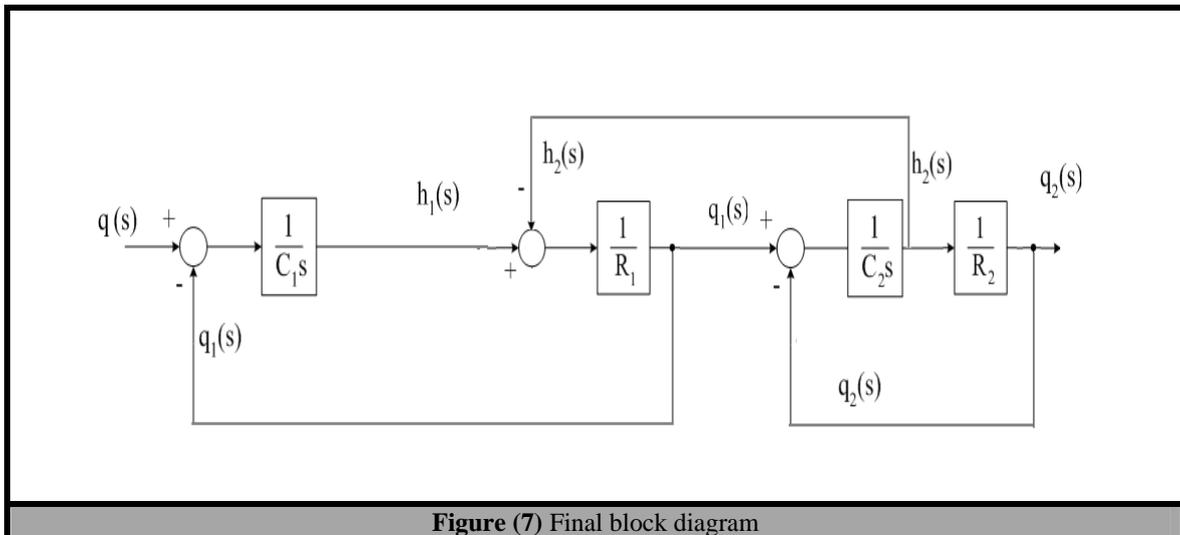
Figure (7) Final block diagram

In this work, from simulation it can know the level that used to control the input flow rate and maintained the water with the desired level so as not to overflow the water.

3. Simulation and Controller
3.1 Simulation

After all block diagram was completed for the liquid level system. It can now be implemented this diagram and system in a simulation model. This block is used to represent the two tanks system. Matlab program was used to simulate this system [6]. A step input in the simulink is referred to the process input as an inflow rate (qi). The simulation in the system consists of a function block of the cross section area(C) and parameter resistivity (R) in a transfer function; it can be obtained it from a block transfer function. A scope is used to display output (q2) and scope1 to display the water level. In the two tanks (h1, h2) this figure illustrates a simulation of model of this system:
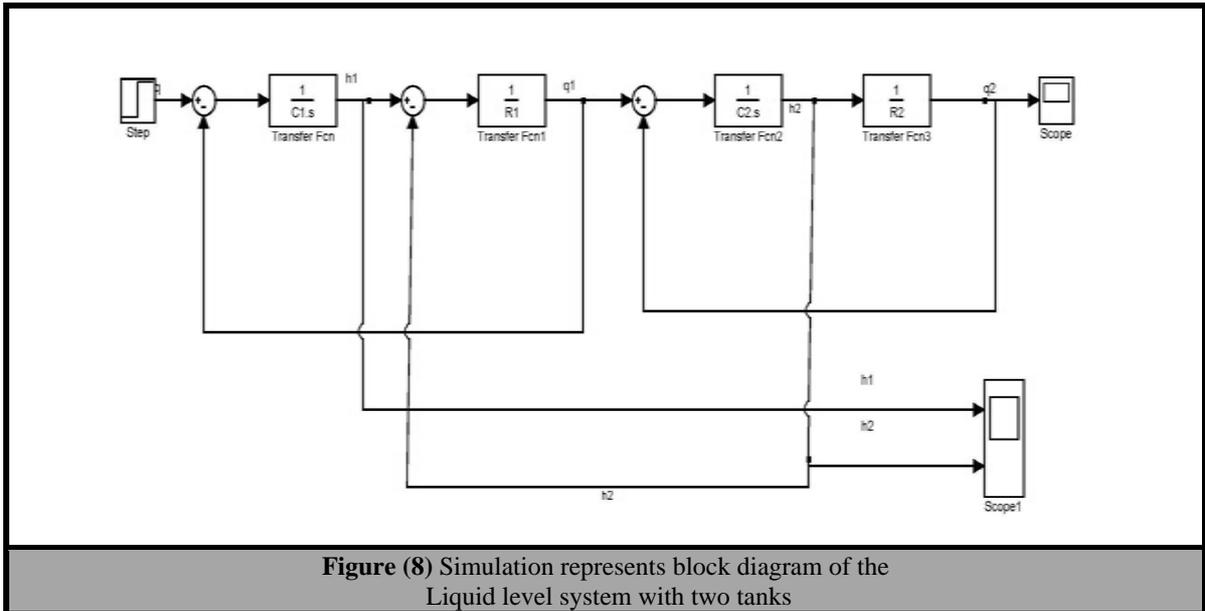
Figure (8) Simulation represents block diagram of the Liquid level system with two tanks

In the simulink, simulate inflow rate to tank 1 (Q=2 m³/s) as a step input is 2 and step time is zero. Let cross section area in tank 1 (C1) equals 0.785 m² and in tank 2 (C2) is equal 0.635 m² (C1 and C2 is constant) in this design. Firstly assume the Resistivity parameters equal (R1=100 s/m², R2= 100 s/m²). It must be changed a stop time 1000 (remember that simulink used second as time unit). From simulink scope monitors (q out), scope1 monitors water level in the two tanks h1 and h2. This figure below illustrates the trajectory of these scopes

.
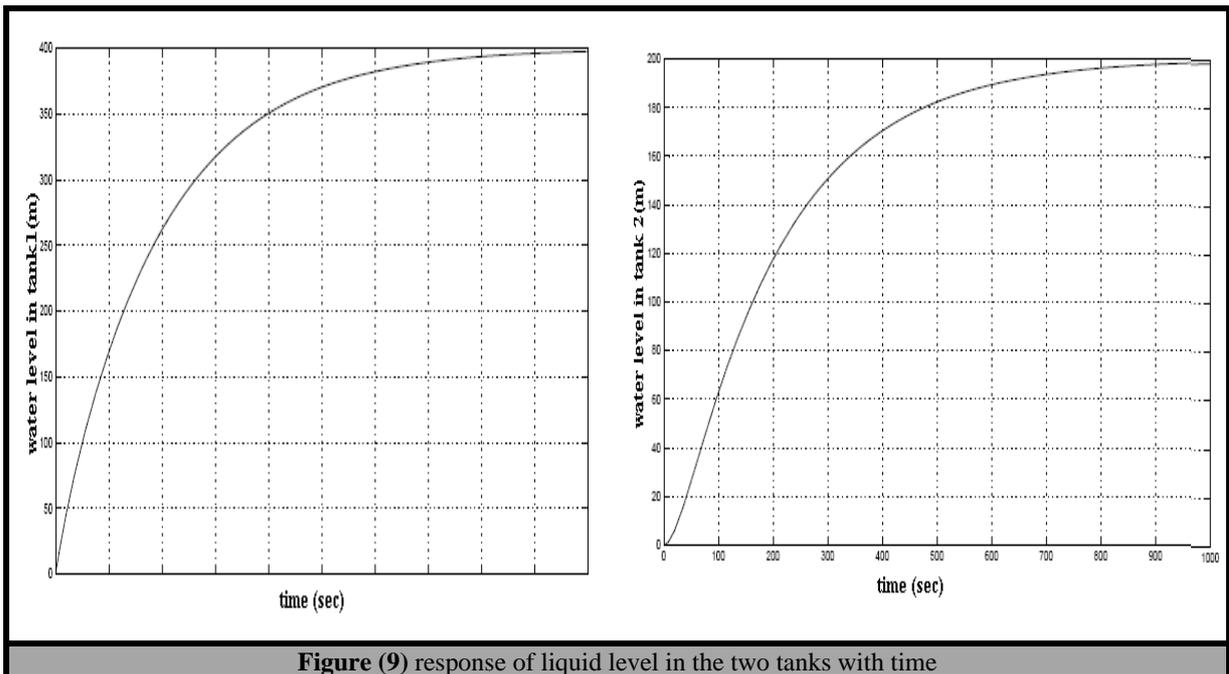
Figure (9) response of liquid level in the two tanks with time

To know that the level in both tanks is less or more than the desire level, A (Compare To Constant) block from simulink is used for implementing this and connect to the level (h1, h2). In this design assume that the height (in both tanks) is 13m and the water level must be less than 10 m. It can implement by using a (Compare To Constant) block from simulink and go to the logic and bit operation. The constant value is compared with h1, h2. If the level of the water equals or less than 10m, The (Compare To Constant) will give an o/p equals 1, else of this (the water level is more than 10m) the o/p is zero. The figure illustrates this process
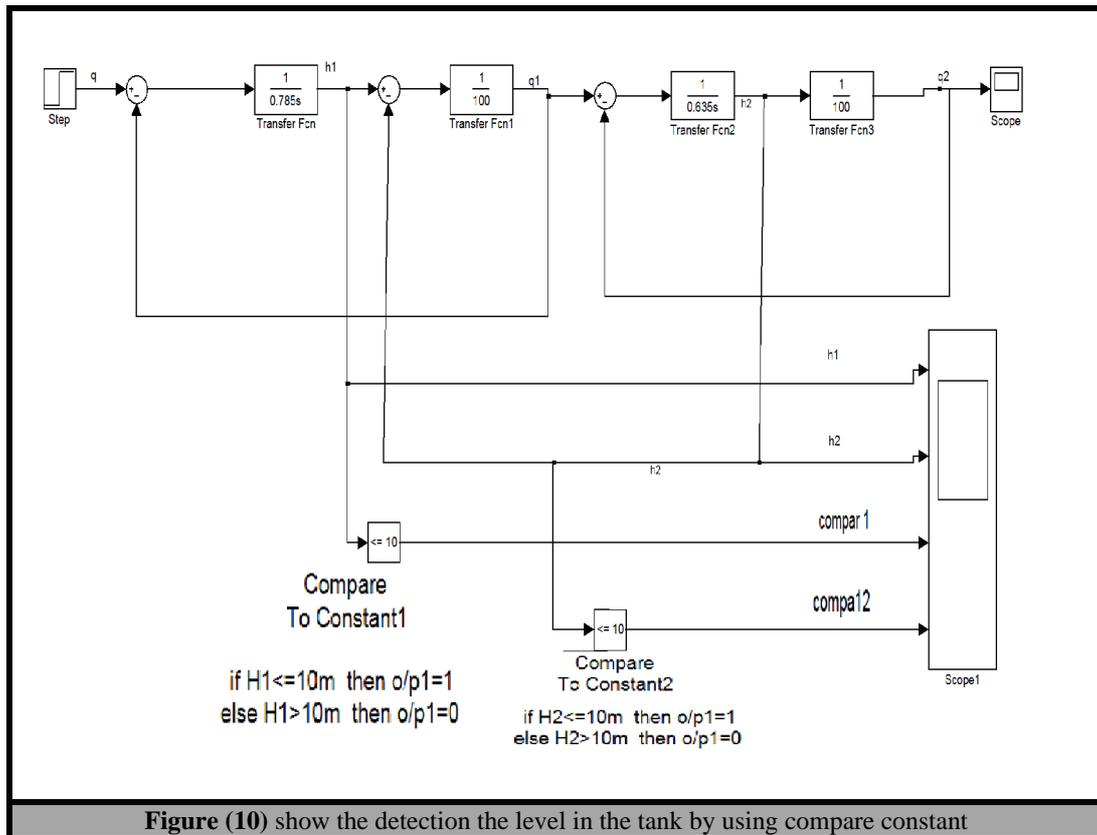

Figure (10) show the detection the level in the tank by using compare constant

From this design (Compare1) is shown from scope1. Firstly Compare To Constant 1 equals 1 depending on h1. If h1 reaches to 10m, constant compare will be zero. Also compare 2 is used for h2 if h2 reaches to 10 m compare2 drops to zero, it illustrates by scope1 in fig. (11)
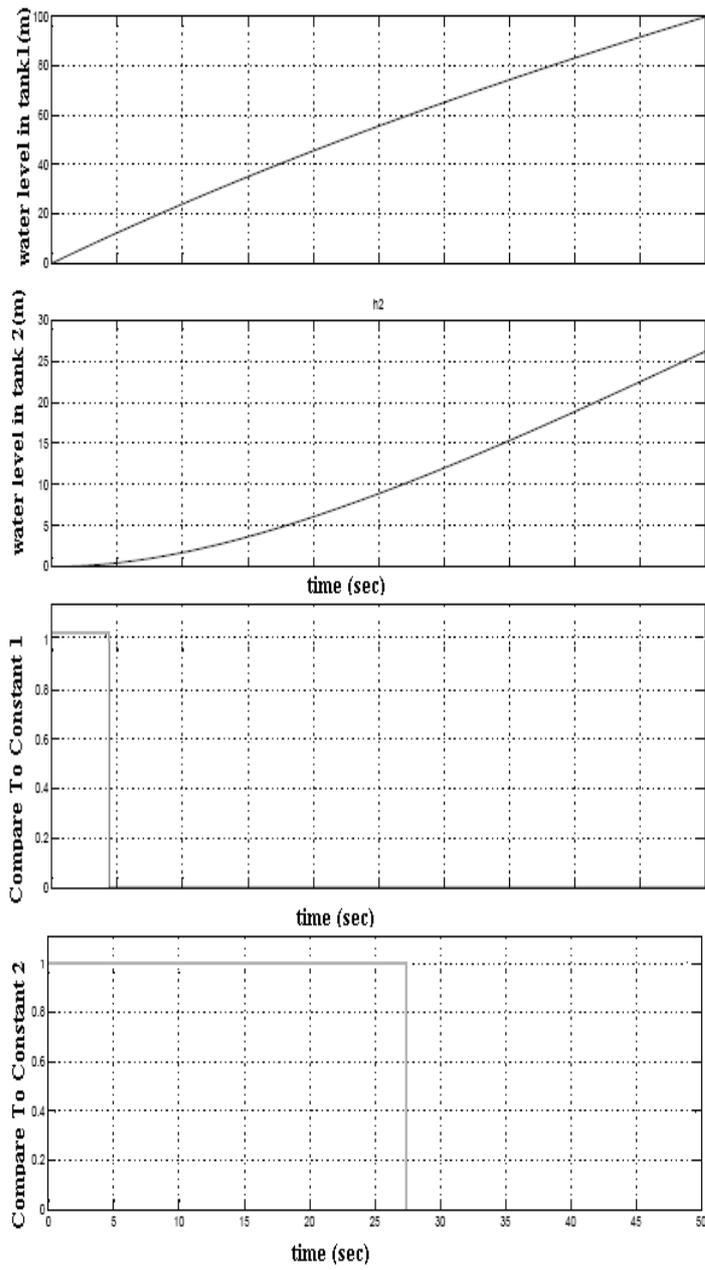
Figure (11) changing in the Compare to constant corresponding with the level in the two tanks

.2 Controller Design

After a (Compare To Constant) block is used in the previous to detect if the water is less or more than ten meters. A control system can be used to open or close the i/p depending on (Compare To Constant) block. The output signal from a (Compare To Constant) block is back to the input and multiplying by using Product from simulink for implementing this controller as show in fig. (12):
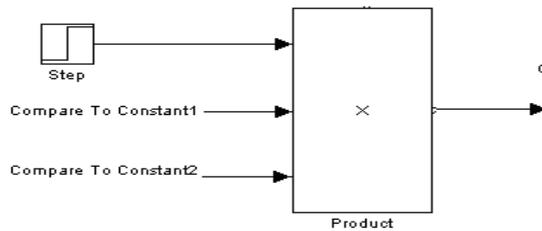

Figure (12) controller design by used product

This control will make the input close if water in tank 1 is more than 10m; also input is close if water level in tank 2 is more than 10m. The table below illustrates this process with

Q = i/p * Compare To Constant 1 * Compare To Constant 1

Table (1) controller effect in the i/p If h1 < = 10 and h2 <= 10 $\Rightarrow$ q is open else q is zero				
Water level in Tank1(h1)	Water level in Tank2(h2)	Comp are To Const ant 1	Comp are To Const ant 2	q
Less or equal 10 m	Less or equal 10 m	1	1	i/p(op en)
More than 10 m	Less or equal 10 m	0	1	0(clos e)
Less or equal 10 m	More than 10 m	1	0	0(clos e)
More than 10 m	More than 10 m	0	0	0(clos e)

We conclude from this if the level of the water is more than ten meter, the inflow will be closed depending on the controller so as no to overflow any tank of this system .The next simulation show in fig. (13) Illustrates this control in the system.
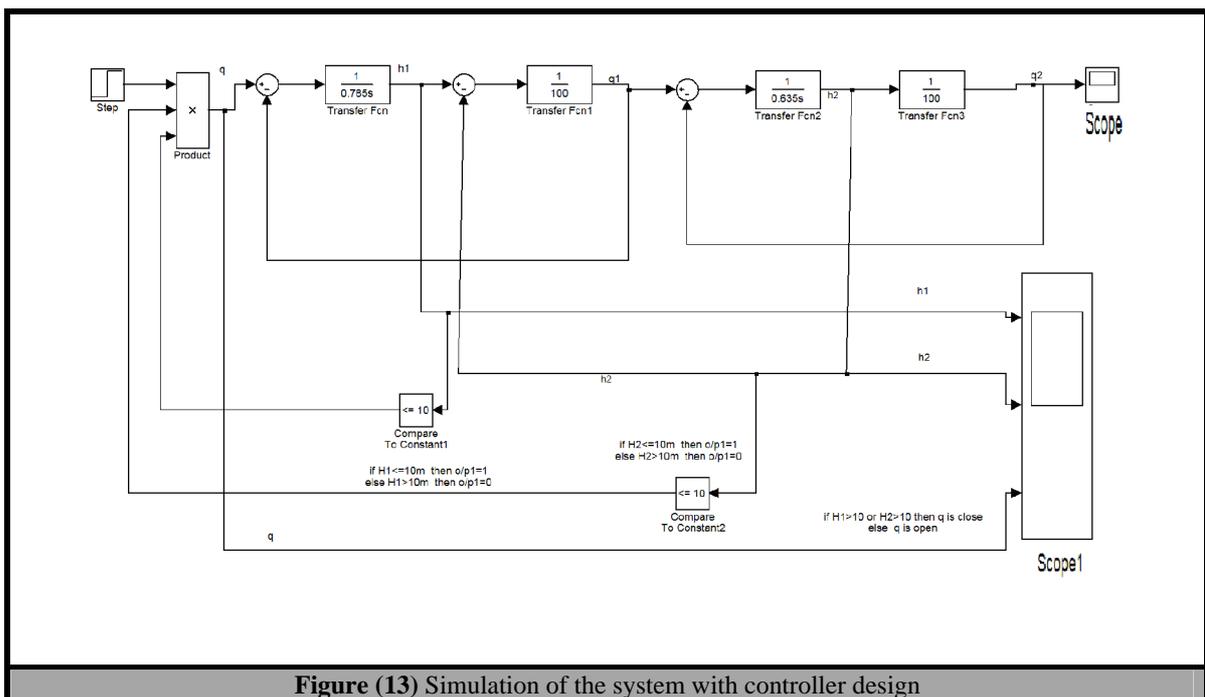

Figure (13) Simulation of the system with controller design

4. Implementation and Result

From fig.(13), after running the system the scope1 shows that the level in both tanks (h1, h2) will increase with the time. The research finds another way to control. The controller is close the input and prevent any increase of the level of the water so as not to overflow any tank. The simulink specification provides information about the level with time and time of opening and closing the input by the controller. The system adjusted to control the water level. Firstly assume that the resistivity parameters is R1=100 and R2=100 and stopping time is 50 seconds. A scope1 shows this process as show in the figure:

Figure (14) result of control of liquid level and inflow using controller design R1=100 R2=100
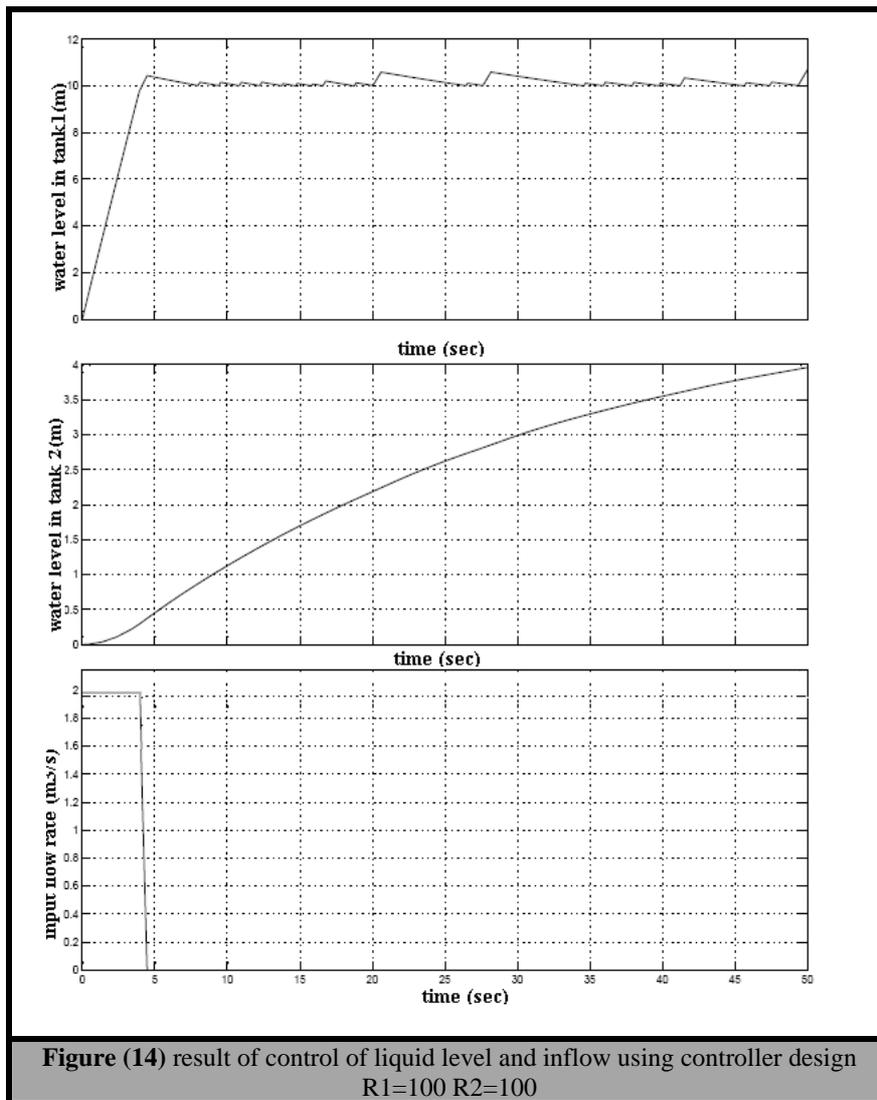
From fig (14) one can notice that, the level in tank1 doesn't increase of ten meters and the input will be close from 2 to zero when the water level will reach to 10m at 4 sec .A series of tests using in the system by changing the parameters R1, R2 and show the comparative result and efficiency of system and controller which describe the output response.

In case 2 .We try to change this parameter by increasing R2 and parameters will be R1 =100,

R2=200 to show the ability and effect in the controller as show in fig. (15):

Figure (15) System behavior and controller by changing Parameters to R1=100
R2=200
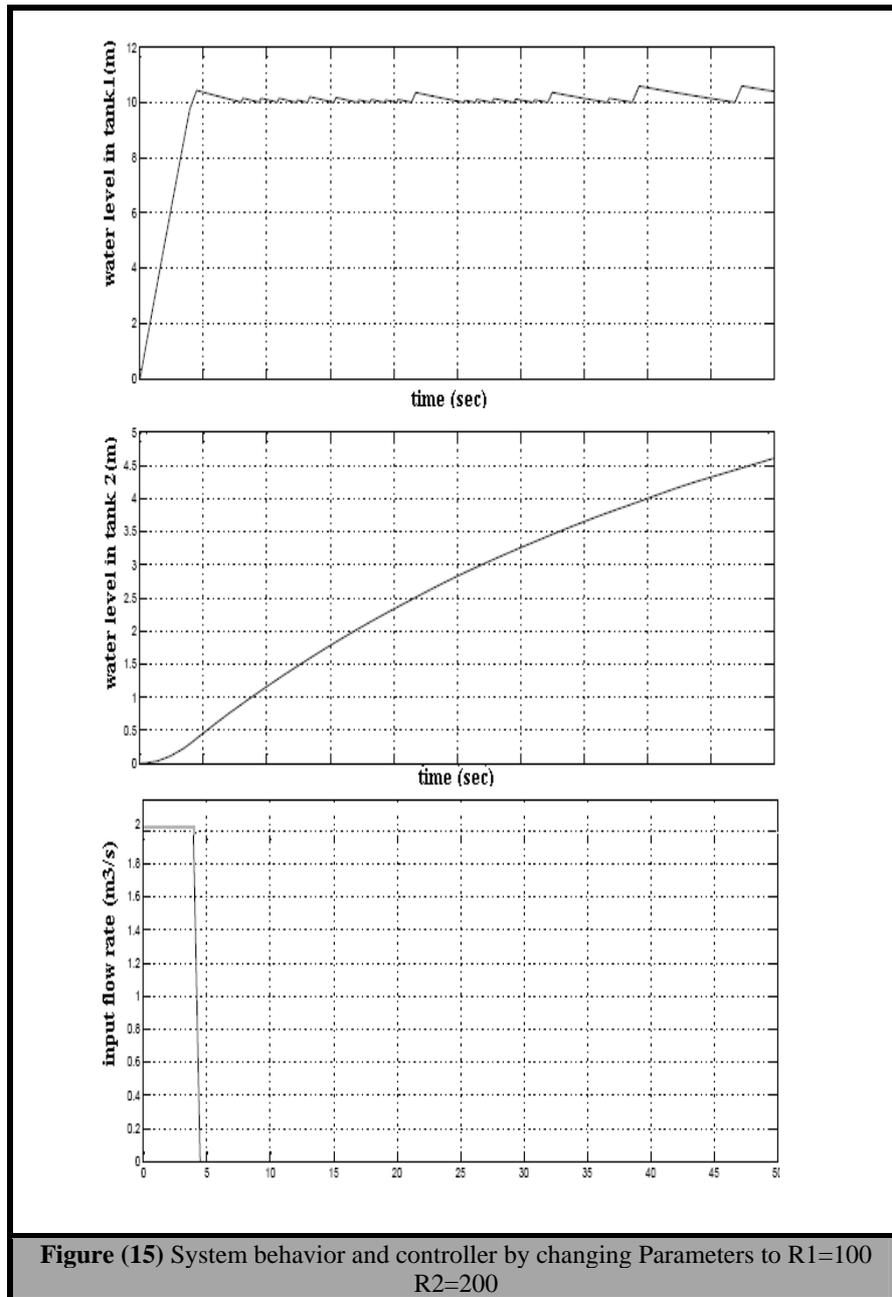
From fig (15), When a scope1 trajectory is finished the change in the resistivity parameter (increasing R2) from 100 to 200 in the system will cause increasing of height in tank2 (R2)

from 4 to 4.5 m. The tank 1 stills in the same height.

In case3, Change the resistivity parameters (by decreasing R1) R1= 50, R2 = 200 in the system and the test results are showed by scope1 as show in figure below:
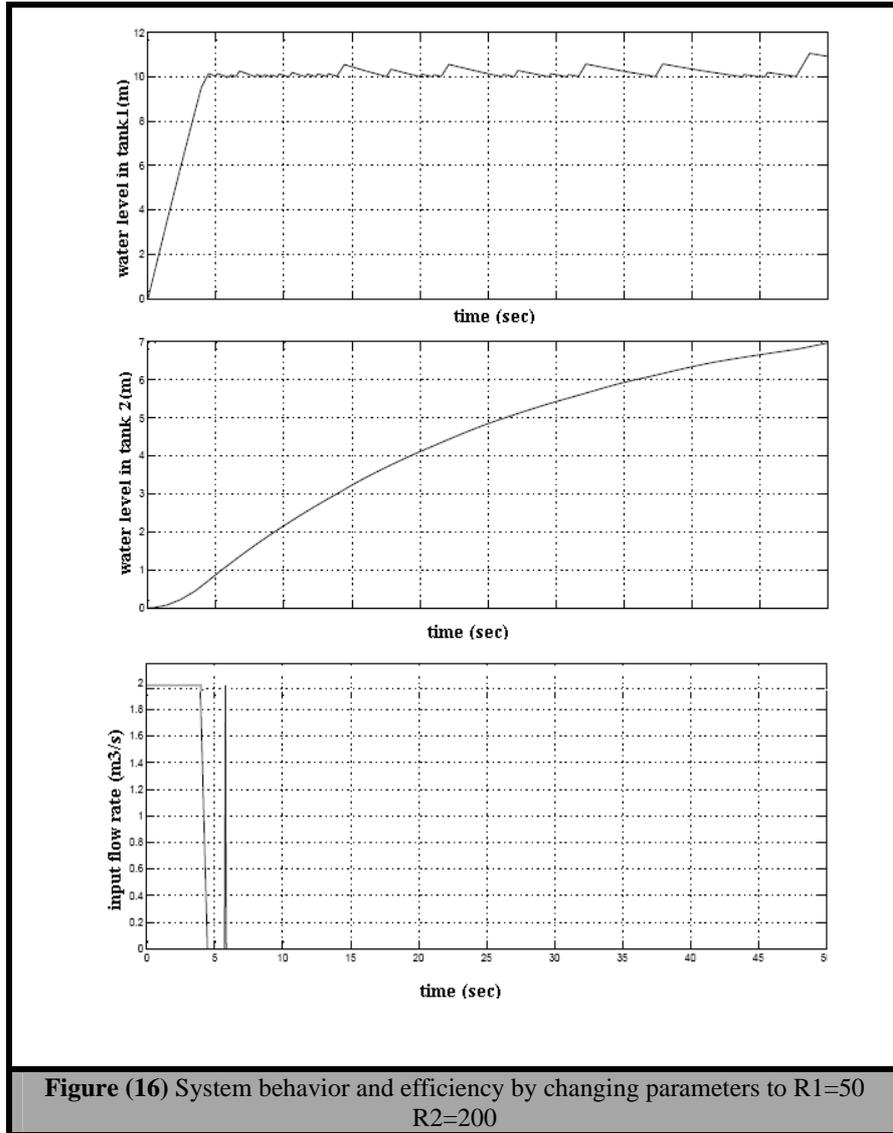
Figure (16) System behavior and efficiency by changing parameters to R1=50 R2=200

From fig.(16) (case3), The changing in the parameters will cause change in the level in tank2 which reach to 7 m and input will close and open more than time.

In the case 4 .Change the resistivity by decreasing R1 , R1= 10 ,R2 = 200 and change

stop time to 1000 to show more effect of controller with the time .This leads to the steady state as show in the fig.(17).
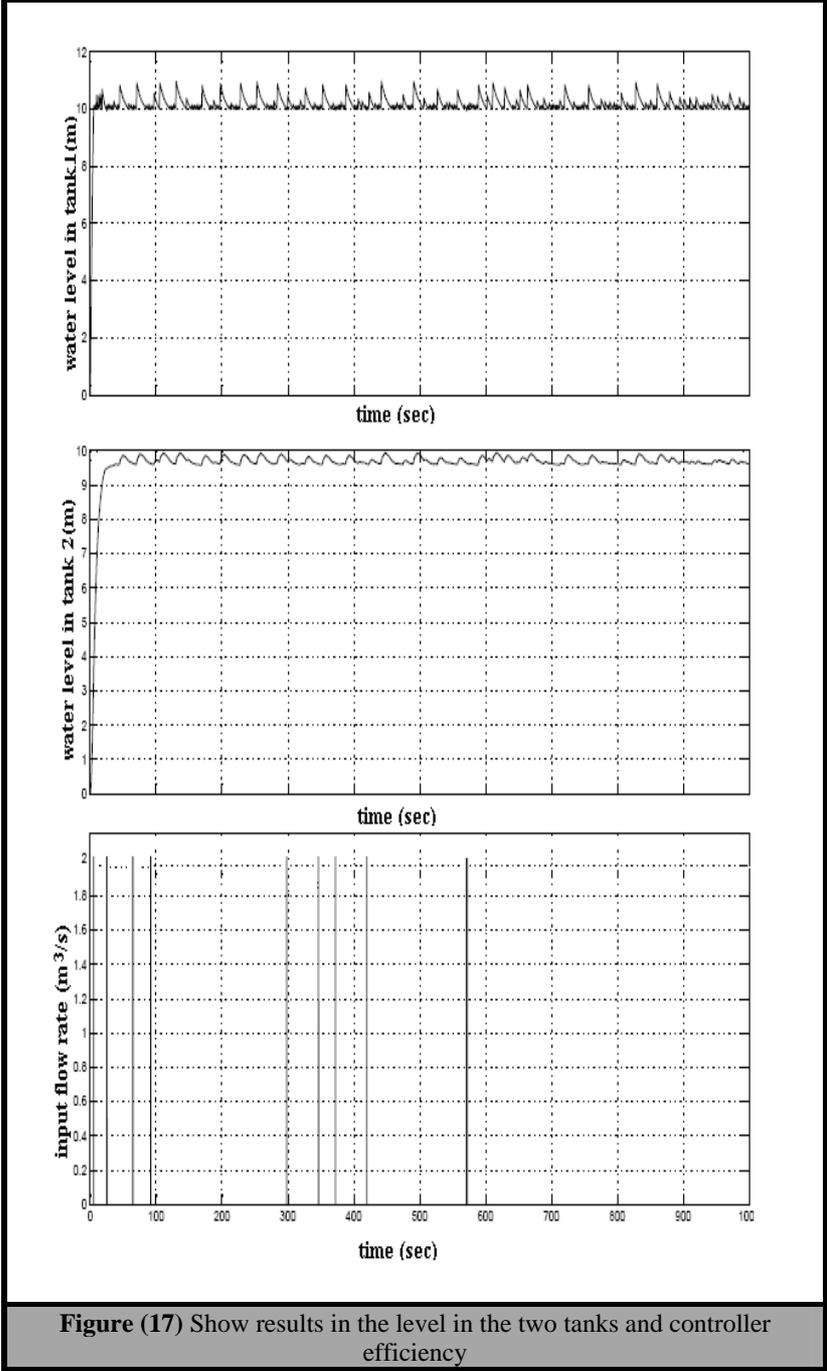
Figure (17) Show results in the level in the two tanks and controller efficiency

almost to ten meter and doesn't access this level. The change in the   parameters can be adjusted the water level.

5. Comparison with other method:

This method gives a lot of information about the system also makes it test and easier to change the parameter as compared with the conventional approach. The parameter can be changed by using the Matlab simulation as shown in the block diagram Fig. (7,8   ) and the simulation results is shown reverse of the conventional method which is more difficult according to the change of the parameter in addition to the change of the parameter, the cross section area of each tank and inputs can be also changed .

It is also avoiding the disadvantage of the conventional method that includes damage of the sensor and the error in the measurement in addition to the difficulty in the system insulation and its installation.

6. Conclusion:

The purpose of this paper is to present a controller of the liquid system with two tanks without using any float, sensor, transducer if we know the parameters of pipe resistance. The problem used to control level in the tanks by adjusting flow rate of the liquid entering the tank. After reviewing the operations of the system, simulations are presented and showed that the level of the water doesn't accessed the desired level although of a little error of a few acceding of the water from desire level because of (Compare to Constant). this work shows high efficiency, fast response and accuracy in the controller. It can be concluded that the controller yield better performance than the other controller. The results of modeling can be present an important means to measure and control more instruments and support the studies in the scientific laboratories. In the experiments installation in Matlab program, we must interface computer with electrical instruments that give the facilities understanding.

References

[1] A.S. Thulkarmine, M.R.A Ghani, S.M. Amin and A.Wahab, "Self-tuning Controllers for a Coupled Tank Pilot Plant: Evaluation and Comparison", IEEE, pp. 580-581, 1993.

[2] V. Ramakrishnan, Y. Zhuang, S.Y. Hu, J.P. Chen, C.C. Ko, B.M. Chen and K.C.   Tan, "Development of a Web-Based Laboratory for Control Experiments on a Coupled Tank Apparatus", *Proceedings of the 2000 American Control Conference,Vol. 6 pp. 4409 – 4413*
.

[3]   CAIRO,"Coupled-tank   Liquid   Level Computer-controlled   Laboratory   Teaching Package: Experimental   and   Operational (Service) Manuals", Augmented Innovation Sdn. Bhd., Universiti Teknologi Malaysia.

[4] J.G. Balchen and K.J. Mumme, "Process Control   Structures   and   Application",   Van nostrand Reinhold Co., New York, 1988.

[5]   G.   Stepanoupoulis,"Chemical   Process Control", Prentice Hall of India, New Delhi, 1990.

[6] Duane Hanselman & Bruce Littlefield,*"Book: Mastering Matlab® 5"*, ISBN# 0-13-858366-8, Prentice-Hall,1998.

[7] Ogata, K.,"Modern control engineering", 4th Edition, Prentice Hall Publisher, 2001.

[8] Selmer A., Goodson M., Kraft M., Sen S., McNeill V.F., Johnson B.S. and Colton   C.K., "Process Dynamics and Control Experiment Performed Across the Atlantic",
Technical   Report   27,   c4e-Preprint   Series, Cambridge, 2004.

 [9] Ogata, K., "System dynamics", 4th Edition, Prentice Hall Publisher, 2004.

تحليل وتصميم مبسط للسيطرة على عمليات المستوى بدون استخدام متحسس

المهندس سيف عبد الجاسم محيسن

قسم هندسة الحاسبات

جامعة النهرين

المهندس زيد عبد الجاسم محيسن

وزارة العلوم والتكنلوجيا

دائرة تكنلوجيا معالجة المياه

الخلاصة:

هذا البحث يتعامل مع سيطرة العملية ،التعريف العام ، التصميم الشكلي لانظمة الجريان والسيطرة عليها مستندا على المقارنة الثابتة كمبدأ لطريقة العمل. بعد مراجعة عملية التصميم نظام مقارنةٍ بين مستوى المطلوب ومستوىَ الماء يُصاغان للسَيْطرَة على نسبةِ الجريان . فيما بعد المخطط يصمم ويقاس ببرنامج الماتلاب .المحاكاة بالماتلاب للتصميم توضح وتبين بان طريقة فتح وغلق المفتاح للنظام افضل و اكثر استعمالا عند مقارنتها مع الطريقة التقليدية

.