IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 4, April 2016

Pitch and Yaw Angle Control in Under Water Vehicle Using P/PI/PD/PID and LQR Controllers

Bhupendra Kumar [1], Mrs. Ekta Tamrakar [2]

M.Tech Scholar, Dept of Electronics and Telecommunication Engg., Bhilai Institute of Technology, Durg, India[1]

Assistant Professor, Dept of Electronics and Telecommunication Engg., Bhilai Institute of Technology, Durg, India[2]

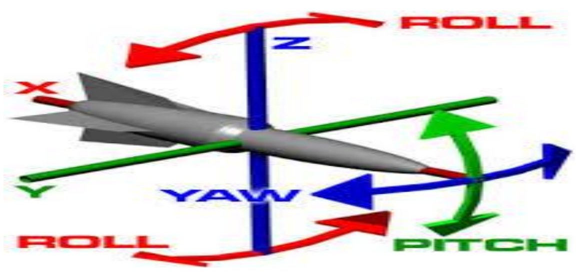
Abstract: In various research and experimental areas under ocean without human intervention we need a vehicle which can accomplish the required task is known as "UNMANNED UNDER WATERVEHICLE". In this project we will efficiently model the system and perform the various simulation tasks for pitch angle and yaw angle control by using classical control techniques i.e. P,PI,PD,PID and linear quadratic controller(LQR). By using these control techniques we will obtain the best possible performance technique to control the pitch angle and yaw angle and also here we will close compare the various parameters of different controllers.

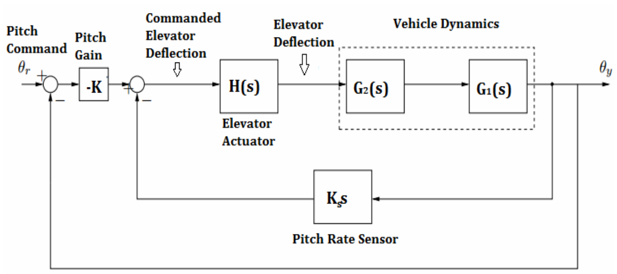
Keywords: MATLAB, P, PI, PD, PID, LQR controllers.

I. INTRODUCTION

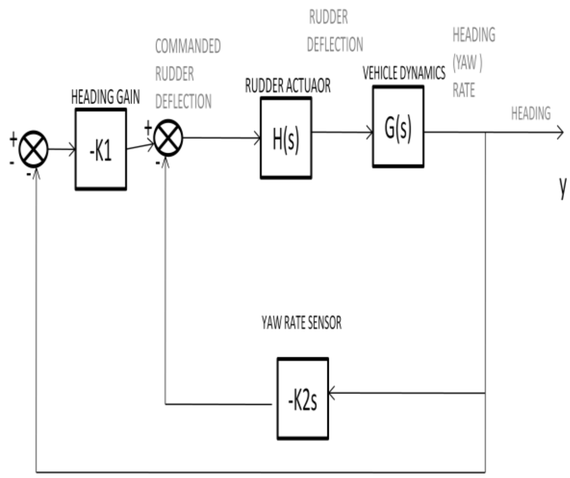
As we know that 70% of the Earth is covered with water and in order to explore various resources under oceans, mankind depends on developing underwater vehicles and employing them. There are various types of underwater vehicles which can be classified into two categories as manned and unmanned under water systems. In various research and experimental areas under the water without human intervention we need "UNMANNED UNDER WATER VEHICLE" [1]. In manned under water system, we have military submarines and non-military submersibles vehicle operated for underwater exploration and assessment. An Autonomous Underwater Vehicle (AUV) is an undersea system which use self power and controlled by an onboard embedded computer while doing a specified task[1].

Pitch angle: Pitch angle is controlled by pitch control system. Figure (1) shows the representation of pitch angle and corresponding pitch control loop is shown in Figure (2).In pitch control loop we will control the pitch angle by using the elevator actuator.





Yaw angle: Yaw angle is controlled by heading control system. Figure (1) show the representation of yaw angle and corresponding heading control loop is shown in Figure (3).In heading control loop we will control the yaw angle by using the rudder actuator.



II. PROPOSED SYSTEM MODELLING

Pitch control system:-

From Figure(2) the respective block equation of elevator actuator and vehicle dynamics are-

$$H(s) = \frac{2}{(s+2)} \quad (1)$$

$$G1(s) = \frac{-0.125(s+0.435)}{s^2+0.226+0.0169} \quad (2)$$

$$G2(s) = \frac{(s+0.435)}{(s+1.23)} \quad (3)$$

Open loop system-

The open loop system are-

$$G(s) = \frac{-0.125*2(s+0.435)}{(s+2)(s+1.23)(s^2+0.226s+0.0169)} \quad (4)$$

And the step response of this system is shown below-

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 4, April 2016

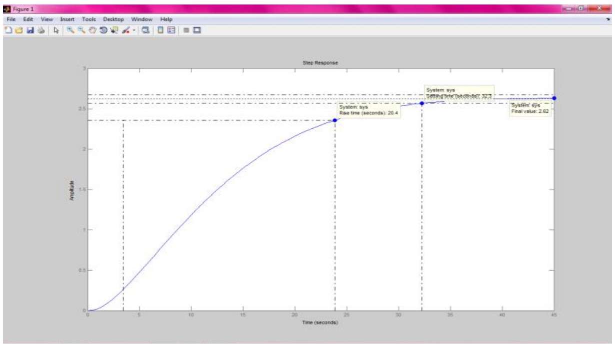


Fig (4)- step response of open loop pitch control system.

Close loop system-
Close loop system are-

$$\frac{\theta_y(s)}{\theta_r(s)} = \frac{0.25*k1(s+0.435)}{s^4+3.456s^3+3.457s^2+(0.719+0.25k1)s+(0.0416+0.109k1)} \quad (5)$$

By using Routh-Hurwitz criteria the stability range of this system are- 0<k<25.87
Now the response of this system for different value of k is shown, Figure (5) show response using k=5, Figure(6) shown below response using k=20 [2].

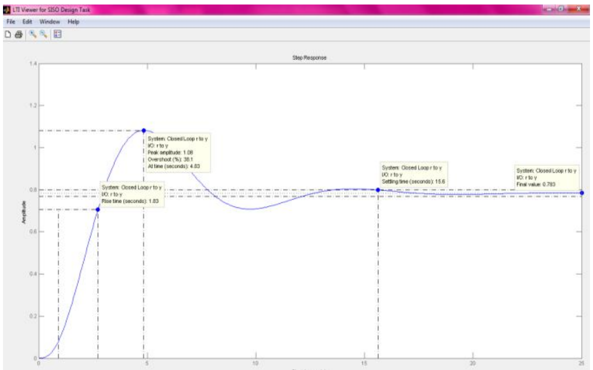


Fig (5)-pitch control system response for k=5

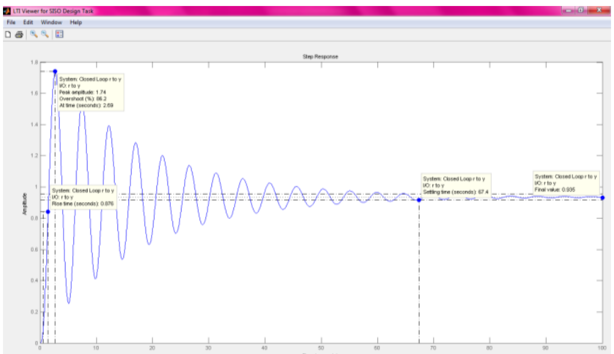


Fig (6)-pitch control response for K=20

Heading control system:-
From Figure(3) the respective block equation of rudder actuator and vehicle dynamics are-

$$H(s) = \frac{2}{(s+2)} \quad (6)$$

$$G(s) = \frac{-0.125(s+0.435)}{s(s+1.29)(s+0.193)} \quad (7)$$

Open loop system-
The open loop system are-

$$G(s) = \frac{-0.125(s+0.435)}{(s+2)(s+1.29)(s+0.193)s} \quad (8)$$

And the step response of this system is shown below-

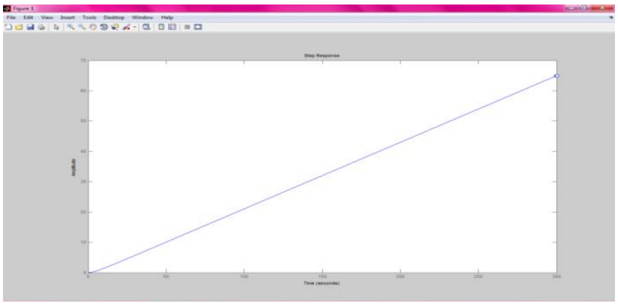


Fig (7)-step response for open loop heading control system

Close loop system-
close loop system are-

$$\frac{\theta_y(s)}{\theta_r(s)} = \frac{0.25*k1(s+0.437)}{s^4+3.483s^3+3.4649s^2+(0.60705+0.25k1)s+(0.10925k1)} \quad (9)$$

By using Routh-Hurwitz criteria the stability range of this system are- 0<k<26.43 .
Now the response of this system for different value of k is shown below, Figure(8) show response using k=5, Figure(9) show response using k=15 [2].

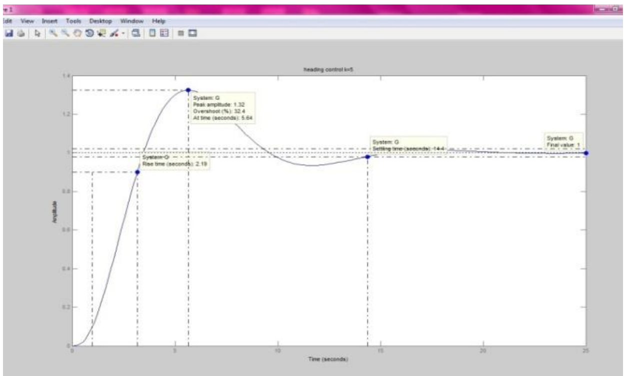


Fig (8)- heading control system response for k=5.

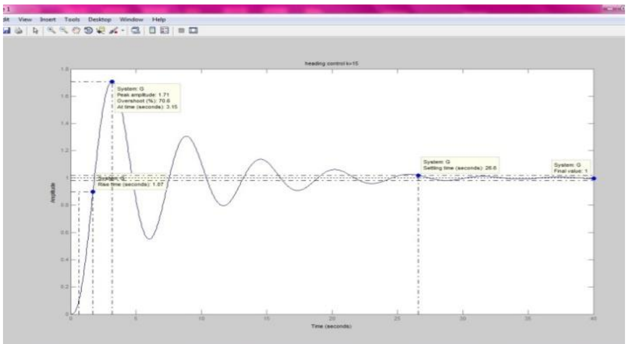


Fig (9)- heading control system response for k=15

Hence we have discussed here the response for proportional controller. To improve the response we will use PI, PD, and PID controller.

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 4, April 2016

PI controller:
Now by using pidtool & sisotool in MATLAB the response OF Pitch control system using PI controller shown below-

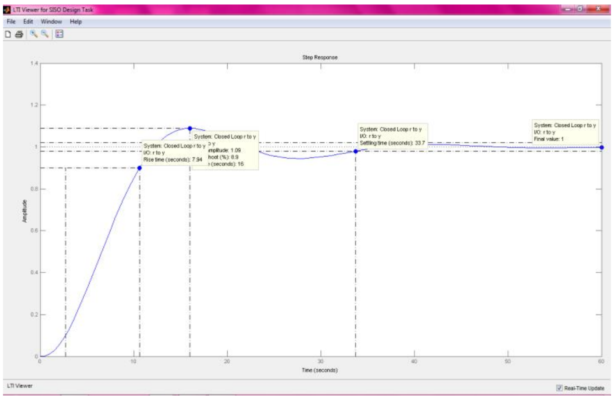


Fig (10) – pitch control system using PI controller.

Response of heading control system using PI controller shows below-

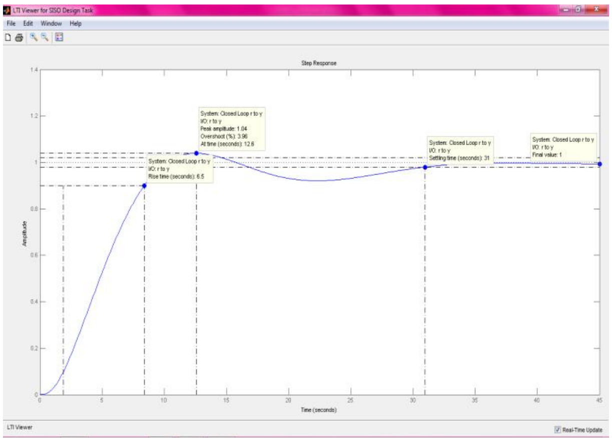


Fig (11)- heading control system using PI controller.

PD controller:
Using pidtool & sisotool in MATLAB the response of Pitch control system using PD controller shown below-

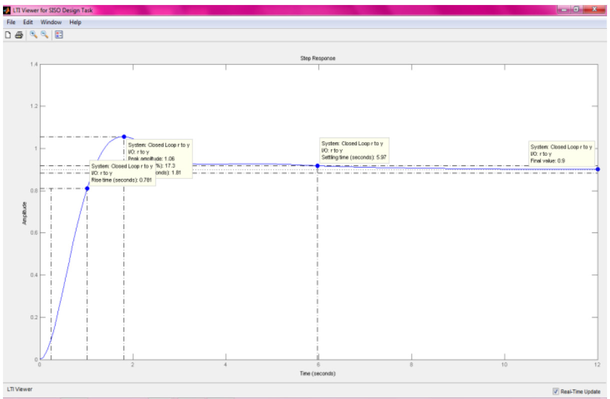


Fig (12)- pitch control system using PD controller

Response of Heading control system using PD controller shows below-

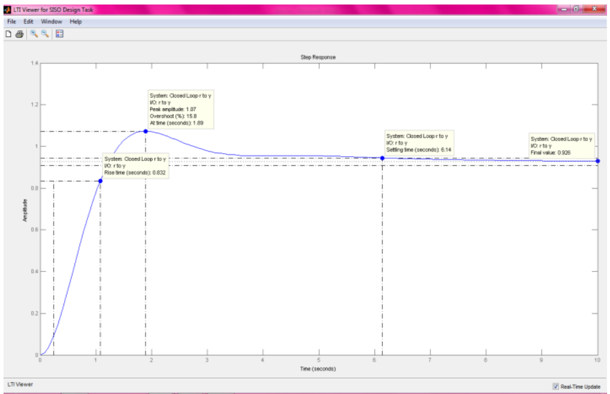


Fig (13)- heading control system using PD controller.

PID controller:
Using pidtool & sisotool in MATLAB the response of Pitch control system using PID controller shown below-

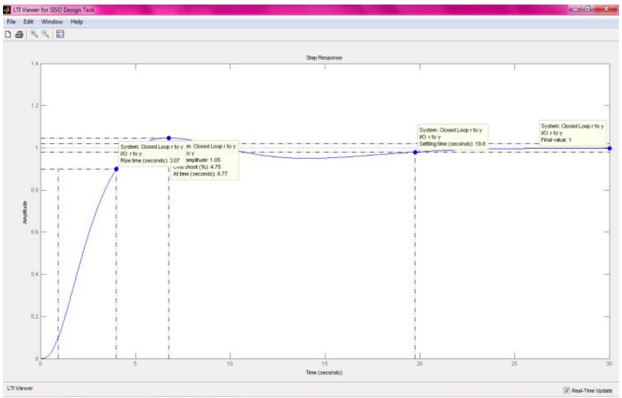


Fig (14)- pitch control system using PID controller.

Response of Heading control system using PID controller shows below-

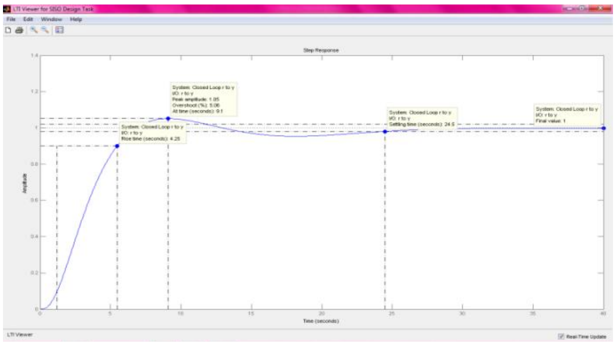


Fig (15) - heading control system using PID controller.

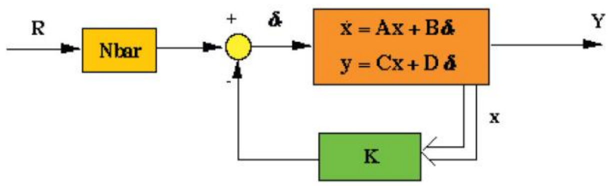
LINEAR QUADRATIC REGULATOR

An advantage of the quadratic optimal control method over the pole placement method is that the former provide the systematic way of computing the state feedback control gain matrix. LQR is a method in modern control theory that used state-space approach to analyze such a system. Using state space methods it is relatively simple to work with a multi-output system. The system can be stabilized using full-state feedback system. In designing LQR controller "lqr" function in Matlab can be used to

IJARCCE
ISSN (Online) 2278-1021
ISSN (Print) 2319 5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 4, April 2016

determine the value of the vector K which determined the feedback control law. In the Linear Quadratic Regulator (LQR) design method it focuses on the selection of Performance Index (PI) weighting matrices Q and R which are the design parameters. By the modifications of Performance Index a wide range of performance objectives can be obtained[7].

Block diagram of LQR with full-state feedback is shown below-



Pitch control system tuning –

Tuning is done by choosing two parameter values, input R= 0.01 and Q=$w * C^T * C$ where C^T is the matrix transpose of C from state equation given below-

$$A=\begin{bmatrix} -3.4560 & -3.4500 & -0.7193 & -0.0416 \\ 1.0000 & 0 & 0 & 0 \\ 0 & 1.0000 & 0 & 0 \\ 0 & 0 & 1.0000 & 0 \end{bmatrix}$$

$$B=\begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$C= [0 \quad 0 \quad 0.2500 \quad 0.1088]$$

$$D= [0]$$

The weighting factor w can be varied in order to modify the step response of the controller, here we have chosen w= 50. (LQR) method to generate the "best" gain matrix K, without explicitly choosing to place the closed loop poles in particular locations. To obtain the desired output, we can scale the reference input so that the output does equal the reference in steady state. This can be done by introducing a pre compensator scaling factor called Nbar. Here for pitch control system we have chosen Nbar=70.

Response of pitch control system using LQR controller-

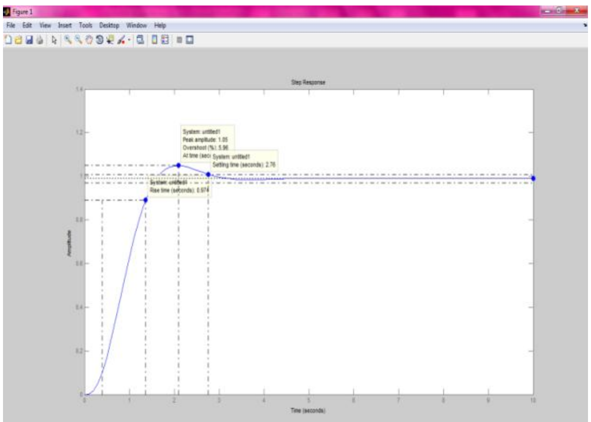


Fig (16)- pitch control system response using LQR.

Heading control system tuning-

Here state space equation are-

$$A=\begin{bmatrix} -3.4830 & -3.4600 & -0.6071 & 0 \\ 1.0000 & 0 & 0 & 0 \\ 0 & 1.0000 & 0 & 0 \\ 0 & 0 & 1.0000 & 0 \end{bmatrix}$$

$$B=\begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$C= [0 \quad 0 \quad 0.2500 \quad 0.1093]$$

$$D= [0]$$

R=0.01

W=50

Response of heading control system using LQR controller-

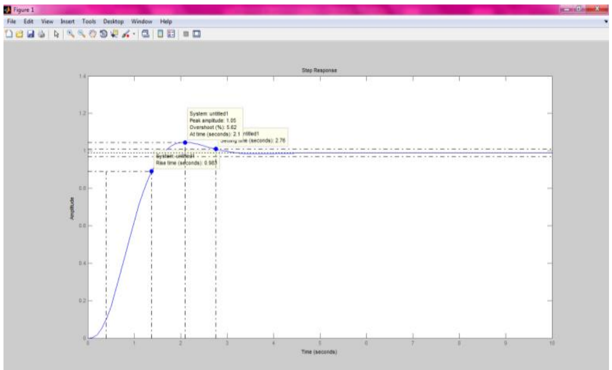


Fig (17)- heading control system response using LQR.

III. RESULTS

Using the above control technique i.e. P,PI,PD,PID the result of various parameters of different controllers for pitch control system shown in table (1). And for heading control system shown in table (2).

Table (1)-parameters for pitch control system-

Parameters	K=5	K=15	PI	PD	PID	LQR
Tr(sec)	1.83	0.876	7.94	0.781	3.07	0.974
Tp(sec)	4.63	2.69	16	1.81	6.77	2.1
Ts(sec)	15.6	67.4	33.7	5.97	19.8	2.76
Overshoot (%)	38.1	86.2	8.9	17.3	4.75	5.96
Peak amp.	1.06	1.74	1.09	1.06	1.05	1.05

Table (2)-parameters for heading control system-

parameters	K=5	K=15	PI	PD	PID	LQR
Tr(sec)	2.19	1.07	6.5	0.832	4.25	0.983
Tp(sec)	5.64	3.15	12.6	1.89	9.1	2.1
Ts(sec)	14.4	26.6	31	6.14	24.5	2.76
Overshoot (%)	32.4	70.6	3.96	15.8	5.09	5.62
Peak amp.	1.32	1.71	1.04	1.07	1.05	1.05

From the simulation and analysis of different type of controllers LQR is giving best optimal response compare to other controllers. However PD controller is not much lagging and can be used whenever our task requires not much precision and when we want to reduce the cost.

IV. CONCLUSION

In this paper pitch and yaw angle control system have been simulated by using P,PI,PD,PID and LQR controller and the outcome of various parameter values is shown in tables. From this analysis we conclude here that LQR controller is giving optimal response as compare to other controllers. The LQR controller giving very improved response particularly in case of settling time and overshoot however the overshoot is approximately same in case of PID and LQR but there is much improvement in settling time in case of LQR.

ACKNOWLEDGMENT

We express our thanks to **Mr. R. M. Potdar,** Sr. Associate Professor, Dept. of ETC, BIT Durg and acknowledge the timely help of **Dr. T. Siva Kumar,** Sr. Associate Professor, Dept. of ETC, BIT Durg. We warmly thank **Dr. Manisha Sharma,** HOD Dept. of ETC, BIT Durg for her kind support and guidance. We render our indebtedness to **Dr. Arun Arora,** Principal, BIT Durg for his constant encouragement given to us throughout the research work. Above all, I render my gratitude to the SUPREME ALMIGHTY AUTHORITY who bestowed self confidence, ability, and strength in me to complete this work.

REFERENCES

1. Mahendra Pratap Singh, Bilas Chowdhury (2011). Control of autonomous underwater vehicles (Unpublished dissertation). Department of Electrical Engineering National Institute of Technology Rourkela.
2. Nise, S. Norman (2015). Control System Engineering, John Wiley & Sons, Sixth Edition, international student edition, India, endpapers, ISBN: 978-81-265-3728-0.
3. Mohammad jawed masud, Faisal fayyaz qureshi, Abdul rehman chishti, (2014). Comparison of pitch control system for an unmanned free-swimming submersible vehicle with pd controller and linear quadratic regulator using matlab. Tomul LX (LXIV), Fasc. 3-4, 20.
4. Khalid isa & MR arsad, (2012).Buoyancy driven under water glider modeling and analysis of motion control. Indian journal of geo marine, vol. 41(6),pp. 516-526.
5. Maziyah mat noh,Mohd rizal arshad, Rosmiwati mohd mokhtar, (2011). Depth and pitch control of USM underwater glider: performance comparion PID vs LQR. Indian journal of geo marine science,vol. 40(2), pp. 200-06.
6. .Preeti and Dr. Narendra Singh Beniwal, (2012). Comparison of Conventional and Fuzzy P/PI/PD/PID Controller for Higher Order Non Linear Plant with High Dead Time. International Journal of Scientific and Research Publications, vol-2, ISSN 2250-3153.
7. Labane Chrif, Zemalache Meguenni Kaddac,(2014), Aircraft Control System Using LQG and LQR Controller with Optimal Estimation-Kalman Filter Design, 3rd International Symposium on Aircraft Airworthiness, ISAA 2013, Procedia Engineering 80 (2014) 245 – 257.
8. Jisha Shaji, Aswin R B, August 2015, Pitch Control of Aircraft Using LQR & LQG Control, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 4.
9. Mrs. M. Bharathi,Golden Kumar, April-2013, An LQR Controller Design Approach For Pitch Axis Stabilisation Of 3-DOF Helicopter System, International Journal of Scientific & Engineering Research, Volume 4, Issue 4.
10. Ruba m.k. ali,mulla hummadi, 2012, simulation of optimal speed control for a dc motor using linear quadratic regulator,journal of engineering, volume 18.
11. Nurbaiti Wahid, Mohd Fua'ad Rahmat, 2010, Pitch Control System Using LQR and Fuzzy Logic Controller, IEEE Symposium on Industrial Electronics and Applications (ISIEA 2010)