Fuzzy controller design for inertially stabilised platform

Anjna Kothari Gaur
Graphic Era University,
Dehradun

Rajesh Kumar
Deptt. Of Instrumentation & Control engg.
Graphic Era University, Dehradun

ABSTRACT
Conventional controllers have been used for controlling the optoelectrical tracking system placed in a moving carrier, carrier is continuously moving hence there are vibrations, and the object of control system is to keep the line of sight of the tracking system stable towards the target in an unstable environment. In this paper an approach is made to design a Fuzzy knowledge base controller for this system. Nonlinearities like dead band and saturation are considered. Noise signal is also added as external disturbance. Matlab Simulation is performed and performance of controller is evaluated on the basis of control output for step command and the control output for disturbance attenuation.

Keywords
Gyro, Gimbal, ISP, and Fuzzy logic

1. INTRODUCTION
Inertial stabilized platforms are used for the stabilization purpose of systems where moving vehicles or moving platform carries the payload which may be cameras, telescopes etc. In this paper an optoelectrical tracking system's line of sight is stabilised and the aim is to track the target and maintaining the angle of azimuth and elevation stabilized irrespective of the vibrations and disturbances of moving platform. Two axis electromechanical gimbal is used to carry the payload in the space. Loops for azimuth and elevation both are to be considered for controlling whole process. But here only azimuth stabilization loop is taken(1).

Conventional controllers posses some limitations and disadvantages of being less effective in the presence of nonlinearities and also the design of conventional controller is based on the mathematical modelling of the system. It requires accurate knowledge of plant dynamics and then accurate modelling of the system, it becomes difficult as the plant becomes complex and also with the aging of system components performance of the system deteriorates.

Artificial intelligence techniques provide a solution over the complexity of conventional control methods. Fuzzy logic control(FLC) system is one of such technique. FLC design doesn't require the knowledge of plant dynamics and the mathematical modelling of the system instead it requires the knowledge of expert. Easy to implement and give better performance under the uncertainties and nonlinearities of the system.

FLC is designed based on the required specifications of the system and performance is evaluated based on the control output for the step command and control output for disturbance attenuation.

The methods of LOS stabilizations have been proposed by Moorty et.al.(2).

2. SYSTEM DESCRIPTION
Gyros are used as sensor which senses the rate or angular velocity of the gimballed payload as the line of sight of system get disturbed. Input of gyros is the rate signal and the output is proportional voltage signal. Controller generate a appropriate control signal and output of controller is fed to a DC servo motor placed on gimbal axis which drives the optoelectrical system so as to maintain the system stable. Two axis Gimbals keeps the payload stationary as the DC motor drives the system as per the control command signal. The resolution of optical tracking system becomes poor due to the disturbances in line of sight. As the optical energy spread over the tracking system increases, resolution becomes poorer. To decrease this effect gimballed system is integrated. Any angular disturbance is sensed by sensor gyros and converted in proportional command signal to stabilize the tracking system within the gimbals.

Taking the effect of saturation and dead band nonlinearities into account and adding noise signal as external disturbance and considering its effect on process a fuzzy controller is designed and performance is evaluated on the basis of control output for step command signal and disturbance attenuation. Disturbance attenuation property is the basic requirement for the controller, as it decides the performance of system under external disturbance signals and tells about the robustness of the controller.

System requirements
Inertially stabilised platform includes several components whose Dynamic modelling have to be known. The system components are as follows:

- Two axis gimballed payload
- Dry tuned gyro for angular velocity sensor
- DC servo motor
- Fuzzy controller

The specifications of system components are as below:

1.DC Motor specification:

- Resistance of motor winding: 5.5 ohm
- Inductance of motor winding: 1.2 mH
- Back emf constant (Kb): 0.144 V/Rad./sec.^{2}
- Torque sensitivity (Kt): 0.144 N-m/A
- Peak torque of DC motor: 0.635N-m

2.Gyro specification:

- Gyro scale factor: 0.72 V/rad./s

3.Gimbal specification:

- Inertia of gimbal J: 0.032Kg m^2
- B/J ratio of gimbal: 6.25 rad/s (1 Hz)

3. DESIGENING FUZZY LOGIC CONTROLLER
The basic fuzzy logic controller designing scheme is shown in fig.1. It consists mainly three parts namely fuzzification, fuzzy inference engine and defuzzification.

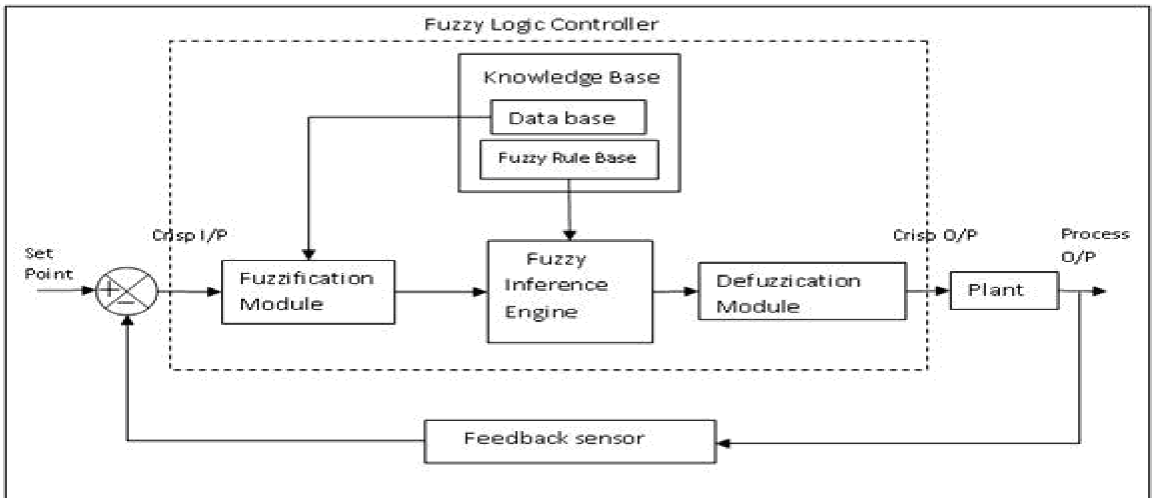

Fig.1 Fuzzy logic controller

3.1 Defining Inputs & outputs:

Fuzzy Knowledge based controller is designed for the process. For designing FLC, first step is to identify the input and output variables. Inputs for fuzzy controller are taken as error and derivative of error, and output of controller will be the command signal which drives the DC servo motor. Error signal is the difference between the gyro output signal and the given command signal.

Gyro output signal is the voltage signal which is proportional to the angular velocity of gimbaled payload. Now angular velocity and rate of change of angular velocity will be the two inputs of fuzzy controller. Error and derivative of error signal are first quantized and then goes to the fuzzy controller. Mamdani type of inference mechanism is used.

3.2 Linguistic variables:

Next step is to divide the input and output variables in several classes, seven classes for both the input and control output variables can be used. These are negative big(Nb), negative medium(Nm), negative small(Ns), zero(Z), and positive small(Ps), positive medium(Pm) and positive big(Pb). In this case dsigmoidal (difference of two sigmoidal functions) membership function has been chosen.

3.3 Parameters of membership function:

	Error	**Error dot**	**control**
Nb	8.74, -1.41, 8.842, -0.606	21.69 ,-1.166, 21.69, -0.834	21.69, -1.166, 21.69, -0.834
Nm	30.59, -0.3677, 30.59, -0.1323	21.69, -0.826, 21.69, -0.494	21.54, -0.7372, 21.54, -0.4028
Ns	76.47, -0.1471, 76.47, -0.0529	25.49, -0.3413, 25.49 ,-0.05871	30.59, -0.2677, 30.59, -0.03226
Z	235.3, -0.01531, 235.3, 0.01531	207.6, -0.0291, 454 ,0.0185	436.9, -0.008242 ,436.9, 0.008242
Ps	76.47 ,0.0529, 76.47, 0.1471	25.49, 0.05871, 25.49, 0.3413	30.59, 0.03226, 30.59, 0.2677
Pm	30.59, 0.1323 ,30.59, 0.3677	21.69 ,0.494, 21.69, 0.826	21.54, 0.4028, 21.54, 0.7372
Pb	8.316 ,0.585 ,8.74 ,1.41	21.69 ,0.834 ,21.69, 1.166	21.69, 0.834, 21.69, 1.166

3.4 Create a Fuzzy rule base:

Now appropriate rule base will be formed which is based on the knowledge of expert that how the output is varied with the variation of input. Here 49 no. of rules are formed.

After designing the rule base the shape of membership function is decided. Any of the shape can be chosen based on certain requirement.

Rule base design:

de / **e**	**nb**	**nm**	**ns**	**z**	**ps**	**pm**	**pb**
nb	nb	nb	nb	nb	nm	ns	z
nm	nb	nb	nb	nm	ns	z	ps
ns	nb	nb	nm	ns	z	ps	pm
z	nb	nm	ns	z	ps	pm	pb
ps	nm	ns	z	ps	pm	pb	pb
pm	ns	z	ps	pm	pb	pb	pb
pb	z	ps	pm	pb	pb	pb	pb

3.5 Defuzzification:

For defuzzification, centroid or centre of gravity method is used. Control output is the change in control signal hence an integrator is used after fuzzy controller to get the exact control output signal. Appropriate gain blocks are used before and after the fuzzy controller.

4. DEVELOPMENT OF INERTIAL STABILIZED PLATFORM MODEL:

In this present work, MATLAB software is used for modeling & simulation of intially stabilised platform(ISP). The simulink model of ISP is shown in fig. 2.

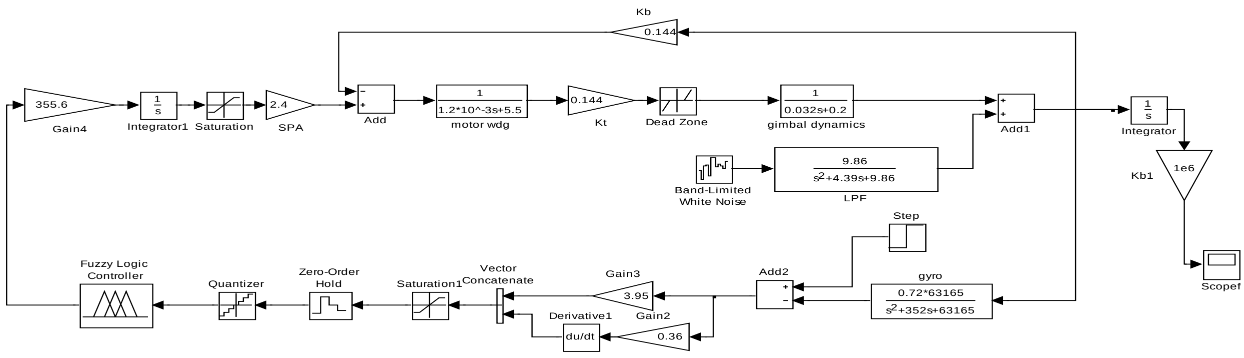

Fig. 2 Simulink model of ISP

After performing the simulation, the simulation results are obtained in figs.3, 4,5,6,and7. Figure 3 shows the disturbance rejection characteristics of the controller for jitter on line of sight for random signal Figure 4 shows the dynamic characteristics of controller that how the step command is followed by the system ? Figure 5 shows the output of controller when step command is given to the system and external noise is not present. Figure 6 shows the output of controller for disturbance input signal only.Figure 7 shows that how the sine command signal is followed by the controller. Figure 8 shows the error signal when system follows the input commandd signal.

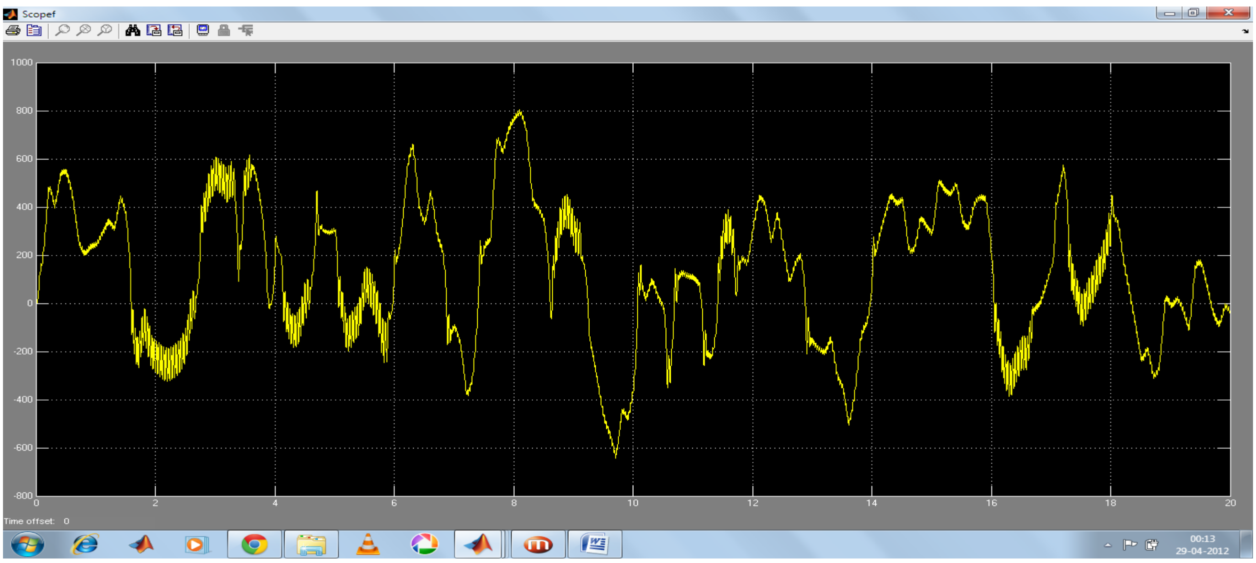

Fig. 3 Jitter on line of sight for random signal

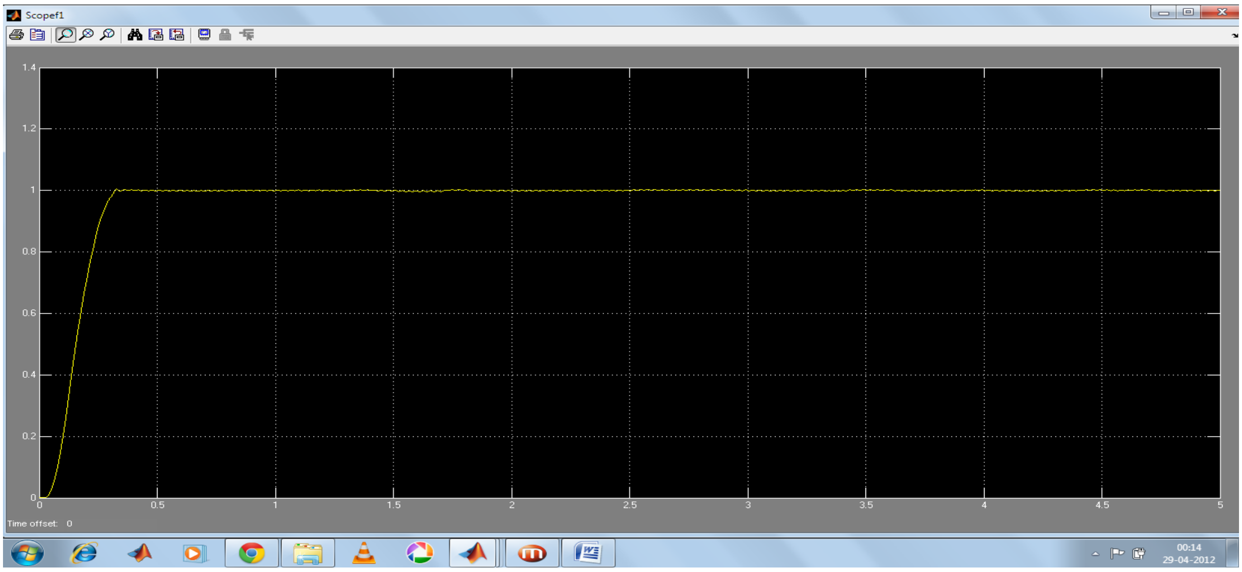

Fig. 4 Dynamic response of the model

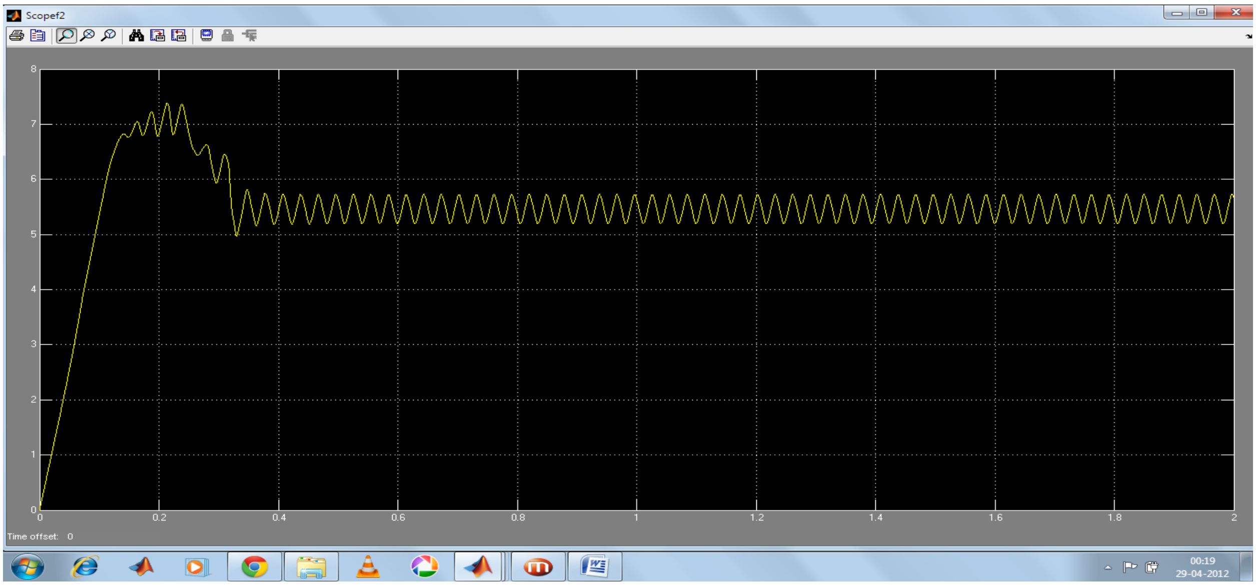

Fig. 5 Control output for step signal(without disturbances)

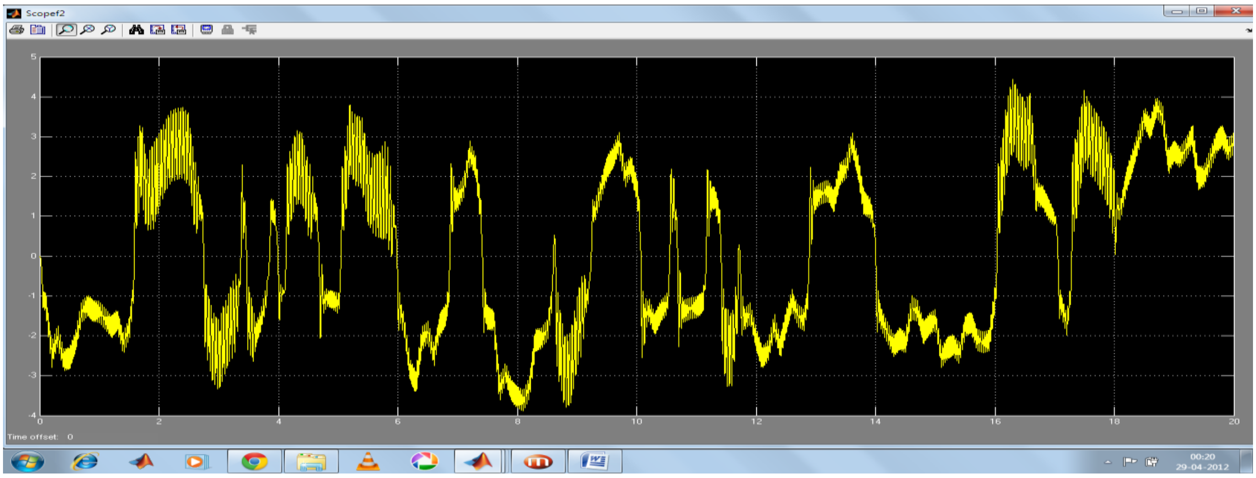

Fig. 6 Control output for disturbance attenuation(without step input)

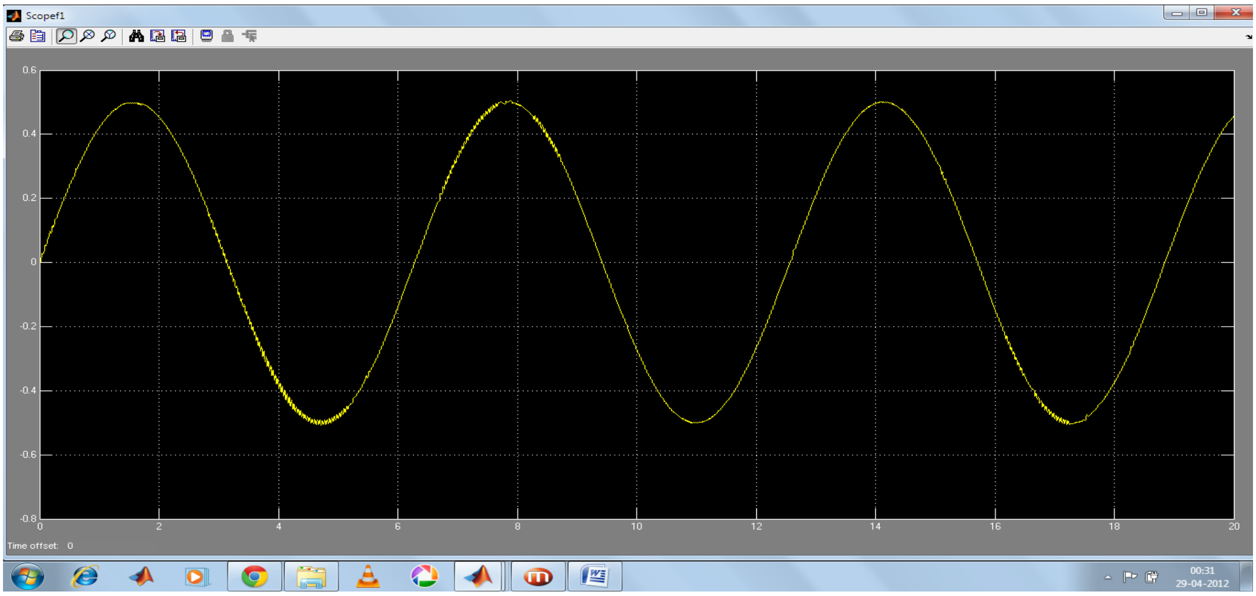

Fig.7 Response in following sine command signal

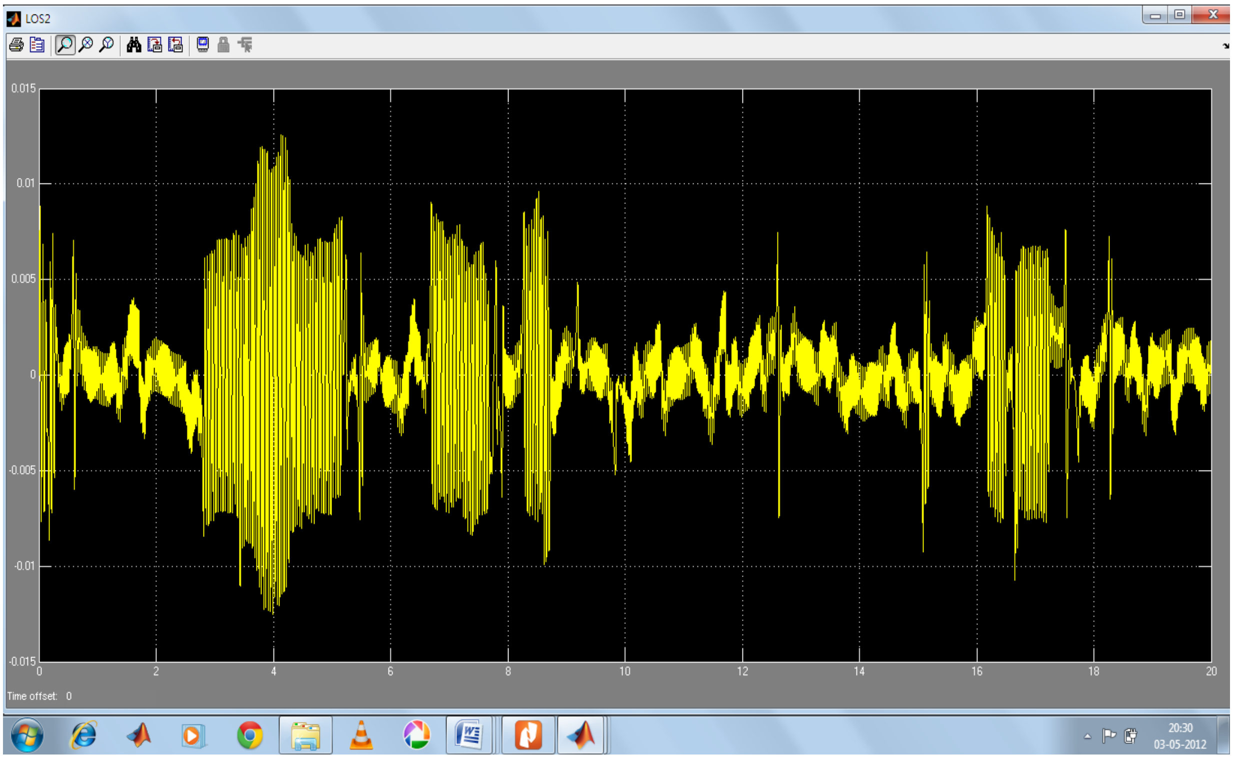

Fig.8 Error in following sine command signal

5. Results & discussion:

It is found that fuzzy controller hence designed is satisfying all the design criteria and performing satisfactorily under the presence of nonlineriaties like dead band due to stiction friction and saturation. It is satisfying the limit for accepted residual jitter on line of sight.

It is also following the step command signal with accepted rise time.Maximum overshoot is also Less than the specified value. Performance of fuzzy logic contoller is evaluated after performing simulation. The perfornace of ISP model is shown in table-1.

Table:1 Designing parameters performance

Designing parameters	Given specifications	Result obtained
Residual jitter on LOS	300 μrad	284 μrad
Percent overshoot	Less than 20%	0.45
Rise time(10 to 90%)	Less than 185msec	179 msec
Settling time	Less than 100msec	32msec

6. CONCLUSION AND FUTURE SCOPE:

It can be concluded that fuzzy controller designed is performing well under the presence of nonlinearities dead band and saturation and external noise signal and satisfying the design criterias. Artificial intelligence techniques are now replacing the conventional control techniques as these performs well under the presence of nonlinearities ,and for highly complex systems where finding the exact plant model is not possible there also it is easy to use these techniques.further there is scope for using artificial neural network, genetic algorithm and hybrid techniques for better solution of control problem.

7. REFERENCES

[1] .M.Hilkert,"Inertially stabilized platform technology, concept and principles", IEEE control systems magazine,February 2008.

[2] J. A. R. Krishna Moorty, Rajeev Marathe, Hari Babu, "Fuzzy controller for line of sight stabilization system", Journal of optical engineering, volume43, no6. june2004 pp.127.

[3] M.K.Masten, "Inertially stabilized platform for optical imaging system",IEEE control system magazine,February2008 pp.47 to64.

[4] H.G. Wang, Thomas C. Villiam, "Strategic inertial navigation system",IEEE control system magazine,February 2008,pp.65to85.

[5] T. J. Ross, " Fuzzy Logic with Engineering Applications", McGraw-Hill,New York1995