Implementation of Two Axises Platform Using PID Controller

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Abstract

This paper describes the design and implementation of two axis platform controller. The term two axis platform is a machine which rotate in two degrees of freedom, mainly it has two axis, one rotate about vertical axis and the other rotate about horizontal axis. The paper deals with two areas, study the DC motor as actuator and how it could be controlled using the computer software ("MATLAB", "Integral") technique to the integrated joint dynamic model and an independent joint control scheme was drive using a classic approach. The results obtained gave the required movement for the platform in terms of fluidity and smoothness in moving from one position to another one.

Keywords: PID Controller, multi-axis, MATLAB, brushless DC motors MAXON**.**

1. Introduction

In the industrial applications, design for the single axis motion control systems has been well investigated with traditional or modern control strategies [1]. Recently, precise contour control for the multi-axis systems has attracted much attention. As an example, defined a position vector and applied a modified and transform to determine the dominant position error vector so as to correct the position error vector in a two axes platform. To achieve a high degree of position and deposition accuracy, a coordination controller using DC servo motor [2].

The main goal of this paper was to develop a model of the two axises platform, design axises control schemes for (current, velocity, position) using classical approach.

Pitch, yaw and roll are the three dimensions of movement when an object moves through a medium. The terms may be used to describe an aero plane's movements through the air. They are also applied to fish moving through water, and spacecraft moving through space, there are in fact six degrees of freedom of a rigid body moving in three-dimensional space.

As the movement along each of the three axes is independent of each other and independent of the rotation about any of these axes, the motion has six degrees of freedom. As illustrated in Figure (1), the Pitch axis which is for nose up or tail up, Yaw axis which is for nose moves from side to side, and finally, the Roll axis which aids a circular (clockwise or anticlockwise) movement of the body as it moves forward.
The surfaces of a plane and the fins of a fish have a similar function. They serve to adjust the object's attitude as it moves through the fluid, submarines face the same dynamic control problems as fish do [1].

The platform can move in two planes (side to side, up and down), and can also rotate around two axis (horizontal, and vertical), so there are four options for changing direction of the motion.

The controllers were implemented using selected hardware which shows satisfactory results.

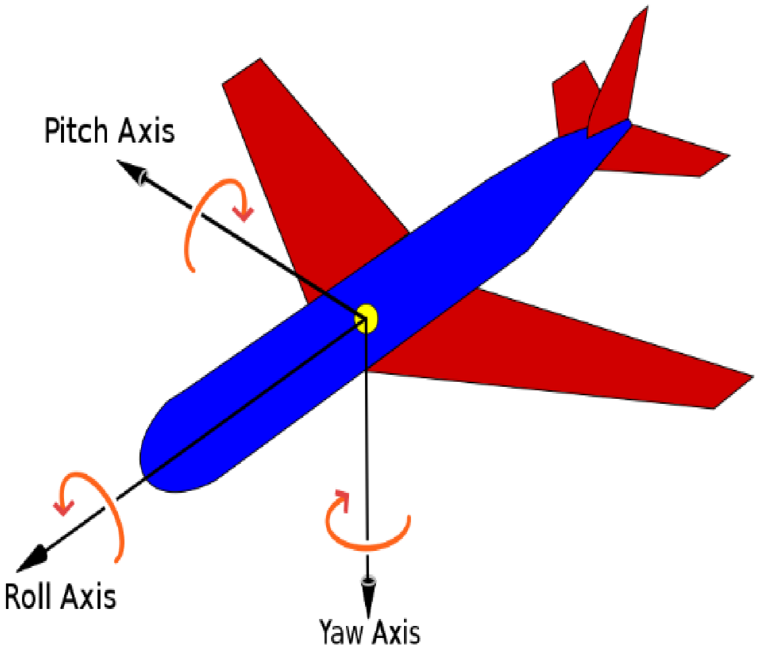

Figure 1: The position of all three axes, with the right-hand rule For describing the angle of its rotations

2. The Proposed System

The proposed system as seen in the Figure 2 consists of four main parts, two axis platform, two motors with drivers, a power supply, and wires for connections, and a programming unit.

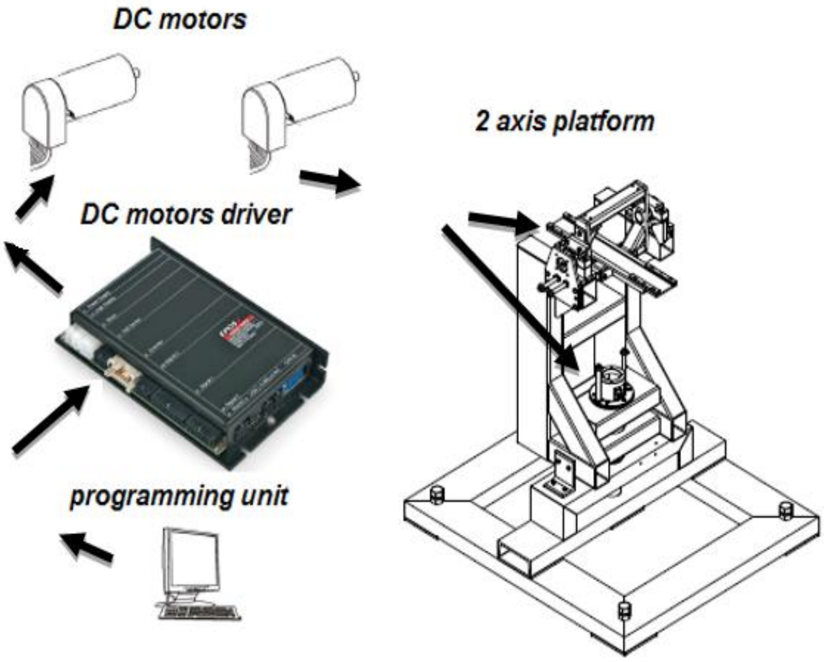

Figure 2: System Assembler

The real implementation of two axes platform is shown in Figure 3

Figure 3: Two axes platform with motors

A two brushless DC motors MAXON type were used as seen in Figure (4) to carry out the required movement and they will be controlled by motors driver **EPOS 7010**.

Figure 4: Brushless DC motors MSXON type

3. Controller Design

3.1 Integral controllers

A closed loop control system is one that determines a difference in the desired and actual condition (the error) and creates a correction control command to remove this error, one form of controller widely used in industrial process control is called three terms, or PID controller, PID control demonstrates three ways of looking at this error and correcting it as shown in Figure 5.

The first way is the (P of PID), the proportional term, this term represents, the bigger the error, the bigger the correction [3].
The (I in PID) is the second way which is for the integral of the error over time. The integral term produces a correction that considers the time where the error has been present. Stated in other words, the longer the error continues, the bigger the correction. Lastly, the (D in PID) way which is stands for derivative. In the derivative term, the corrective action is related to the derivative or change of the error with respect to time. [3]

In other words, the faster the error is changing, the bigger the correction. Control systems can use P, PI, PD, or PID in creating corrective actions. The problem generally is “tuning” the system by selecting the proper values in the terms [3].

The transfer function of the controller is:

$$\boldsymbol{Gc(s) = Kp + \frac{Ki}{s} + sKd} \tag{1}$$

$$\boldsymbol{Gc(s) = \frac{Kds^2 + Kps + Ki}{s}} \tag{2}$$

The controller provides a proportional term, an integration term, and a derivative term. The equation for the output in the time domain is:

$$\boldsymbol{u(t) = Kpe(t) + Ki \int e(t)dt + Kd\frac{de(t)}{dt}} \qquad (3)$$

The three-mode controller is also called a PID controller because it contains a proportional, an integral, and a derivative term [2].

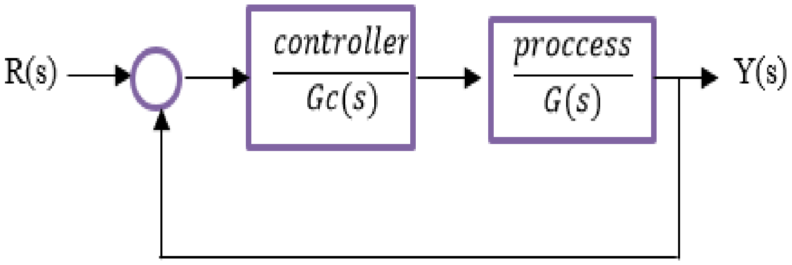

Figure 5: Closed-loop systems with a controller

3.2DC motor modeling and PID controller

3.2.1 Physical setup

A common actuator [6] in control systems is the DC motor which directly provides rotary, the electric equivalent circuit of the armature and the free-body diagram of the rotor are shown in Figure 6.

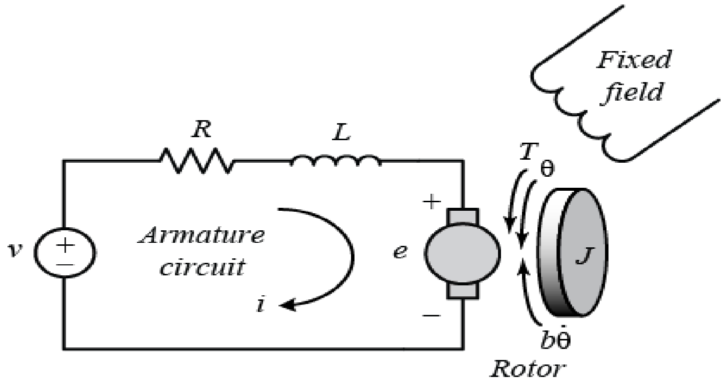

Figure 6: The electric DC motor equivalent circuit of the armature and the free-body diagram of the rotor

3.2.2 Plant to be controlled

The plant to be controlled as illustrated in Figure (7) is the actual DC motor base assembly with a simulated inertial load platform. The simulated moment of inertia is less than the actual DC motor moment of inertia. The effective gear ratio is 93:1 (from the motor armature shaft to the actual load) [6].

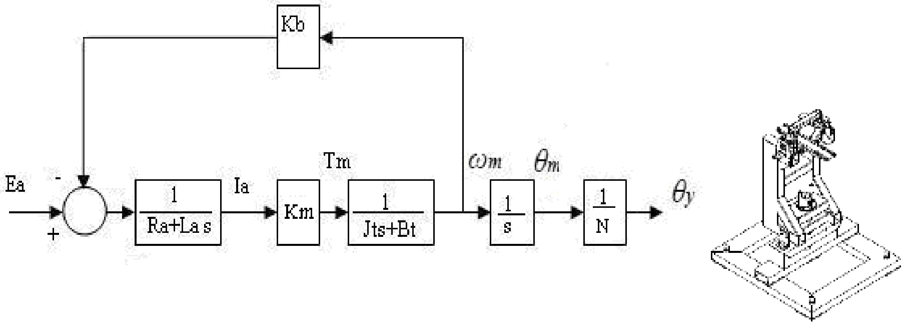

Figure 7: Block diagram of integrated model for (YAW or PITCH axis rotation)

The sensor used is a 500--line optical encoder. It is directly mounted to the armature shaft, so that it rotates at the armature speed. Either of the two encoder signals, A~or~B can be used to measure velocity. Since there are 500 pulses per armature revolution, the number of pulses per load revolution is (93 shaft rev./1 load rev.) * (500 pulses /shaft rev.) [5].

The open loop transfer function of single joint relating the angular displacement to the applied voltage of the joint platform is as follows [6]:

$$\boldsymbol{Gs = \frac{\theta y}{Ea} = \frac{Km}{Ns[Ra(Jts + b) + KbKm\, l}} \qquad (4)$$

SO:

$$\boldsymbol{Gs = \frac{\theta y}{Ea} = \frac{Km}{Ns[sRaJt + Rab + KbKm]}} \qquad (5)$$

$$\boldsymbol{Gs = \frac{Km}{Ns[Ra(Js + b) + KbKm]}} \qquad (6)$$

$$\boldsymbol{Gs = \frac{Km\,/(Ra + KbKm)}{N\,s(\tau 1\, s\, +\, 1)}} \qquad (7)$$

$$\boldsymbol{\tau 1 = \frac{RaJ}{Rab + KbKm}} \qquad (8)$$

And the relation between the angular velocity *ωm(s)* to the armature voltage *Ea*is given by:

$$\frac{\boldsymbol{\omega m}(\boldsymbol{s})}{\boldsymbol{Ea}(\boldsymbol{s})} = \frac{\boldsymbol{Km}}{[\boldsymbol{s\,RaJt} + \boldsymbol{Ra\,b} + \boldsymbol{KbKm}]} \qquad (9)$$

Where:

Km= (Nm/A) torque constant
R= (ohm) resistance
L= (Hennery) inductance
*Kb= (rad*sec/V) back emf*
N= gear ratio

The transfer function of the Maxon Motor can be derived using data from Characteristics of brushless dc motor in the reference [5]

4. Controller Architecture

The EPOS controller architecture furthermore explained will be mapping of internal controller parameters to controller parameters in SI units, and vice versa. In addition to PID position regulation, are described.

The current control loop is used in all operation modes. In the position and velocity based modes there is also a superior position or velocity controller used.

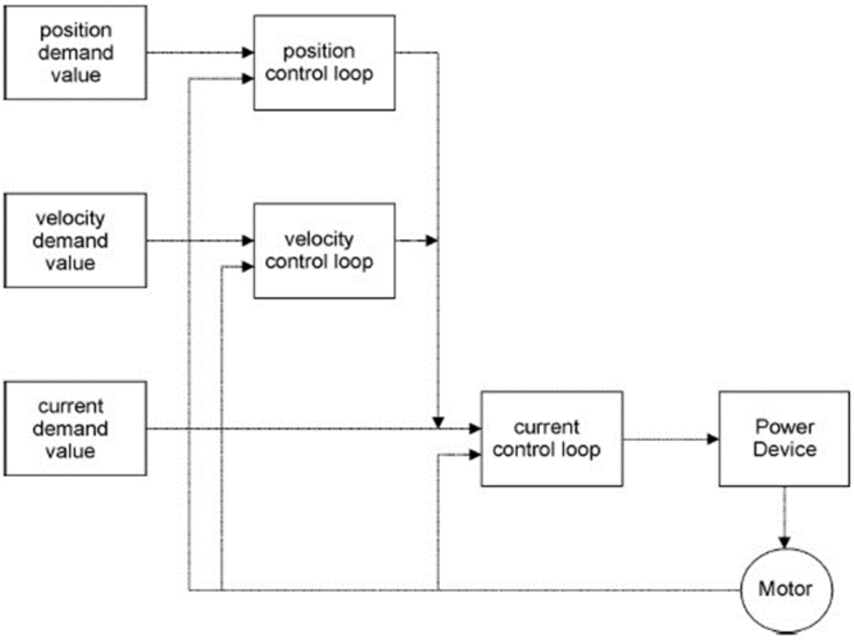

Figure 8: Controller Architecture

5. Plant Model using MATLAB Simulink.

In general, the mathematical equations representing a given system that serves as the basis for a Simulink model can be derived from physical laws. In this paper we will demonstrate how to derive a mathematical model and then implement that model in Simulink and how to employ Simulink to design and simulate the PID controller for a system [7]. The Block Diagram for plant using MATLAB Simulink is shown in Figure 9.

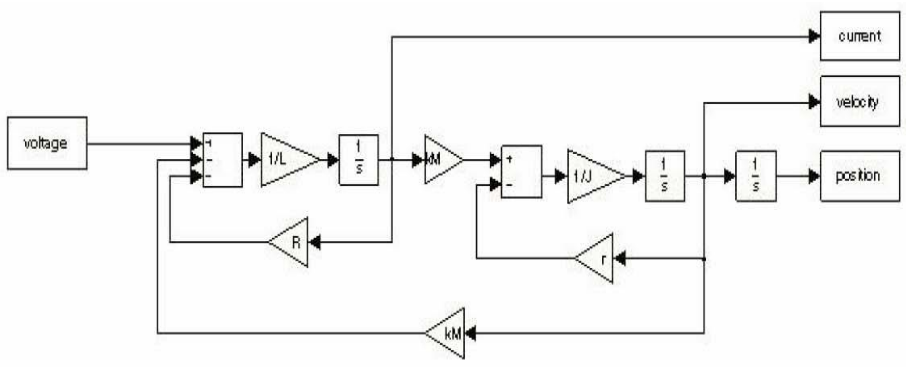

Figure 9: Block Diagram for plant using MATLAB Simulink

$K_m = 147\ mNm / A$

$J = J_{Motor} + J_{load}$

$$r = \frac{KmIo}{\frac{n0\ 2\pi\ rad}{1} \times \frac{1min}{60s}}$$

$$r = \frac{44.7mNm}{324.6\ rad^2} = 137.7\mu Nm\ /\ rad\ /s$$

6. Current Controller regulation

The plant is connected to the PI current controller.

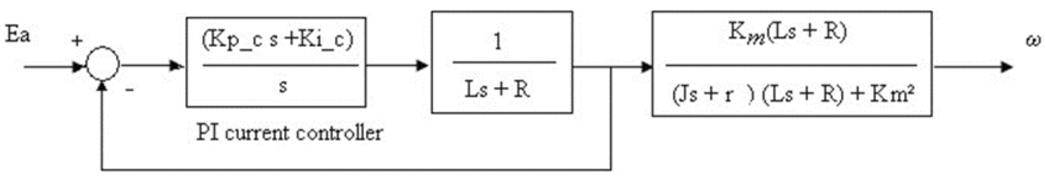

Figure 10: Current Regulation, Block Model

Current controller parameters can be used in analytical calculations, respectively numerical simulations via transfer function:

Ccurrent = *kp* + *ki / s*

We are used Ziegler-Nichols tuning methods to tuning PI current controller is:

Kp_c = 16 Ω , Ki_c = 31.28 k Ω/s

While:

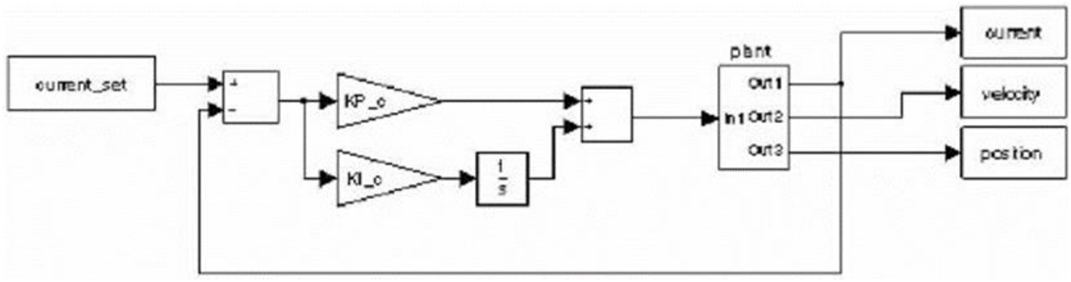

Figure 11: PI current controller block diagram

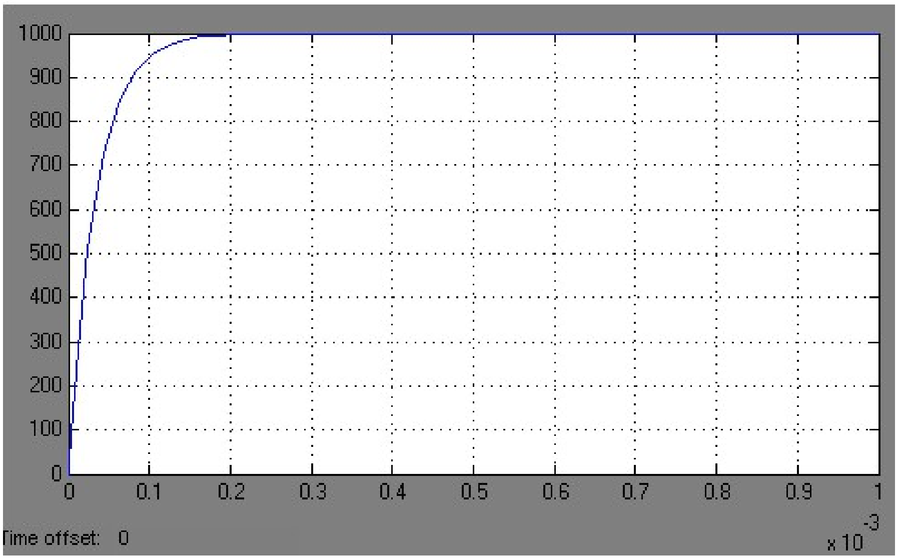

Figure 12: Current Regulation, simulated

7. Velocity Controller regulation

Designing a PI Compensator Using the Ziegler-Nichols Tuning Algorithm method.

$$G(s) = \frac{(Kp\_c\, s + Ki\_c) * Km\,(Ls + R)}{s\,[(Ls + R)\,[(Js + r)\,(Ls + R) + Km^2]]}$$

The PI velocity controller is connected to current regulation.

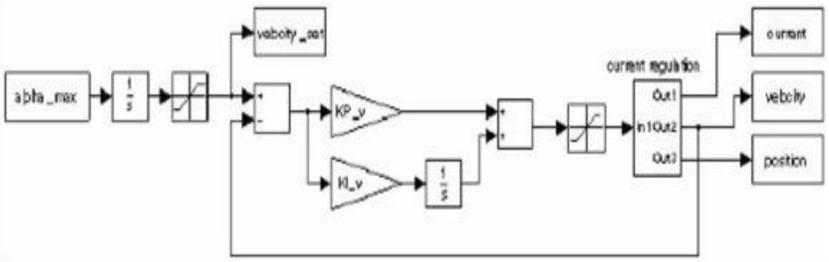

Figure 13: Velocity Regulations, Block Model

The PI velocity controller is:

$$Kp\_v = 100 \; \frac{m\,A}{(rad/s)} \quad ; \quad Ki\_v = 0.4 \; \frac{A/s}{(rad/s)}$$

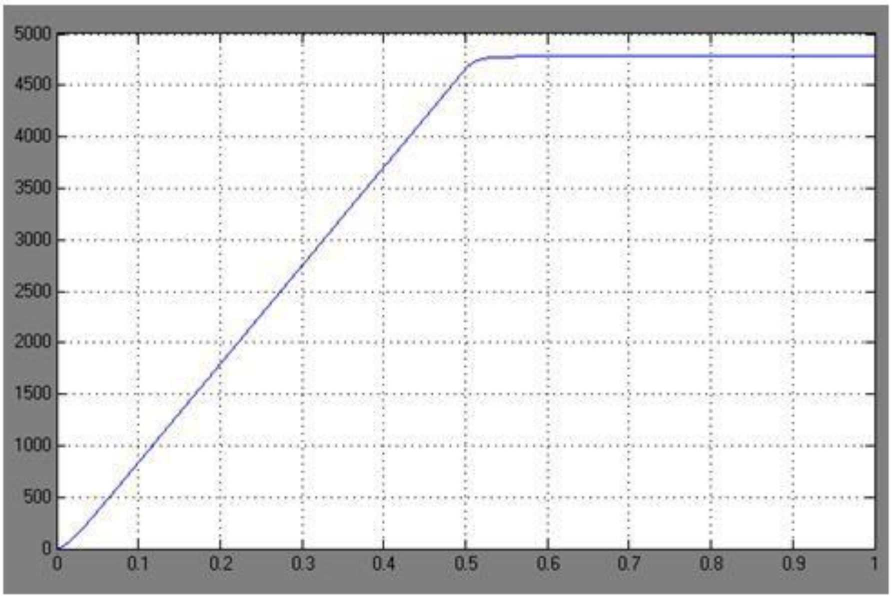

Figure 14: Velocity Regulation, simulated

8. Results and Discussion

Whereas the system Input is the voltage at the motor winding and the system outputs are current, velocity or position.

This was the result of the mathematical process of the integrated system (the platform, motors and system feedback). After the simulation process with the Simulink MATLAB program, an angular velocity is accrued which will be tested as in the Figure 15 by step response.

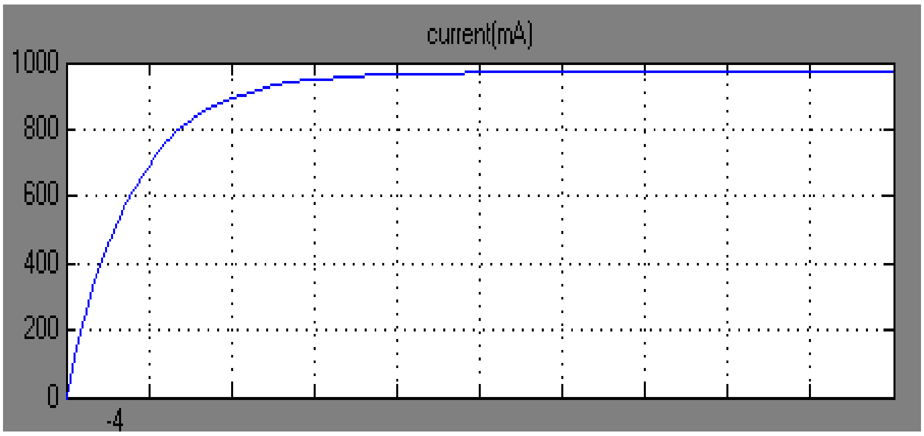

Figure 15: Open loop step response

In this system have three curves we observe current, velocity and position, observe the current curve was stable [5].

The response of the closed loop velocity control system to changes in gain agreed with theory, the closed loop system responds well to changes in load, the amount of error between the input command velocity and the motor velocity can be reduced by increasing the gain; this is what will be discussed in another research paper.

9. Conclusion and Future Work

This paper is to develop a model of the two axis platform, design axis control schemes for (current, velocity, position) using classical approach. The controllers were implemented using selected hardware which shows satisfactory results.

A model for the actuator motor and the platform axis load was developed. An electro-mechanical model of DC motor key control parameters were identified to develop theoretical and build MATLAB/Simulink model of DC motor. A transfer function for each axis actuator motor was developed.

Our work has a number of limitations, which we propose to address in future work:

- Using EPOS software to operate EPOS EC motor controller instead of using our designed MATLAB program.
- Carry on Comparative performance analysis between auto integral and manual tuning integral.

References

[1] R.C. Nelson, "Flight Stability and Automatic Control", McGraw Hill, Second Edition, 1998.

[2] LI Wei1, DUAN Cuifang, HUA Weijuan. Design of the Multi-axis Motion Control System [J]. Agricultural Science & Technology and Equipment, 2010.

[3] Nakamura, M. (Masatoshi), S. Gotō, and N. Kyūra. Mechatronic Servo System Control : Problems in Industries and Their Theoretical Solutions. Berlin ; Springer, 2004. Print.

[4] P.Pillay ad R.Krishnan, "Modeling, Simulation and Analysis of a Permanent Magnet Brushless DC motor drive part II: The brushless DC motor drive," IEEE Transactions on Industry application, Vol.25, May/Apr 1989.

[5] Documentation of Maxon EC motor, May 2010 edition, EC 60 Ø 60 mm, brushless, 400 Watt .

[6] Benjamin C. kuo, Automatic control systems Seventh edition.

[7] K. Ang, G. Chong, and Y. Li, "PID control system analysis, design and technology," IEEE Trans.Control System Technology, vol. 13, pp. 559-576, July 2005. (Pubitemid 41005115)