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Design of Phase Compensation for Solar Panel Systems for Tracking Sun

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Abstract

The compensation for solar panel systems in order to tracking sun has been studied and represented in its equivalent closed loop control system. These systems improved the performance of solar panel systems to produced maximum power efficiency. The response of this controlled system showed sluggish performance. Therefore, it is necessary to introduce proportional derivative integral (PID) controller and (Lead-Lag) phase compensator to improve the dynamic response of the system. The required specifications are to obtain faster response with the minimum peak overshoot (Mp). The closed-loop system is initially built in Simulink / Matlab package and the (PID) controller and (Lead-Lag) phase compensator has been build into special subsystem. The components of control system have been dragged directly from Simulink library. Results showed that when compensator is properly designed the response would be acceptable in the sense of required specifications.

Keywords: Post-Kyoto – Conference of Parties – Solar energye - Energy Efficiency - Renewable Energies.

K_p	Proportinal constant.
K_D	Derivative constant.
K_i	Integral constant.
T_m	Torque motor.
ω_n	Angular velocity of motor

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1. Compensation

Compensation is a very important requirement for amplifier design. When feedback is applied to an amplifier, the possibility for instability is inherently introduced. Compensation is a means for controlling the location of poles, by inserting a dominant pole, and thus guaranteeing the stability of the amplifier. Instability refers to the chance that the output changes sign so that the output actually adds to the input, instead of subtracting. This will cause the output to grow without bound and saturate the amplifier. There are a number of different compensation units that can be employed to help fix certain system metrics that are outside of a proper operating range. Most commonly, the phase characteristics are in need of compensation, especially if the magnitude response is to remain constant

2. Controllers:

There are a number of different standard types of control systems that will study extensively. These controllers, specifically the proportional (P), proportional derivative (PD), proportional integral (PI), and proportional integral derivative (PID) controllers are very common in the production of physical systems, but as we will see they each carry several drawbacks.

PID controllers are combinations of the proportional, derivative, and integral controllers. Because of this, PID controllers have large amounts of flexibility. We will see below that there are definite limits on PID control. The transfer function for a standard PID controller is an addition of the Proportional, the Integral, and the Differential controller transfer functions (hence the name, PID). Also, we give each term a gain constant, to control the weight that each factor has on the final output:

$$D(s) = K_p + \frac{K_i}{s} + K_d s \qquad (1)$$

3. Phase Compensation:

Occasionally, it is necessary to alter the phase characteristics of a given system, without altering the magnitude characteristics. To do this, we need to alter the frequency response in such a way that the phase response is altered, but the magnitude response is not altered. To do this, we implement a special Variety of controllers known as **phase compensators** fig (1)**.** They are called compensators because they help to improve the phase response of the system.

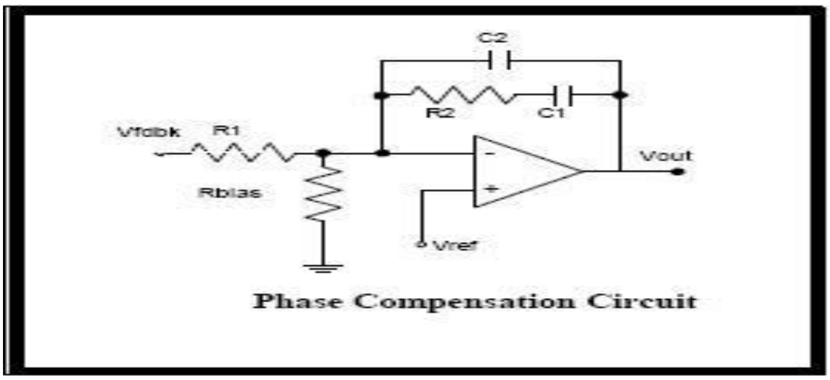


Fig (1).phase compensation circuit

There are two general types of compensators: **Lead Compensators**, and **Lag Compensators**. If we combine the two types, we can get a special **Lead-Lag Compensator** system. When designing and implementing a phase compensator, it is important to analyze the effects on the gain and phase margins of the system, to ensure that compensation doesn't cause the system to become unstable.

4.1 Panel Sun control system:

For the purpose of moving the solar panel was used the Dc motor has design an electronic circuit to control the movement of Dc motor through the program has been stored on the microcontroller programmer language. The solar panel by this way can track the movement of the sun to get a highly efficient, figure (2), which structure base of the solar panel. the kits board was design to examine the performance of the solar panel by converting voltages from DC to Ac by using inverter. The control charge was design to control of batteries charge, as in figure (3). The voltmeter device was used to monitor of voltage change due to movement of the solar panel, as in figure (4).

Fig.(2) Base structure

Fig.(3) Kits board

Fig.(4) Voltemeter monitor

4.2 Implementation of the electronic part

In this part the circuit is built to drive the motors attached to each axes, since they are DC motors that has to be work in both forward and reverse the best way to manage it is by using H-bride configuration this can be done directly using the L293D(see fig. 5) integrated circuit which it is a Quadruple half H-Bridge with 600mA current and 36volts for each channel, connecting the pins from the parallel port connector a pair for each motor and given the table that shows how this work

Pins of parallel port		Motor movement	Description
0	0	Break	The motor stops
1	0	Forward	Forward movement
0	1	Backward	Backward movement
1	1	Not allowed	Not valid

The following figure is the L293D chip

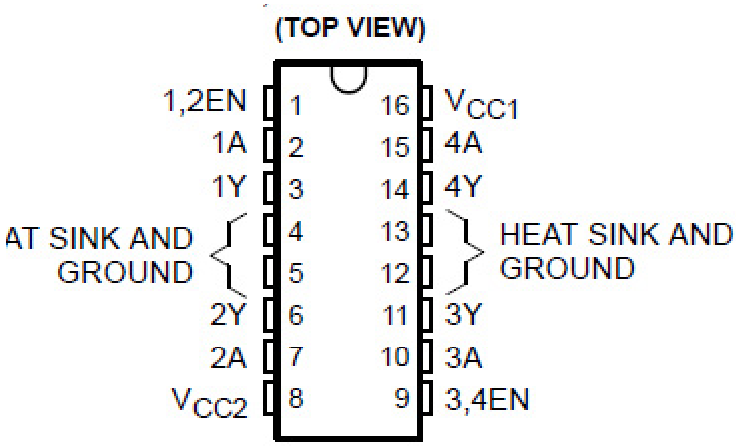


Figure (5) Layout of the L293D integrated circuit

This is done for each one of the DC motors and all connected to the parallel port cable which in turn connected to the PC, the power supply is external to the system and work with 24v this is not suitable for the IC so a voltage regulator L78CV05 is used to regulate it to 5volt to validated the IC voltage, but this generates a large amount of heat even when connected to a heat-sink so we used a L78CV12 first then its output is supplied to the 5v regulator.

The following figure shows the circuit of the electronic board as implemented, see fig.(6&7)

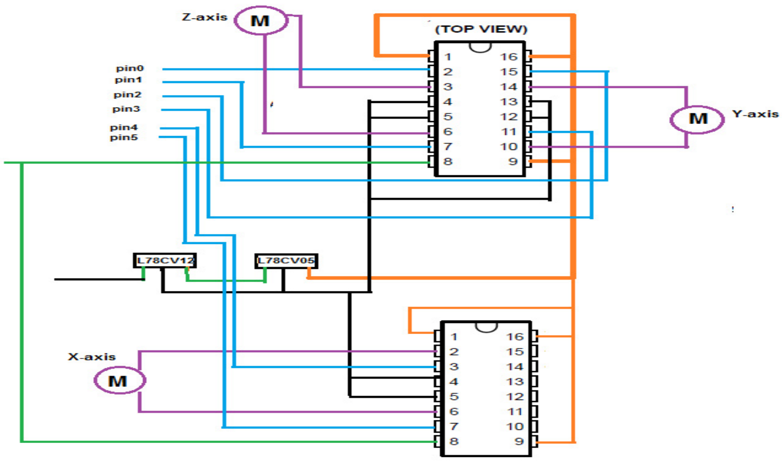


Fig. (6) Circuit diagram of the controller

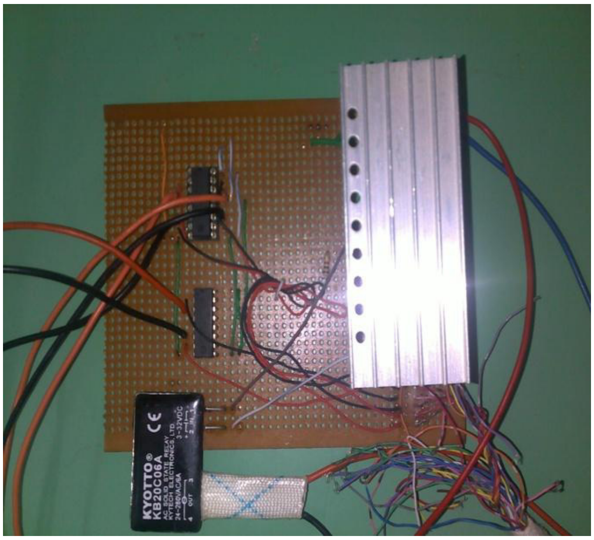


Fig. (7) The controller board

4.3 Servo amplifier:

The gain of the servo amplifier is $–K_a$. , the output of the servo amplifier is expressed as

$$e_a = - K_a (e_0 + e_T) \quad (2)$$
$$= - K_a e_s$$

4.4 Tachometer:

The output voltage of the tachometer e_T is related to the angular velocity of the motor through the tachometer constant K_T; that is

$$e_T = K_T \omega_m \quad (3)$$

The angular position of the output gear is related to the motor position through the gear ratio I/n. thus

$$\theta_0 = \frac{1}{n} \theta_m \quad (4)$$

4.5 Armature-controller DC motor:

The armature-controller dc motor has been modelled earlier. The equations are

$$e_a = R_a i_a + e_b \quad (5)$$

$$e_b = R_b \ \omega_m \quad (6)$$

$$T_m = K_m \ i_a \quad (7)$$

$$T_m = J \ \frac{d\omega_m}{dt} B\omega_m \quad (8)$$

Where J and B : the inertia and viscous friction coefficient. The inductance in the motor armature is neglected in equation above .A block diagram in that characterizes all the functional relations of the system.

5. Results and Discussion:

5.1 Transient response analysis:

During various setting of PID controller, the closed-loop system has been subjected to unit step degree input. The system is built in simulink and a measuring oscilloscope is used for monitoring reference input (θ_i) and actual output (θ_i). The system parameters are defined in a Matlab script file "initial .m" which is initially run before executing simulink file "Haitham mdl". The simulation has been started by setting KP=1, KD=0 and KI=0. Fig (8), Shows how well the response is , yet , the system shows a sluggish response with this setting. An other guess of kp=10 , kd=0 and kI=0 shows another response , which is much faster than the previous one , but a peak-over shoot has raised , see fig (9) .Another trial of controller setting (kp=100, kd=0 , kI=0) will show the fastest response than the previous ones .How ever, the response of figure (10) crucial over shoot, and one may conclude that the system stability has degraded with the increasing proportional gain of PID controller.All the above responses have been summed up in figure (11). One can easily see the difference in transient parameters at gain increasing, the response become faster but the peak over shoot is also increased. If one investigate the steady-state error of these response, he will see that all above responses track input with zero steady state error (i.e , ess=0 or Ki=0 at $t \rightarrow \infty$). In figure (11), the gain kp has been breezed or fixed at value (10) and the value of kd is set at kd=1 and ki=0. one can easily see from figure (13) that the peak over shoot is damped to a lower value is compared to response with kd=0. If the value of kd is increased to kd=10 the response shows an excellent performance, as the peak-overshoot has completely vanished. If one compare the response of figure (8) and figure (12), the condition would be that the effect of proportional gain has made the response quicker but more increasing in overshoot and the effects do kd. Comes eliminate that over shoot due to increased kp. The result is a faster response without over shoot. Fig. (11) mixes two responses of two setting of kd (kd=1 and kd=10). One might think to increase kd, but the result would not be so pleased as the increased sluggish and slow.

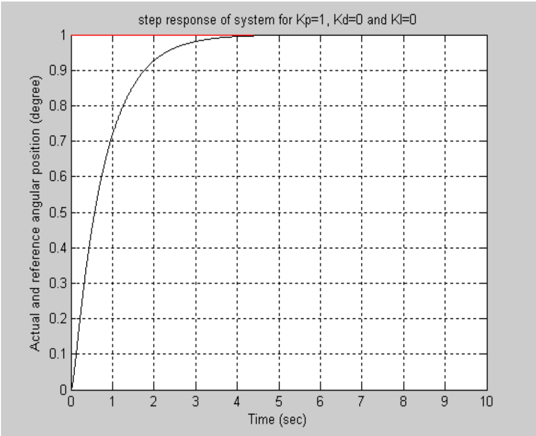


Fig. (8) Sluggish response.

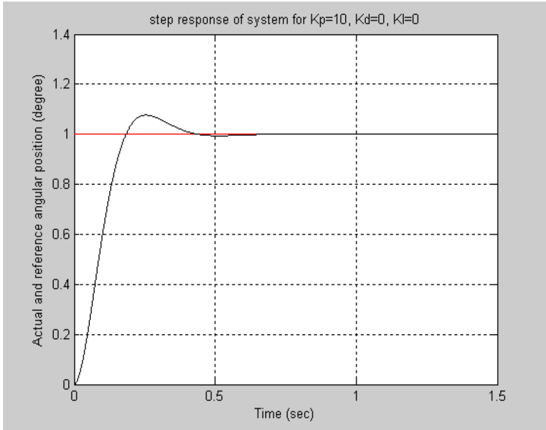


Fig. (9) Another trial of controller setting

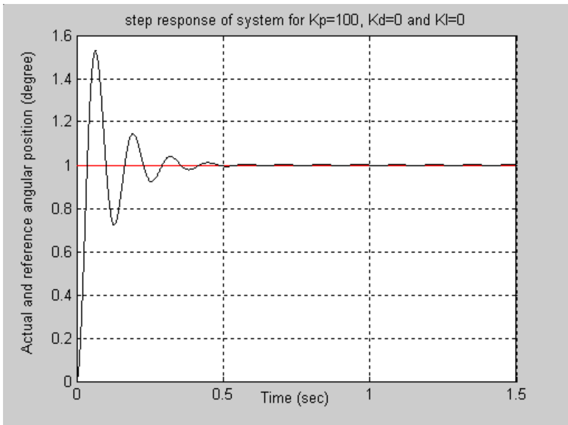


Fig (10) crucial overshoot

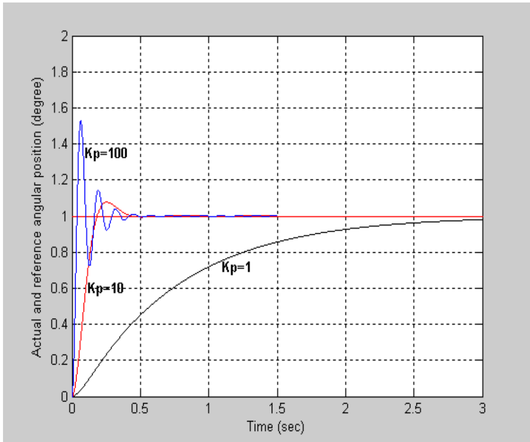


Fig (11) Summed of fig(8), fig(9), fig(10).

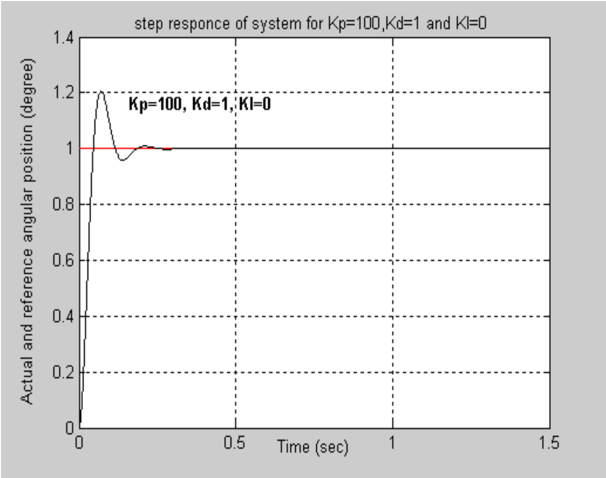


Fig. (12) The peak overshoot is damped to lower value as compared to response

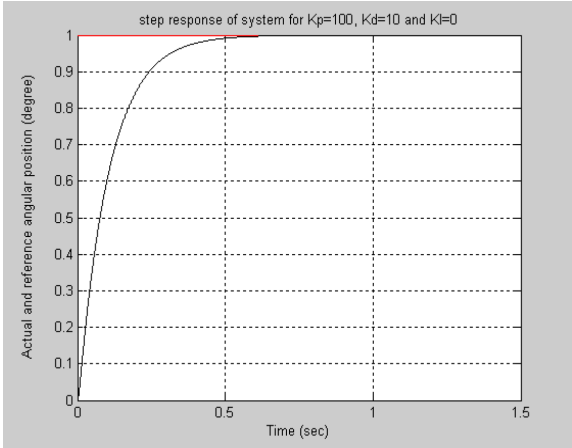


Fig. (13) The conclusion would be that the effect of proportional gain.

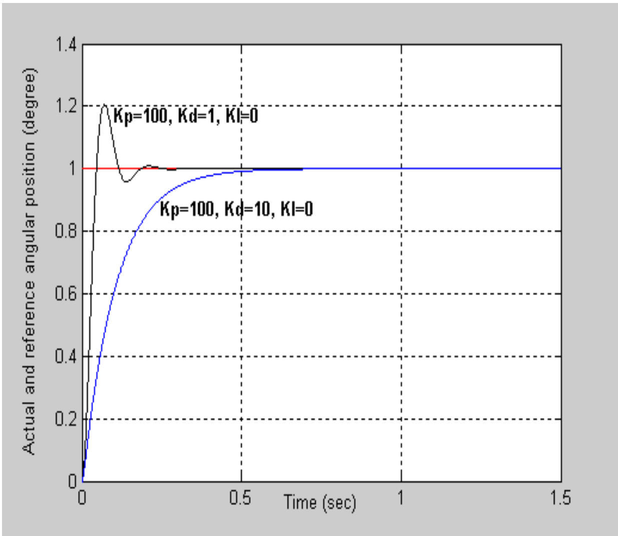


Fig. (14) Summed of fig. (12), fig. (13)

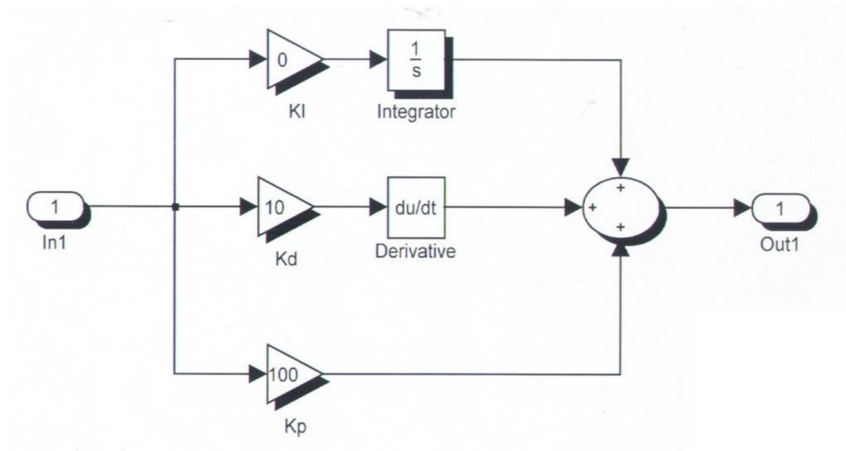


Fig. (15) PID Controller.

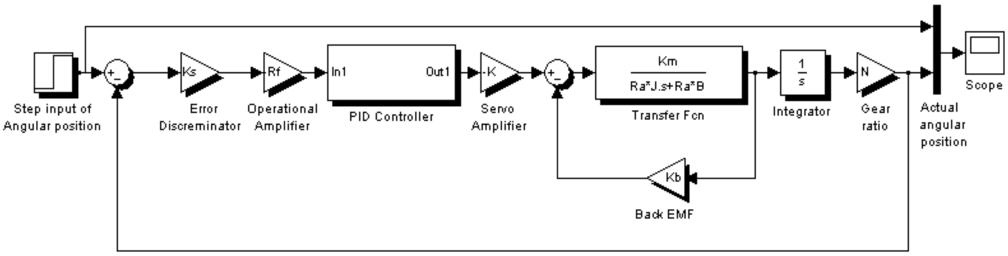


Fig. (16) Seeker with PID Compensator.

5.2 Lag Compensator:

From the simulated response, one can see that the system fig(17-a) is slow and sluggish see fig(17-b), therefore we will use Lag compensator to improve behavior of this system.

The simulation has been started by setting Z=10 and p=1 fig(18),The effect of increasing No.(z) will lead to increase in peak overshoot with keeping T(time constant) constant see fig(19). This effect in overshoot will degrade the system stability ,another set Z=30,P=1 this will lead to uncontrollable behavior (unstable response) see fig(20).

Now increasing in No.(p),set as(Z=30,P=5)this will make the system faster(decrease time response), and another effect will degrade in peak overshoot see fig(21).

The best situation become when we set(Z=30,P=10) because we have to a minimum overshoot and time response ,therefore increasing in No.(z)and No.(p) will decrease tr(rise time),T(time constant), and tp(peak time),this will lead to speed up the transient response of this system see fig(22).

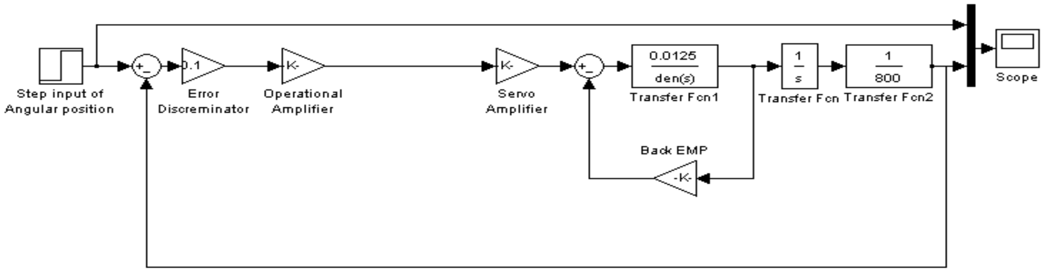


Fig (17-a) Control System without Compensator.

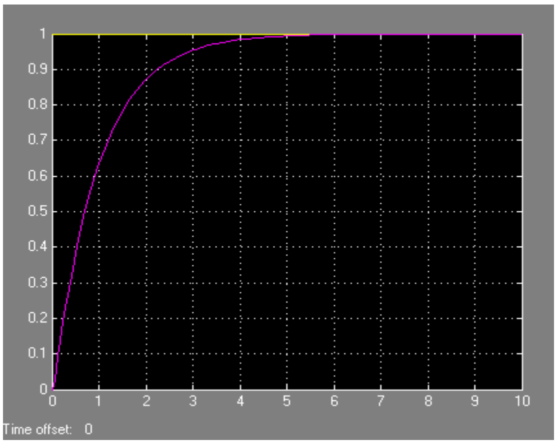


Fig (17-b) Slow and sluggish System.

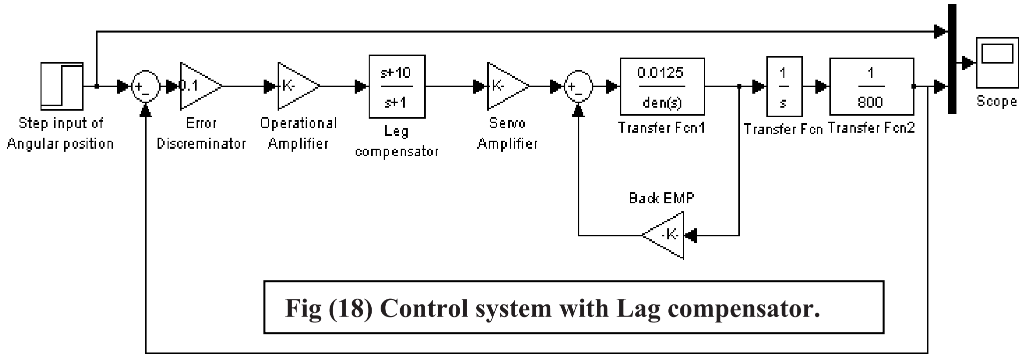


Fig (18) Control system with Lag compensator.

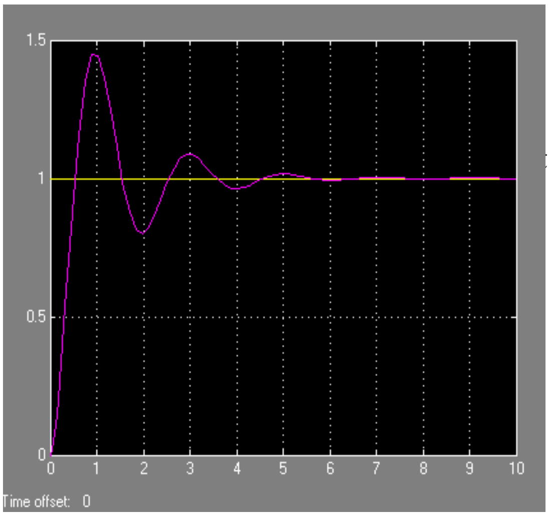
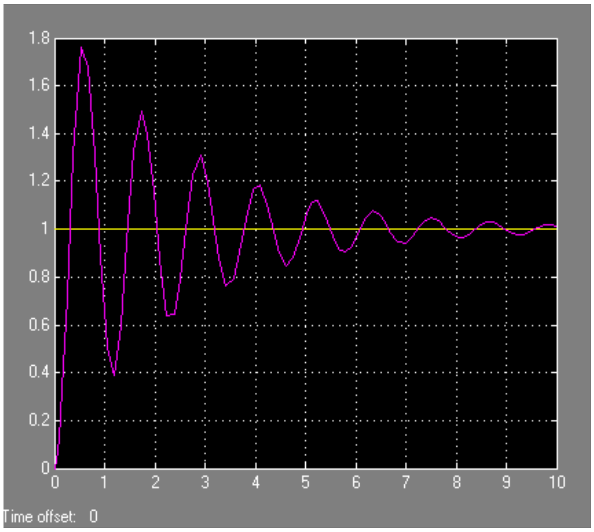
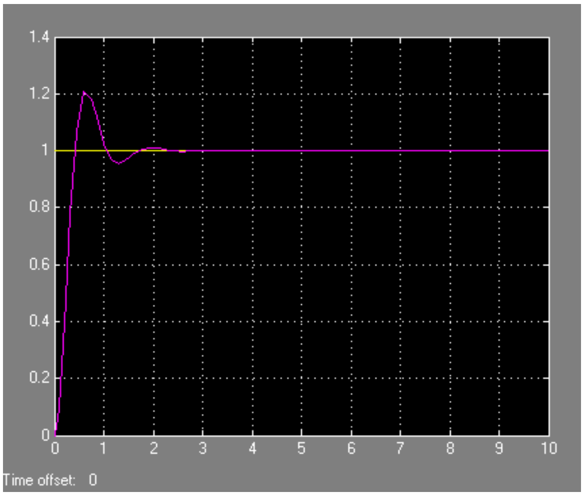


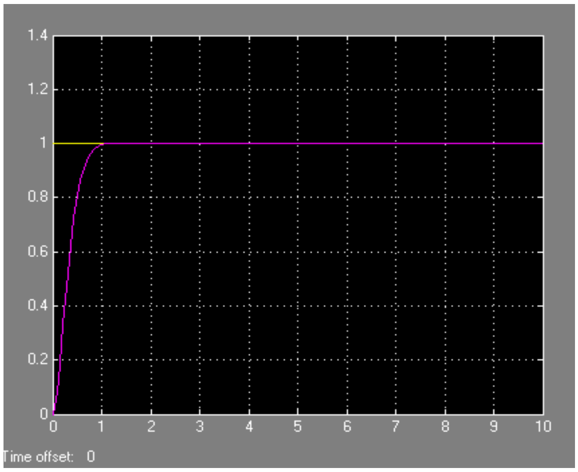
Fig. (19) increase in peak overshoot



Fig(20) unstable response.



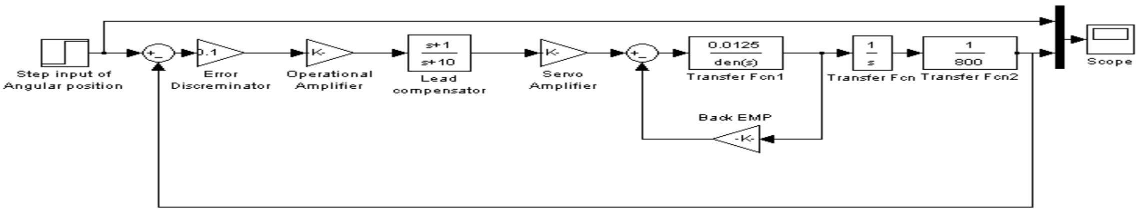
Fig(21) degrade the peak overshoot.



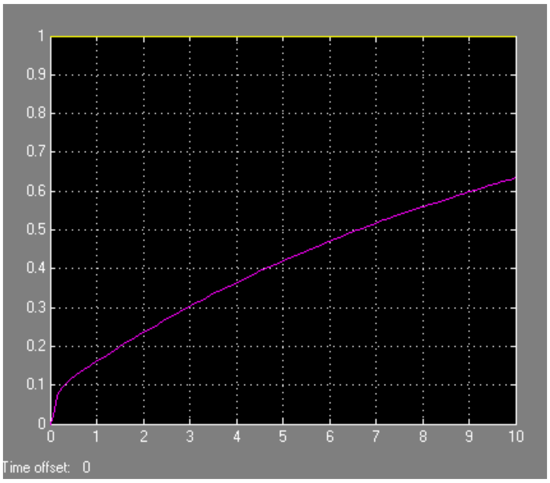
Fig(22) speed **up the transient response without overshoot.**

5.3 Lead Compensator:

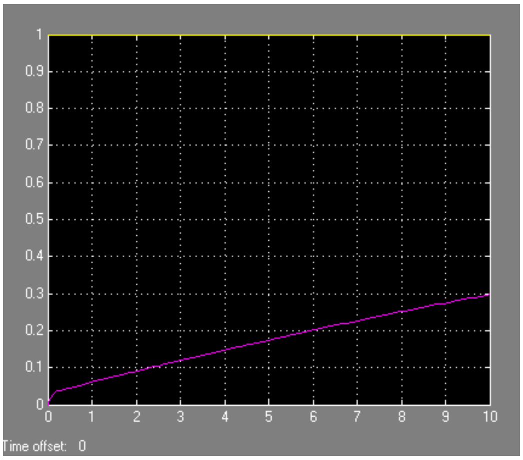
The simulation has been started by setting Z=1 and P=10 fig(24), the increasing of No.(p) will lead to effect in steady-state error of this system see fig(25). This increasing will make the system unacceptable. more increasing in No.(p),set as(Z=1,P=30) lead to increase in (steady –state error), T(time constant), and tr(rise time) this will make the response slower and more sluggish see fig(26). Now increasing in No.(z) (Z=10,P=30) with respect to Lead compensator condition of (p)>(z), will decrease in steady-state error, but still there is delay in time response and increasing in T(time constant),this might lead to slower and uncontrollable behavior (unstable response), see fig (26).



Fig(23) control system with Lead compensator



Fig(24) increase in steady-state error.



Fig(25)more increasing is steady-state error.

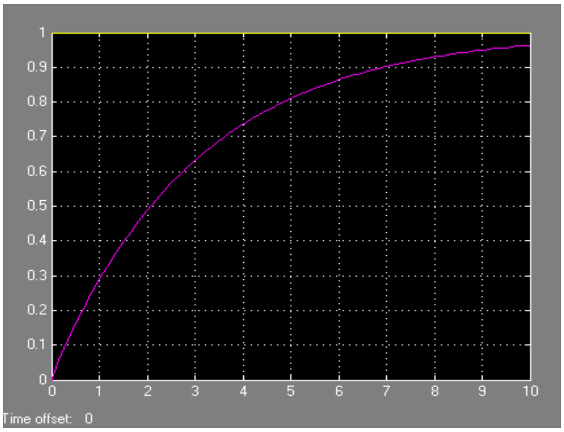


Fig (26) The response slower and more sluggish.

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