Design of Tracking of Moving Target Using PID Controller

Ajeet Singh[#1], Dr. S. Chatterjee[#2], Ritula Thakur[#3]
[#1]M.E Student, [#2]Professor and Head, [#3]Assistant Professor
Department of Electrical Engineering, NITTTR, Chandigarh

***Abstract*--The Line-of-Sight stabilization and tracking control based on gyro stabilized platform is required to isolate Line of sight from the movement and vibration of carrier and ensure pointing and tracking for target in electro-optical tracking system. This work describes the design of a high performance controller for an electro-mechanical target tracking system with an optical sensor for sighting. The control law has been obtained using a linear model of the electro mechanical system. The modelling of the system has been carried out using the experimental frequency response data. In the present work, PID controller is used to design the line-of-sight stabilization and tracking system. The conventional PID controller has been incorporated to regulate the speed of the platform and moving object. The PID controller has been tuned using Ziegler Nichols method and optimized by using simplex pattern search Genetic Algorithm method. The performance of the optimized PID controller has been compared with the PID controller. The proposed controller has been tested by incorporated non-linearity into the system. Simulation results tested with conventional PID controller and optimized PID controller. It is observed that optimized PID controller provided better result.**
***Keywords:*..LOS, PID, GAPID, Stabilization, Tracking**.

I. INTRODUCTION

The Line-of-Sight is the vector drawn between an imaging sensor and target. Electro-optical (EO) imaging sensors mounted on a mobile platform usually require some form of control to stabilize the sensor pointing vector along the target LOS. Such a system is termed as LOS Stabilisation System[1]. It is an essential feature of electro- optical imaging tracking system on a movable carrier, such as infrared missile seeker, airborne electro-optical detector, etc. This technology is applied to isolate the LOS of sensor from carrier disturbance, in order to guarantee accurate aiming and tracking for the target in inertial space. LOS stabilization and tracking control system works on the measurement of moving object orientation which is measures with the help of gyroscope, which rather than indicating direction, indicates the rate of change of angle with time[2]. Rate gyro is used to measure a rate of angular moment which is mounted on the stabilized axis of the gimbal as the speed sensor of the stabilization platform. The control system manipulates the platform, which is driven directly by DC motor, and keeps LOS of imaging sensor stabilized. The stabilisation system must limit the amount of image motion in the field of view of the optical sensor during a frame i.e. sensor integration period[3]. The allowable jitter is a function of the sensor resolution and beam width of the pointing device, and these in turn are usually determined by the angular substance of the target at the desired operating range. The torque disturbances in the system can be due to bearing and motor friction, unbalanced aerodynamics, vibration forces from on-board mechanisms, spring torque forces from wires or flexures or due to some non-intuitive torques. The design of tracking system controller is carried out for two-axis gimbals. The LOS is stabilized in elevation as well as in azimuth with a high degree of disturbance in both the axes[4]. High precision two-axis gimbals are engineered with very good stiffness properties. The inertial rate of the payload is sensed by very high performance dynamically tuned gyros (DTG), which are characterized by very low drift values of the order of 0.00001 deg. /sec[5][6]. Two stabilization loops work simultaneously for the overall stabilization of the optical sensor in the space. The plant model is generated using experimental frequency response data.

II. TRACKING AND STABILIZATION

Design of control system for tracking of moving target is of significance in video surveillance. The system works on the principle of closed loop servo control. A complete electro-optical tracking system consists of an imaging sensor (typically CCD), which is mounted on a two-axis stabilized servo platform, and a tracker, which controls the position of the platform, based on the scene observed through the imaging sensor[7][8]. In the case of a manual tracking system, an operator controls the position of the platform (via joystick, etc.) based on the image observed via a video monitor. In this way, the operator will attempt to drive the platform so that the object of interest is fixed on the bore sight. In the case of an automatic tracking system, the operator is replaced by an electronic system which processes the video images directly in real-time to ascertain the position of a designated object with respect to the sensor bore sight. Stabilization error is used to control the platform stability and attached sensors accurately follow the target. Line of sight stabilization is achieved by taking feedback from rate gyros mounted on azimuth and elevation gimbals of sight head[9]. A two-axis gimballed stabilization system in air vehicles must stabilize the line of sight toward a target against the external motion induced by air vehicle manoeuvring and aerodynamic forces. It is well known that the target tracking and pointing performances of the air vehicles are largely affected by air vehicle motion decoupling capability. This introduces a servo drive model for a two-axis gimballed stabilization system, and presents robust controllers for the air vehicle stabilization system. The mutation results are compared to confirm the validity of the suggested simulation model and the control design procedures for the line of sight stabilization and tracking system applied to moving object[10][11]. The control system utilize two-axis gimballed stabilization system consisting of target tracker, pitch and yaw axis gimbals and DC drive system. The servo drive of such air vehicles is composed of tracking and search loops which commonly include the stabilization loop as an inner loop. The stabilization loop plays an important role in searching and tracking a target. Generally, the two axis gimballed platform is used to achieve the rapid and precise response characteristics and also stabilized the moving platform during tracking the target[12]. The tracking performance of the air vehicles depends on stabilization of platform which is able to isolate the target tracker disturbance induced into the tracking loop by an air vehicle body motion, vibration, background radiation, and Atmospheric attenuation. Here the gimbal pay load is having freedom of two degree so it is free to move in X and Y direction[13]. The aim of control algorithm is to stabilize the pay load against the disturbances and at the same time it should follow the command given by the user. A fire control system is an integral part of a weapon system of any military vehicle. The engagement capability of the modern weapon platforms has been increased over the conventional system by integration of new technologies. Observation / recognition range / capability have been increased under both static and dynamic conditions by stabilizing the line of sight (LOS)[14]. Aline of sight stabilization system consists of a precision electro-mechanical assembly, gimbals, optical sight and control electronics etc. This paper discusses the design of PID controller for tracking & LOS stabilization[15][16].

III. SIMULINK MODEL OF STABILIZATION AND TRACKING CONTROL SYSTEM WITH PID CONTROLLER

The block diagram of line of sight stabilization and tracking control system shown in figure 1. The LOS tracking close loop system having tracking and stabilization feedback loops with positive and negative feedback respectively.

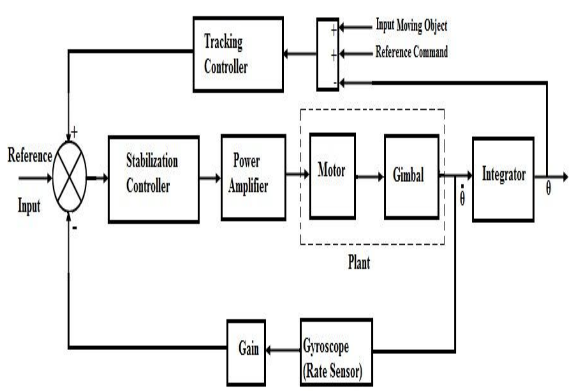

Fig.1 Block diagram of LOS Tracking Control System

Simulink model of line of sight stabilization and tracking closed loop control system is shown in figure 2. The stabilization PID controller having the gain coefficients K_{ps}, K_{is} and K_{ds} and tracking controller gain parameter is K_{pt}, K_{it} and K_{dt}.

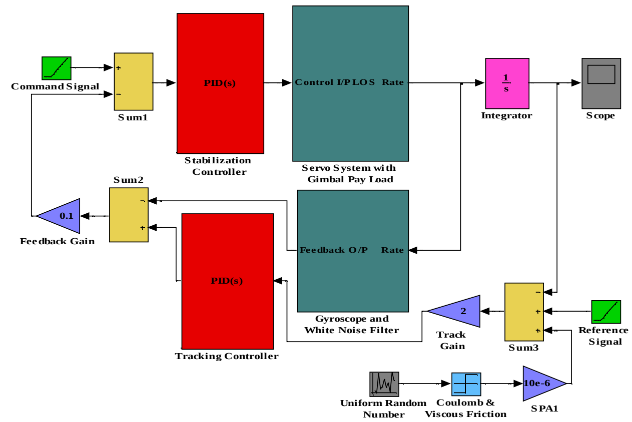

Fig.2 Simulink Model of LOS Stabilization and Tracking System

Simulink model of gimbal payload subsystem with resonance is shown in figure 3.

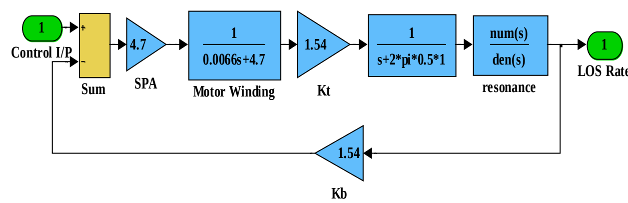

Fig.3 Simulink Subsystem of Servomechanism Gimballed Payload

Figure 4 shows the Simulink model subsystem of LOS tracking system Gyroscope with white noise low pass filter PID based.

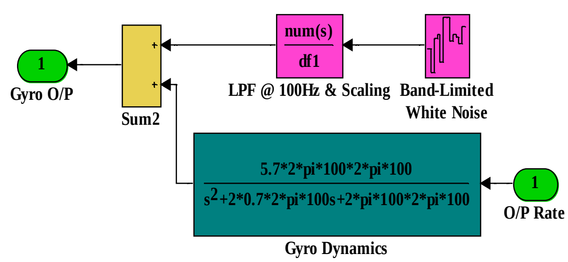

Fig.4 Simulink Model of Subsystem Gyro Dynamics & Band Limited White

The tuned parameters of the PID controllers is given in table I. The effectiveness of the controller for the system response in terms of: Objective of line of sight tracking control system is achieved by the complete Simulink model shown in figure 4.8. The robust control system design tuned parameter of the tracking and stabilization PID controller with filter coefficient given in table 4.5.Servo system with gimbal payload having resonance introduce into servo mechanism which produce small periodic driving force into mechanical system because resonance having tendency to oscillate with greater amplitude at some frequency by which system show oscillatory response to compensate the oscillation to provide line of sight stabilization we have to use stabilization controller into forward path to compensate the resonance. The moving object is treated as disturbance and introduced into the system with coulomb and viscous friction and compared with the angular displacement of the moving target. The tracking controller gives the positive movement of bore sight with the help of servomechanism and system is again stabilized by the negative feedback loop.

TABLE I
SELECTED PARAMETERS OF PID STABILIZATION TRACKING CONTROLLER

PID Tracking Controller Parameter	Gain
Proportional Action Gain (K_{pt})	20
Integral Action Gain (K_{it})	5
Derivative Action Gain (K_{dt})	0.4
PID Stabilization Controller Parameter	
Proportional Action Gain (K_{ps})	39.42
Integral Action Gain (K_{is})	12.81
Derivative Action Gain (K_{ds})	30.42

IV. RESULTS, AND DISCUSSIONS

The line of sight stabilization and tracking control system is implemented with the help of PID controller and lead or lag Compensator. The optimised PID controller response is compared with lead or lag compensator. The responses of effectiveness of the controller in terms of controller parameters. The time response characteristics of LOS stabilization control system using PID controller. The result shows the rise time 0.00567 sec., settling time 0.0311 sec., and peak overshoot 22.8 percent. The time response characteristics of LOS stabilization and tracking control system using PID controller is shown in figure 5. The result shows that the settling time 3.45 seconds, rise time 0.268 seconds and peak overshoot 28 percent. Line of sight stabilization and tracking control system controlled by PID controllers used in the tracking and stabilization loop, the bode frequency response is shown in figure 6 the result shows gain margin 50.8 dB and phase margin 72.5 degree in the line of sight stabilization and tracking control system having bandwidth in the range of 3.7 Hz.

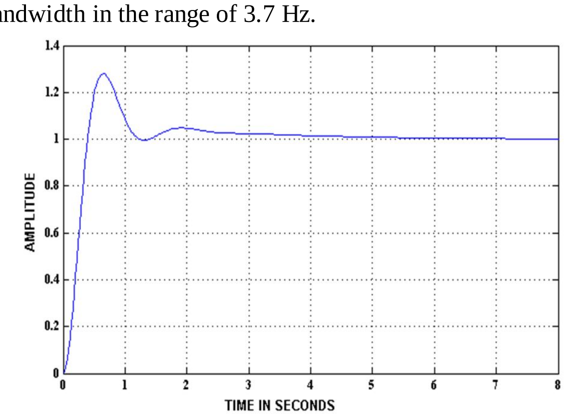

Fig.5 Step Response of LOS Stabilization with Tracking PID Controller

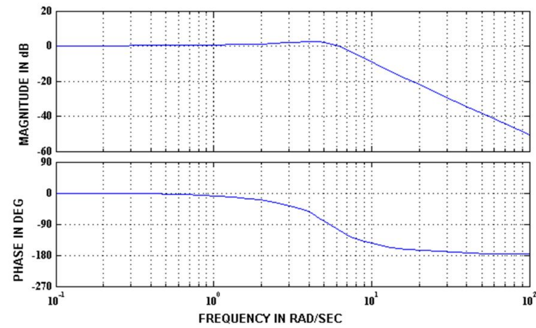

Fig.6 Bode Response of LOS Stabilization with Tracking PID Controller

The LOS stabilization and tracking system using PID controllers are optimized using optimized simplex pattern search method genetic algorithm taking 5000 iterations. The optimized time response characteristics is shown in figure 7. The result shows that settling time 0.11 seconds, rise time 0.025 seconds and peak overshoot 7.53 percent.

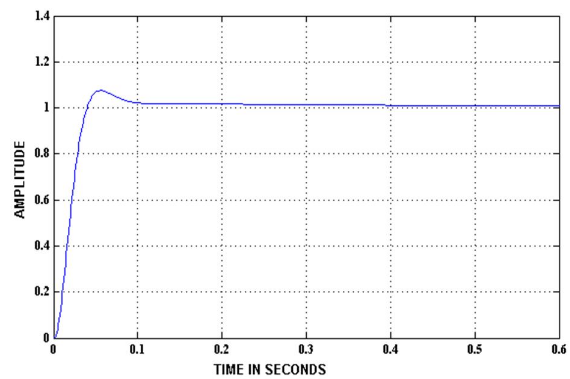

Fig.7 Step Response of Optimized PID Controller LOS with Tracking System

TABLE II
PARAMETER OF OPTIMIZED PID AND PID CONTROLLER

Parameter	PID	Optimized PID
Rise Time t_r	0.27	0.025
Settling Time t_s	3.45	0.11
Peak Overshoot M_p	1.28	7.53
Peak Time t_p	0.65	0.056
Gain Margin G.M.	50.8	40.2
Phase Margin P.M.	72.5	132

The optimized response is achieved as compared to tuned response of PID controllers is better. The stabilization loop optimized controller parameter are K_{ps}=2.10180179690939e-10, K_{is} = 6.28833377115443e-15 and K_{ds} = 7.83994856114218e-08 with filter coefficient 0.0035 and tracking loop PID optimized gain controller parameter K_{pt} = -2545008843229.17, K_{it} = - 1911220082395.12, and K_{dt} = -341602568351.156 with filter coefficient 123.745.The bode frequency response characteristics of LOS stabilization with tracking control system is shown in figure 8. The result shows that gain margin 40.2 dB and phase margin 132 degree and bandwidth in the range of 13.7 Hz.

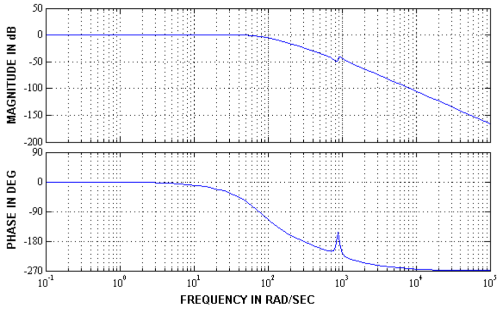

Fig.8 Bode Response of Optimized PID Controller LOS with Tracking System

V. CONCLUSION

Non-linear behaviour of line of sight stabilization and tracking control system introduces a challenge for the design of low bandwidth, faster response and negligible disturbances. In the real time control system application which is having large environmental disturbances, resulting undesired echoes should be reduced. The present work gives an overview of PID and lead or lag controller. Besides these controllers present work optimized through the pattern search using genetic algorithm method. In this system PID controllers are used in the stabilization and tracking loop respectively and the challenge in system is to tune both the controllers simultaneously. To achieve the response of tracking of moving target controller parameters are evaluated in term of rise time, settling time and percentage of peak overshoot. To overcome the limitation of PID controller, lead or lag controller has been designed. Simulation response of lead or lag controller shows that it reduces the settling time, rise time as compare to PID controller. To achieve the further improvement of PID controller optimized by using the pattern search genetic algorithm method. The simulation results shows that it improve the step response of the system reduces the settling time, rise time and bandwidth of the system.

VI. REFERENCES AND BIBLIOGRAPHY

[1] Michael K. Masten and Henry R. Sebesta, “Line-of-Sight Stabilization/Tracking Systems: An Overview”, Proceeding of the IEEE Conference on American Control, Minneapolis, MN, USA, pp. 1477-1482,10-12 June 1987.

[2] Peter J. Kennedyand Rhonda L. Kennedy, “Direct Versus Indirect Line of Sight (LOS) Stabilization”, IEEE Transactions on Control Systems Technology, Vol. 11, and No.1, pp. 3-15 January 2003.

[3] Vladimir N. Dobrokhodov, Isaac I. Kaminer, Kevin D. Jones, and Reza Ghabcheloo, “Vision-Based Tracking and Motion Estimation for Moving targets using Small UAVs”, Proceedings of the IEEE Conference on American Control Minneapolis, Minnesota, USA, June 14-16, 2006.

[4] Dr. H. Ambrose, Z. Qu and R. Johnson, “Nonlinear robust control for a passive line-of-sight stabilization system”, Proceeding of the IEEE conference on Control Application, Mexico City, Mexico, pp. 942-947, September 5-7, 2001.

[5] Tian Qi, Wenzhou Su and Jie Chen, “Optimal Tracking Design and Performance Analysis for LTI Systems with Quantization Effects”, Proceeding of the 48th IEEE Conference on Decision and Control, China, pp.4945-4950, December 16-18, 2009.

[6] Chong Jiang, Dexin Zou, Qingling Zhang, and Heli Hu, “Optimal Tracking Control for a Class of Large-Scale Interconnected system with Time-varying Delay”, Proceeding of the International Conference IEEE on Control and Automation Guangzhou, China, pp.2529 – 2534, May 30 June 1, 2007.

[7] Zhong-Hua Li and Miroslav Krstic, “Optimal Design of Adaptive Tracking Controllers for Nonlinear Systems”, Proceedings of the American Control Albuquerque conference, New Mexico,Vol. 2, pp. 1191-1197, June 1997.

[8] Hongwei Zhang, Frank L. Lewis, and Zhihua Qu “Lyapunov, Adaptive, and Optimal Design Techniques for Cooperative Systems on Directed Communication Graphs”, IEEE Transactions on Industrial Electronics, Vol. 59, pp. 3026-3041,7 July 2012.

[9] Yandong Zhao and Xianli Chen, “Design of Optimal Tracking Controller for Systems with Control-Affine Form”, Proceedings of the IEEE International Conference on Automation and Logistics, Jinan, China, pp.2472-2476, August 18 - 21, 2007.

[10] Maria Nevia Ferrara and Andrea Torre, “Automatic moving targets detection using a rule-based system: comparison between different study cases”, Proceeding of international symposium on Geosciences and remote sensing, Vol. 3, pp. 1593-1595, 6-10 July 1998.

[11] Liang Sun and Hong-Wei GAO, “Approximately Optimal Tracking Controller Design for Nonlinear Interconnected Large-Scale Systems with Time Delays”, Proceeding of the 7th World Congress on Intelligent Control and Automation, Chongqing, China, pp. 905-910,25 - 27 June 2008.

[12] Cheng-Ming Zhang, Gong-You Tang and Shi-Yuan Han, “Approximate design of optimal tracking controller for systems with delayed state and control”, Proceedings of the International Conference on Control and Automation Christchurch, New Zealand, pp. 1168-1172, 9-11 December 2009.

[13] Ying-Lu Zhang and Gong-You Tang, “Approximate Design of Optimal Tracking Controller for Linear Systems with Time-delay”, Proceedings of the International Conference on Systems, Man, and Cybernetics, Taipei, Taiwan,pp.4557-4562, 8-11 October 2006.

[14] Xiao-Han Wang, Gong-You Tang, and Hai-Hong Wang, “Approximate Design of Optimal Output Tracking Controller for Time-Delay Systems with Sinusoidal Disturbances”, Proceedings of the 9thInternational Conference on Control, Automation, Robotics and Vision, Singapore, pp. 1-6, 5-8 December 2006.

[15] Alan J. Lipton, Hironobu Fujiyoshi and Raju S. Patil, “Moving Target Classification and Tracking from Real-time Video”, Proceedings of the IEEE 4th Workshop on Applications of Computer Vision, Princeton, pp.8-14, 19-21 October 1998.

[16] Peter I. Corke and Seth A. Hutchinson, “Real-Time Vision, Tracking and Control”, Proceedings of the International Conference on Robotics & Automation, San Francisco, CA, pp.622-629, 24-28 April 2000.