Design of Motion Control for Mobile Robot Manipulator

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***Abstract*—The aim of this paper is to examination application of Proportional, Integral and Derivative Control (PID) to regulate the movements of the mobile robot arm gripper. Simulation and experimental methods were utilized to verify the sophistication of PID control to regualte the mobile robot manipulator in the collection and placement of several kinds of objects quickly, accurately and correctly. The mathematical modeling is used to utilize the integration of Auto-Desk (Inventor) and MATLAB / Simulink / SimMechanics software. This method works by converting the physical model file into the xml file. This method is absolutely accurate to build the modeling and design robotics. The automatic control design of this robot manipulator is validated in simulations and experimental in control labs as evidence that the mobile robot arm control design can achieve the best performance such as the error signal is lower than 2%. The maximum overshoot signal is less than 2.5% and the stability signal response is achieved within a short time of 5s.**

***Index Terms*—pid control, control motions, mobile robot arm gripper, performance**

I. Introduction

The technology of automatic robot manipulator has developed to support in the world of industries, space exploration, university laboratory and human life. Mobile robot arm gripper is a robot system which is used to pick-up some tasks automatically. Along with the breadth of industrial robot use in recent time of the year, research on control methods for mobile robot arm has become a popular research topic of engineering. Given the complex nonlinear and limiting factors, it is very difficult to design a natural system with a high degree of difficulty in mathematical methods.

Mobile robot arm gripper car has 8 Degrees of freedom. This robot car has 4 wheels driven by using a servo dc motor respectively. His arm is driven with 5 pieces of motor dc and the gripper is driven by single of dc motors. Time optimal planning for robot manipulator is demonstrated to follow the track of Cartesian trajectory. To move the radius it will be installed a revolute joint that is connected with a virtual actuator in the form of a DC motor [1].

The force analysis for multi fingered robot gripper was demonstrated to pick up some different objects. Each of fingers pressured the surface of object with different force [2]. According to E. Shojaei Barjuei [3], analysis of hybrid position control for spatial compliant mechanism was developed in high accurate dynamics system based on rigid link theory and finite element. The performance of motion control is measured to achieve the minimal error signal of trajectory tracking is 2.6 degree.

The method of trajectory control was developed to effectiveness to movement the gantry cranes to handling some objects. Some tracking simulations of gantry cranes robot was demonstrated to perform of robot capability of simple method [4]**.** The simulation of PID control robot manipulator with five fingers was demonstrated to get the best performance of kinematics motions. Each of fingers can move as similar with the input references [5,6].

In this research, the author’s has used both a simulation and an experimental to build a mobile robot arm gripper using MATLAB/Simulink software to compute the response transients. The purpose of this research is to get precise and accurate method in modeling and designing hand robotic cars. Therefore, in this research will be introduced how to model 3D car robot manipulator gripper with multi DOF with accurate as well as make programming control system prototype car robot hand with MATLAB / Simulink.

This PID control is the most important substance in the distribution of hand car robot control systems. Proportional, integral and derivative controls are the feedback control methods as the main tool of the user. Advance PID tuning is able to adjust both kinematics and dynamic system gain parameters quickly and accurately.

PID control is expected to achieve the smaller errors and overshoot signals until finally reaching steady state. The system response can be seen after the system is given different input signal. This combination of input signals and control actions will produce different responses). Simulations using computer software will be done before the creation of a prototype. The optimization of classical PID control for robot manipulator was presented [7]. The

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method of control is to adjust the line tracking robot arm with high speed line tracking.

The use of PID control in the simulation of robot arm is able to accelerate the arm movement response. The fast responses makes the drive error signal (the reference motion - actuator motion) emerging so small that steady state will be obtained quickly too. The design of the PID control system with the help of MATLAB software makes it very easy to get the results as desired [8,9]. If the arm motion control in the simulation is successful, then the control will be used to control the actual arm movement. The goal of research design is to get minimum error signal less than 2%, maximum overshoot is less than 2.5% and peak quickly the stability response.

II. Research Methods

A. Description of Research

Fig. 1 shows the design of a mobile robot arm gripper that designed in Inventor program. Mobile robot arm gripper mounted on romper and robot that can move back and forth to reach the target.

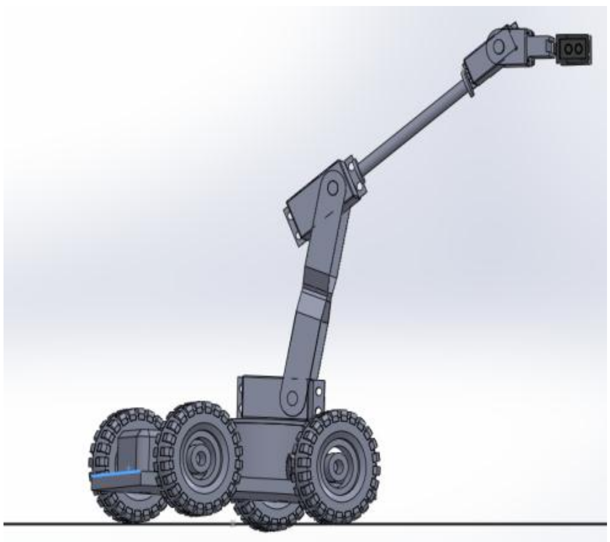

Figure 1. Design of Mobil Robot Arm Gripper.

Mobile Robot Arm is composed of a cart equipped with 4 wheels each wheel driven by a servo motor respectively. Robot arm mounted on the base of the mobile robot where the arm is composed of the base arm which is driven by a rotating servo motor that is fully rotated and above the base arm in pair servo motors that can move rotation with a maximum rotation of 180^o. The base of the second arm is moved by servo motor which moves rotation with a maximum rotation of 180^o. And at the end of the arm is also driven by a servo motor that moves a maximum of 180^o. Gripper with the movement of prismatic mounted on the end of the arm that is used to retrieve certain objects that are driven by a servo motor.

B. Flow Chart of The Research

In generally there are some of step to run this research that is shown in Fig. 2.

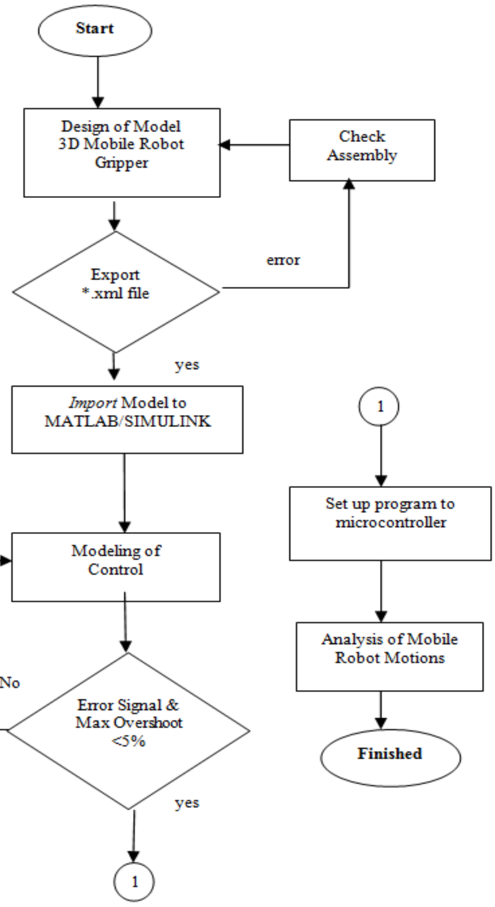

Figure 2. Flow chart of the research.

The 3D design of the mobile robot manipulator assembly is made in the inventor software. After the image is complete then the file is exported to MATLAB / Simmechanic. The file will change from a physical model to xml file. Next, at each joint actuator into the block diagram model of the robot is added with PID control system. This control system will control the output signal in the form of an angle. The process of changing from a coordinate position to a join angle is called inverse kinematics. The next step is to simulate the PID control system model so that it can know the indicator parameters of the output signal. If the error signal and the maximum overshoot of the response are less than 5%, then this response meets the requirements of the control system. And if not, then the control modeling system needs to be improved again. The next step is to generate the code into the microcontroller system.

C. Diagram Block Simulink of Robot Manipulator

Mobile robot gripper is a common, high multivariable type order, and nonlinear system. The process of formulating the mathematics model is a difficult. Furthermore, at least the application of model-based control design strategies are very complex or deliver insignificant performance improvements with respect to straight forward design solutions based on linear control. A new approach that does not directly model mathematical functions becomes an attractive alternative. The application of MATLAB/Simulink toolbox is described. Now a mobile robot arm gripper model is made as a detailed sample.

Mathematical modeling for mobile robot arm system is implemented in program using SimMechanics program. The mathematical modeling is illustrated in the block diagram as shown in Fig. 3.

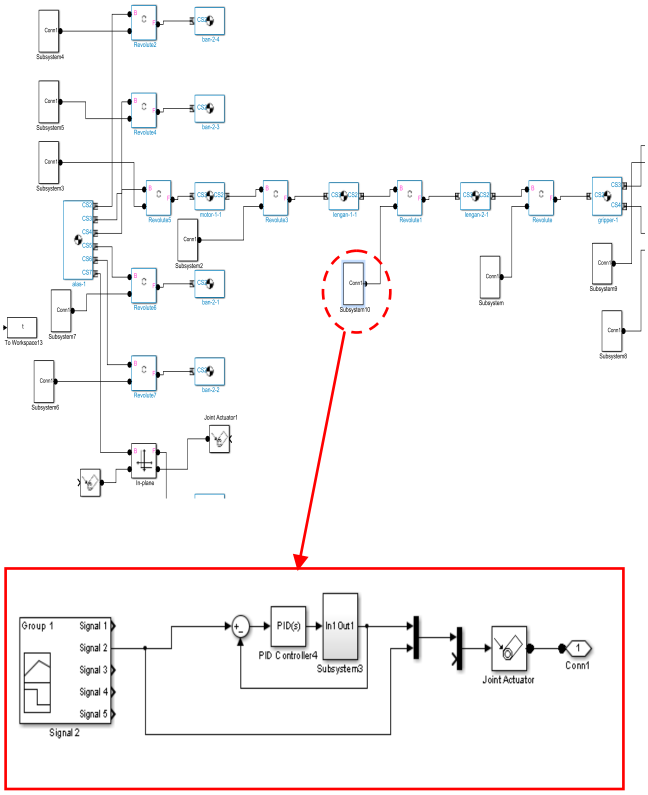

Figure 3. Diagram block simulink for mobil robot arm.

Most PID controllers are customized on site that there are many types of tuning rules that have been proposed in the research. Using the automatic tuning method has been developed in a mechanical system. The usefulness of the PID control lies in their general application for most control systems. In the field of process control systems, it is well known that the basic PID control and modification schemes have proven their usefulness in providing satisfactory control. Adaptive PID control was used to control the torque of a permanent magnet synchronous motor. The result of desired response has shown that adaptive PID control to be affective to track the desired torque.

Advance PID tuning is able to adjust the gain system parameter dynamically quickly and appropriately to get the robust design with response time is ideal and can be used on single and multi-loop PID tuning methods. Special model of working order with PID tuner is following some rules.

The input reference is built as a pattern of the speed DC motor which uses the signal builder block. Fig. 4 shows the movement of a mobile robot arm gripper can be visualized using SimMechanics Toolbox in Simulink. This robot arm car moves according to the desired reference input and will generate actual output.

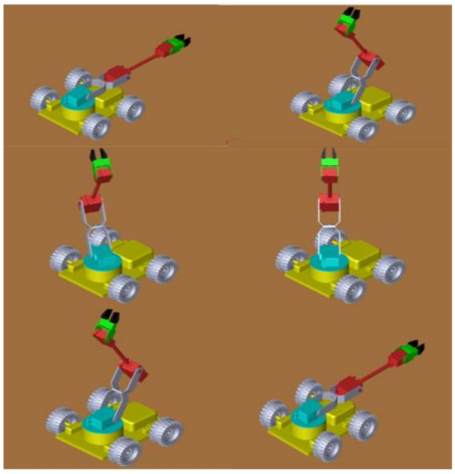

Figure 4. The Visual Movement of mobile robot arm in MATLAB / Simulink.

D. Simulation Testing

By using SimMechanics in the MATLAB / SIMULINK program, simulation testing of robot arms can be carried out. The mathematical model of the servo motor and the PID control system can be attached to each joint motor contained in the robot arm joints. The installation of PID Control and mathematical models of the motor servo on each arm can be seen in the following Fig. 5.

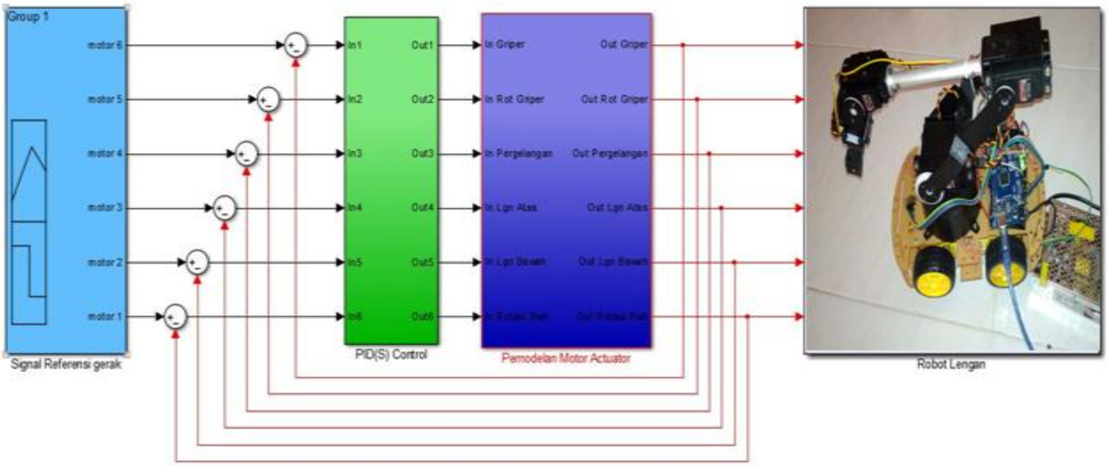

Figure 5. The block diagram of PID control.

The motor lever motion reference is determined by varying the reference being tested so that variations in the response of the work of each actuator are obtained. Because each arm's actuator is not the same in its angle of motion, the references given are different. The simulation test with reference variations is carried out for 10 seconds.

PID control will control the position, angular velocity, and angular acceleration at the joints of each lever of the robot arm joint. By clicking the "Tune" button. The MATLAB program will identify the plant that was made and provide the PID parameters that match the plant.

By using Tune PID, we get Kp = 1.3245, Ki = 12.5862, and Kd = 0. The response of the system using these parameters can be seen transient response from the simulation test results on the forearm for 20 seconds obtained,

- Delay time, td <0.8s
- Rise time, tr < 2s
- Peak time (tp time), tp < 2.7s
- Maximum overshoot, Mp <2.5%
- Settling time, ts < 5s

E. Prototype Building

The assembly of the mobile robot arm gripper is shown in Fig. 6. The prototype robot matches the initial design is drawn in 3D Inventor software. This robot has used an Arduino AT Mega 2560 as a microprocessor. The support package Arduino AT Mega program has installed in toolbox MATLAB/Simulink. When the simulation program is ready to get a good performance that the prototype of robot arm is started to build. The construction of mobile robot arm is demonstrated in Fig. 6.

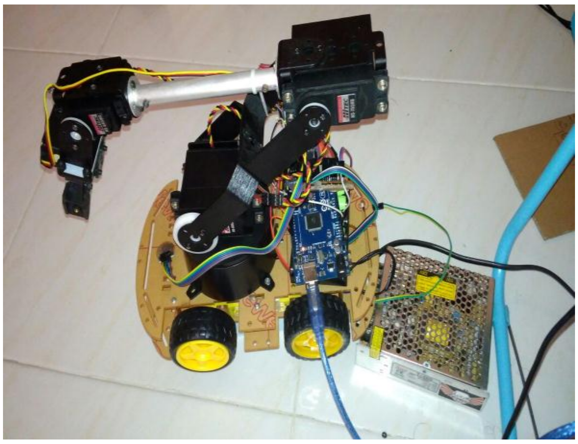

Figure 6. The Prototype of Mobile Robot Arm Gripper.

Fig. 7 shows the block diagram of mobile robot arm in MATLAB/Simulink. The reference input as a dc servo motor movement reference is controlled by PID Control then the output signal is forwarded to the mathematical modeling of the motor dc system. The Mathematical modeling toolbox with the Arduino servo block is obtained by installing the support package from Mathworks.com. Furthermore, if the output is not in accordance with input reference then the output is in correction a again until obtained the output in accordance with the will of the user.

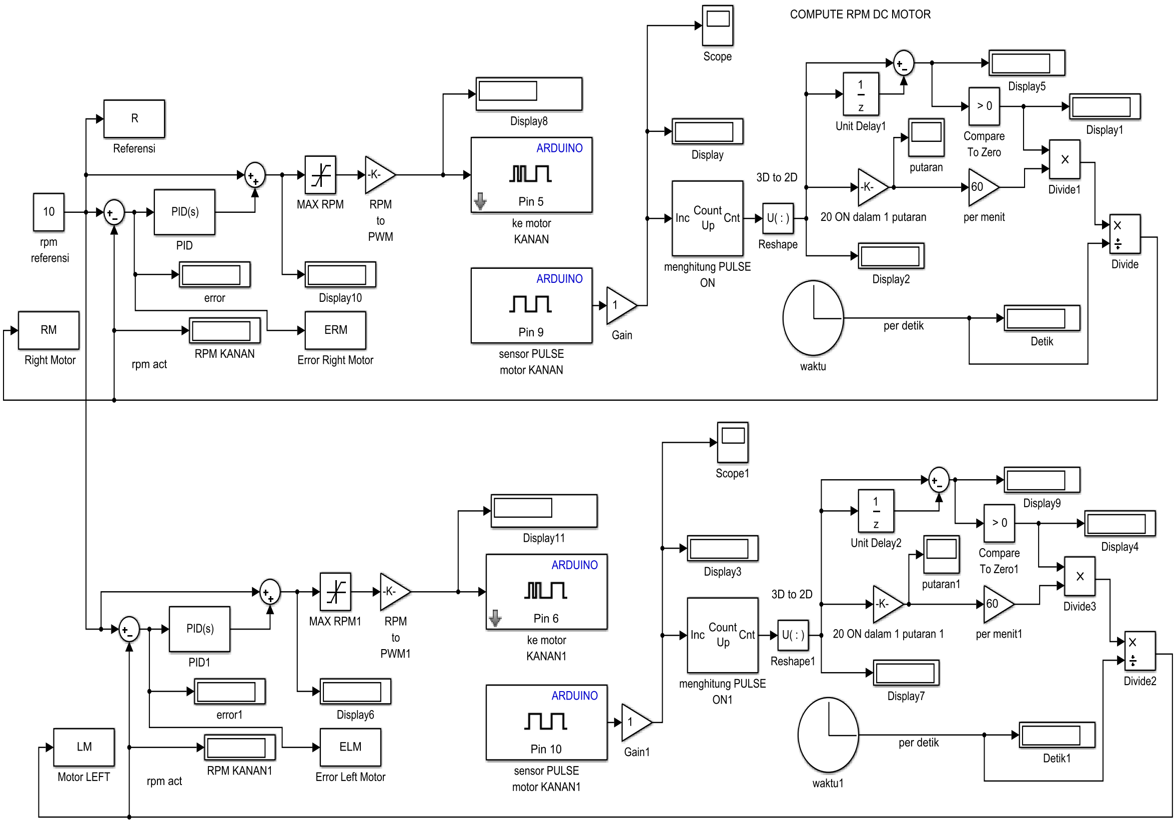

Figure 7. The bock diagram Mobil Robot Arm Gripper in MATLAB/Simulink.

This motion of robot car is navigated by using an application of android in mobile phone. The use of Bluetooth signal is used to manage the movement of mobile robot arm gripper from long distance without using cable. This application is made in mobile phones based on Android. By selecting a button that the user is already installed in the hand phone so that this robot car can move in accordance with our request. The navigation of the mobile robot is installed in the application of Bluetooth mobile hand phone. The user can move up, down, right and left from each of DC motor in which installed in each of joint of robot.

III. Results and Discussion

A basis of comparison of performance of various control systems has been in analyzing and designing control systems. This basis can be formed by specifying a particular test input signal and by comparing the various system responses to this input signal. The desired performance characteristics of control systems are specified in terms of domain quantities. Often, the performance characteristics of the control system are determined in terms of the transient response to the step unit input. The signal builder is used to arrange the input signal of the systems. The comparison of the actual response for the left and right motor angle servo motors can be seen in Fig. 8.

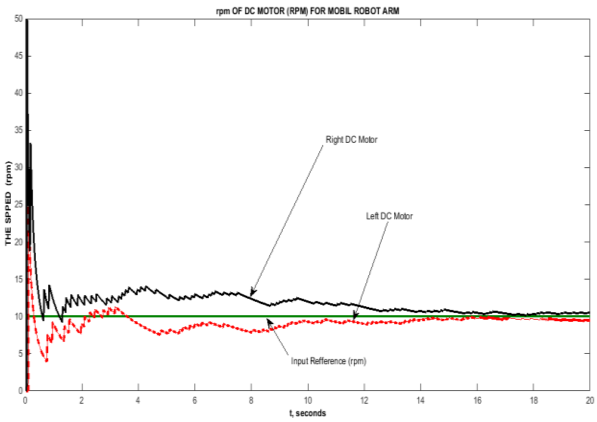

Figure 8. Actual response rpm in tire of DC motor.

The Fig. 9 shows the rpm of error signal in tire of DC motor. PID control is used to adjust the magnitude of amplifier parameters so that the desired response signal matches the design model desired by a designer. In the design of this control system has used proportional integral and derivative control by adjusting the amplifier value until the signal error signal is smaller than 2% and with a little overshoot and the response stability is achieved within a short time of 5s. The rotation dc motor per minutes between left and right tire is close similar.

The Fig. 10 shows the control of motions of each dc motor in the arm. The desired response for rotation of dc motor move as similar with angular position input references.

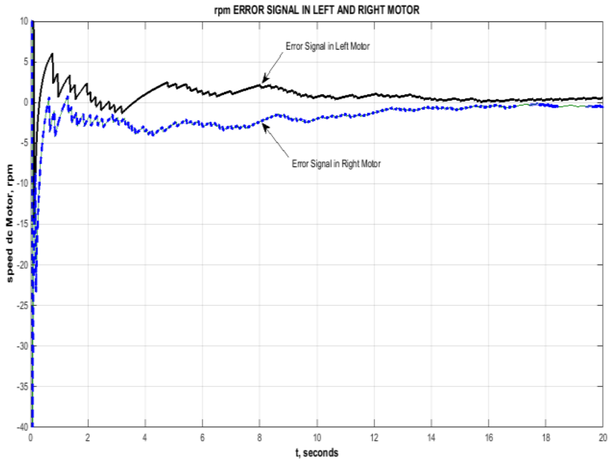

Figure 9. Rpm Error Signal in Tire of DC Motor.

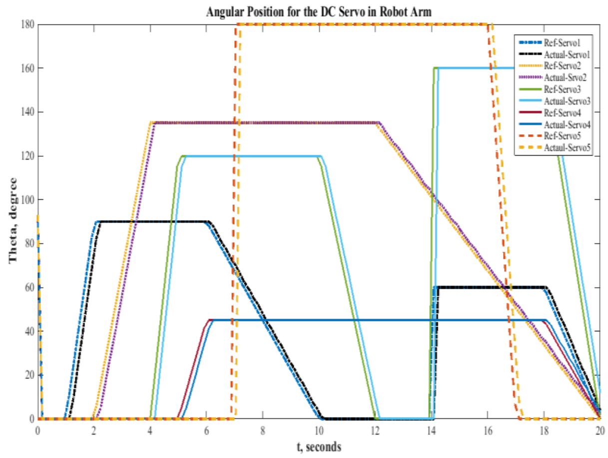

Figure 10. Motions of each dc motor in robot arm.

The error signal of position is shown in Fig. 11. The robot arm has achieved a good performance with smaller error signal, minimum overshoot and quickly to find the stability response.

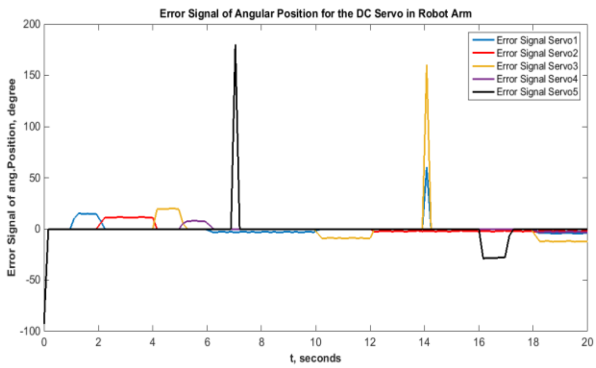

Figure 11. Error signal of angular position for robot arm.

In prototype testing, there are still subtle potentiometer movements. When references are given a fixed value for a long time, small oscillations will occur in prototype testing. In the simulation test there is no linear oscillation. The effect of the External mode used in the prototype test was the start of the motor moving at 90^o so that on the graph the test results obtained the initial motion was not at condition 0.

The prototype test results show that the time needed for the motor is longer than the simulation test. Prototype test results are not much different from the results of simulation testing, servo motors need a few seconds to reach the given reference point. An oscillation occurs in the prototype test results that replace this sensor which replaces non-linear. These disturbances change with each trial prototype, making it difficult to resolve the exact problem.

IV. CONCLUSION

The auto PID control system can speed up the response of a system. Utilizing auto tuning on the PID controller in the SIMULINK / MATLAB toolbox makes it easy to specify optimal PID parameters. From the results of the transient response obtained the speed of motion response from DC motors can be improved and can achieve stability quickly. The prototype test results obtained Delay time is approximately 0.8s, rise time is less than 2s, peak time is achieved at 2.7s, settling time is less than 5s, maximum overshoot is less than 2.5% and error signal is approximately 2%.

CONFLICT INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, W.W. and C.G.I.P.; methodology, W.W, I.G.N.N.S.; software, W.W., and C.G.I.P.; validation, W.W., I.G.N.N.S. and C.G.I.P.; formal analysis, W.W.; investigation, W.W. and I.G.N.N.S.; resources, W.W.; data accurate, W.W.; writing—original draft preparation, W.W.; writing—review and editing, W.W. and I.G.N.N.S.; visualization, W.W.; supervision, W.W.; project administration, C.G.I.P.; funding acquisition, W.W.

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