Design and Implementation of No Load, Constant and Variable Load for DC Servo Motor

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Abstract*—Simulations were conducted to improve and design an appropriate control system and obtain a model with the required development to suit the operation of the engine with constant and variable loads, which are the proposed working conditions that are suitable for many applications. The current simulation aims to build and design a model for an electric motor (DC Servo motor) and a model for a conventional controller (PID). The proposed model addresses the cases of fixed and variable loads in terms of using the controller that improves the performance of the motor's work for different conditions. Three cases were developed to conduct the proposed tests, which included the case of no-load, fixed and variable load. Tests were conducted. Without the console and for the purpose of comparison and observation of improvement, the test was conducted with the addition of the console. The results showed system performance may improve depending on usage using traditional control systems. Performance measurement criteria are adopted for the purpose of comparison and observation of performance improvement. The criteria that are adopted are rise time and stability (steady state) in addition to the ratio of the rate of under and over-shoot. Where it can be deduced from this the possibility of using different control systems, including traditional ones, to improve performance, and they include controlling the speed of the motors, as well as controlling the effort, and the consequent effects on the subject of the study, as it deals with transient cases and changing operating conditions with more than acceptable efficiency and relatively high quality. There are four state simulation include, 1st at no load without controller: rise time equal 309.886ms , overshoot equal 44.203% and undershoot equal 9.597%.2nd at load without controller: rise time equal 216.319ms , overshoot equal 58.654% and undershoot equal 0.210%.3rd at no load with PID controller: rise time equal 1.177s , overshoot equal 0.505% and undershoot equal 1.914%.4th at load with PID controller: rise time equal 1.112s , overshoot equal 0.509% and undershoot equal 5.856%.

***Keywords*—DC Servo Motor; PID Controller; No-load; Constant Load; Variable Load.**

I. INTRODUCTION

During the previous years, research was presented to develop control techniques due to the need for robot technology, which depends in industrial systems with high efficiency and performance [1-3]. The importance of the robot's manipulator comes because it works in dangerous and unexpected conditions that humans cannot deal with, such as the chemical and nuclear sectors [4-5]. A DC servo motor (DCSM) is the best example of a robotic manipulator. Servo motor is the heart of industrial applications as it is used in precision control applications, automatic doors and drives [6]. In (DCSM), the variable control logic is developed to improve their efficiency, but these motors suffer from non-linear data change, which leads to a change in the overall efficiency of the system. Changing the load connected to the motor leads to unpredictable working conditions, which increases the complexity of the application.

In robotic technology, (DCSM) is used because it has many advantages such us energy efficiency fast response, less noise, little volume, Inertia-torque ratio, low manufacturing cost, high precision [7-8], high torque when working at any speed, its ability to change the direction of rotation quickly, and it can withstand any instant static position in servomechanism and robotic mechanism [1]. In study [9] a high-accuracy, efficient and responsive system was obtained by developing experimental data with changing working conditions, where a servo motor and model simulation were used in two cases without a controller and a process simulation with a traditional pid controller. In work [10] the researchers worked on developing a model according to a mathematical method with a simulation test of the model by adopting the simulation computer program for an electro-hydraulic servo motor (EHSM) By adopting control units within a wide and effective range, it handles transient cases for accurate and fast motor control. LiqaaMezher in [11] proposed a powerful pid regulator by adjusting the parameters of ki, kp, pd to control the position of the electric motor DCSM and use matlab software to apply calculations called strong pid. Study [12] includes the position and pressure of the pneumatic servo system was controlled by used pid controller and its mathematical model was established. This pneumatic servo system is used to remove the ship hull rust and the spraying process. In [13] the The researchers presented one of the control methods, which is a control unit by adopting fuzzy logic to organize and tune the traditional type of Fuzzy-PI to obtain better performance of electric motor I.M, where the FLC controller adjusts within various work tests that include an operating condition without load, as well as the variable and constant load conditions, according to the reliability of the parameters of the conventional controller and its design according to the best results compared to the performance measures used to determine the parameters of the conventional PI controller. The traditional PID controller widely used in the electromechanical actuator control systems in process industries because of its accurate, high reliability, simple design and efficient turning of parameters (ki, kp, kd) [14-18]. The pid controller has the ability to have a good output response to a rotational speed for DC motor, but the parameter tuning implementation of this controller is complicated The PID controller has the ability to get a good output response represented by the rotational speed of the DC servo electric motor, but to implement and adjust the parameters of the conventional controller may be somewhat complicated [19-20].

Many researchers presented their studies on electric motors, including the servo motor, and dealt with many matters, including the operation of the motor according to a system suitable for industrial applications, other household and agricultural applications, and others [21-25]. In the current study, such as changing loads, and among the applications of the current study are industrial applications, and they include changing the number of passengers in electric cars, as well as climbing and descending hills and mountains, turning to the right or to the left, and changing the direction of rotation, and it results in changing the load according to the number of people. Likewise, the electric elevator can affect the number of people by loading on the engine [26-30].

The current research also aims to address the cases that accompany the change of the system through the difference in loading and the transient cases that need to be overcome in the fastest time and the highest efficiency and with high quality and accuracy by referring to the stable state of the system. These solutions to the problem are distinguished by the fact that simulations were conducted for different cases that are suitable for what is similar to them in real time represented by industrial applications Such as using the servo motor to move a cart for an elevator or an electric car or something similar in terms of obtaining the best performance in a way that suits effective and safe operation [31-35].

II. System Description and Mathematical Model of DC Servomotor

The simulation includes a proposal to adopt suitable characteristics for applications suitable for the use of DC servo motors, which were used in its conversion function, which can represent a simulation model, in addition to the presence of a test case for initial and other parameters that are the best during control using the traditional PID controller, which gives, according to the proposed performance measure, the best performance.

Electric servomotor are important in modern industries such as industrial electronics, robotics, precision and speed control [36-38], also this motor is one of the important motors that are used in automatic systems, because these systems need a good performance actuator [39-40], there for this paper proposes the performance of this motor and using traditional controller to improve working. In the Fig. 1 and Fig. 2, two diagrams can be shown that represent each of the DC servo motor circuits, first, and the other represents a block for this motor [41-45].

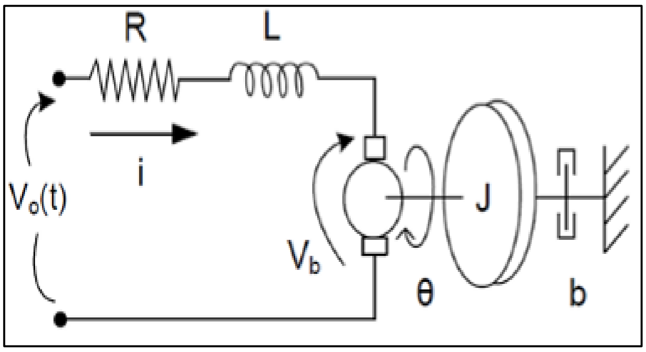


Fig. 1. Diagram a DCSM

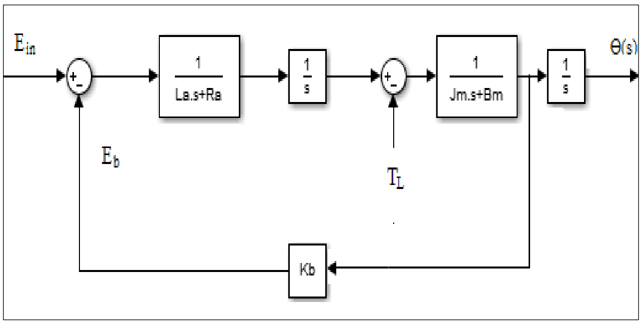


Fig. 2. Representation a DCSM

From Fig. 2, the dynamic behavior of DC motor can be represented in these equations (1) to (5) [39].

$$E_a = R_a I_a(s) + L_a I_a(s) + E_b(s) \tag{1}$$

$$T_m(s) = K_t I_a(s) \tag{2}$$

$$E_b(s) = K_b s \Theta(s) \tag{3}$$

$$T_m(s) = (J_m s^2 + B_m s)\Theta(s) \tag{4}$$

$$T.F = \frac{K_t}{L_a J_m s^3 + (R_a J_m + L_a B_m)s^2 + (K_b K_t + R_a B_m)s} \tag{5}$$

Where the parameters of DCSM can be shown in Table I.

TABLE I. Parameters of DCSM

Parameters	Units	Values
armature resistance (R_a)	ohm	2.23
armature inductance (L_a)	H	0.23
Moment of inertia (J_m)	Kg.m^2	0.00006286
friction coefficient (B_m)	Rad /sec	0.0000708
torque constant (K_T)	N-m-s / rad	0.121
back emf constant (K_B)	V/(rad/s)	0.121

The expression and transfer function of PID controller can be shown in equation (6) and (7) respectively whereas Fig. 3 block diagram of PID controller [46-51].

$$U(t) = K_p e(t) + K_1 \int e(t)dt + K_d \frac{de(t)}{dt} \tag{6}$$

$$G_c = K_p + \frac{K_i}{s} + K_d s \tag{7}$$

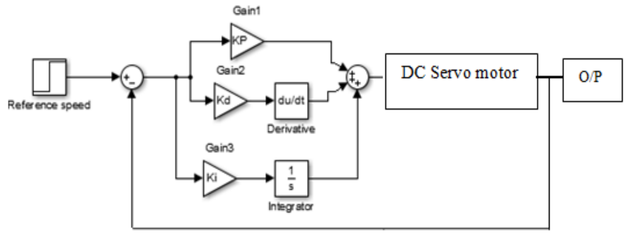
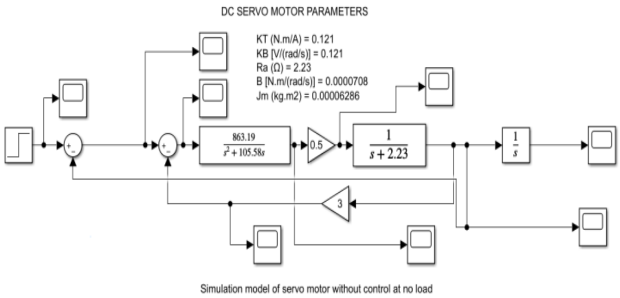


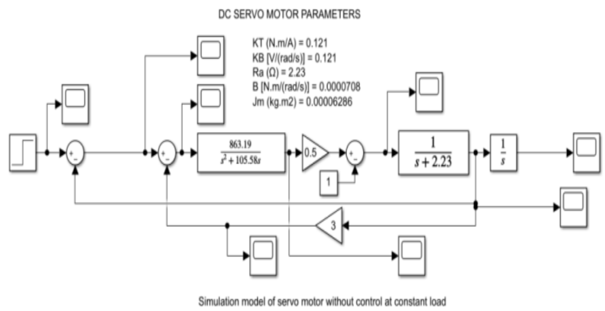
Fig. 3. Block diagram of PID controller

III. Simulation Model of DC Servo Motor

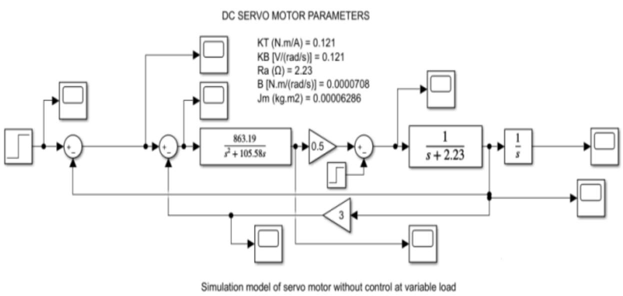
This paper proposes a model by using MathLab Simulink program to design and implementation efficient simulation model with three different operation condition are presented in no loads stste, variable load state and constant load state with and without PID controller for dc servo motor to obtain excellent results. Fig. 4 shows the simulation model.



(a)



(b)



(c)

Fig. 4. Simulation model of DC servo motor (a) no load without PID, (b) constant load without PID, (c) variable load without PID

IV. Prepare Simulation Results and Discussion

The first tests are simulated by adopting the electric motor simulation model, as shown in Fig. 4, the required operating conditions can be represented for the three cases without a control unit. The first was in the no-load condition, the second was the constant load, and the third was the variable load.

This part discusses simulation results for performance of DC servo motor with and without using PID controller at three different operation conditions (no load, constant load and variable load) and comparison between these two states in order to improve and develop performance of the motor and obtain best simulation results. The values of control parameters for PID controller in this paper are shown in Table II.

TABLE II. Parameters of PID Controller

Parameters	Value
Kp	5
Ki	3
Kd	5

A. Simulation results at no load

The Simulation results and the responses of dc servo motor at no load can be shown in figures below, so Fig. 5 and Fig. 6 indicates to speed and torque while Fig. 7, Fig. 8, and Fig. 9 show other response of motor are represented in current, voltage and error respectively.

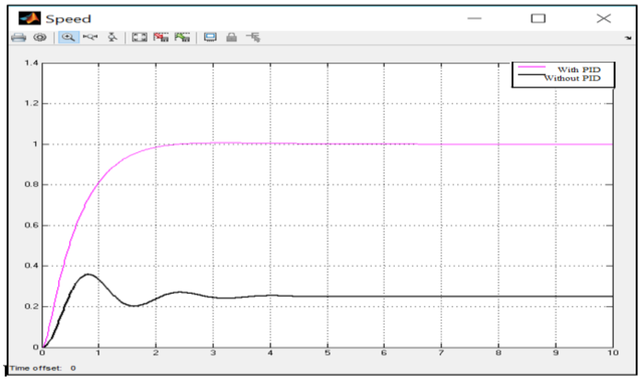


Fig. 5. Speed of no load without PID

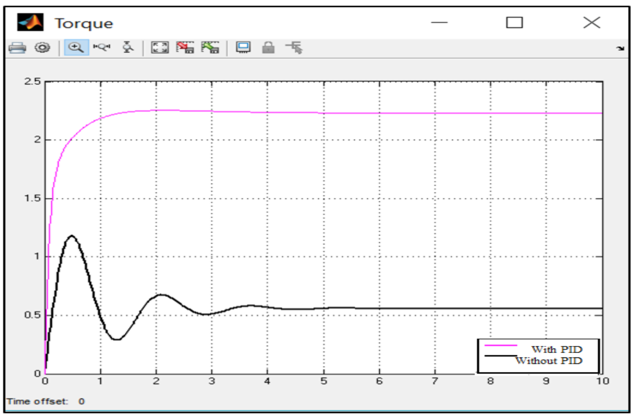


Fig. 6. Torque of no load without PID

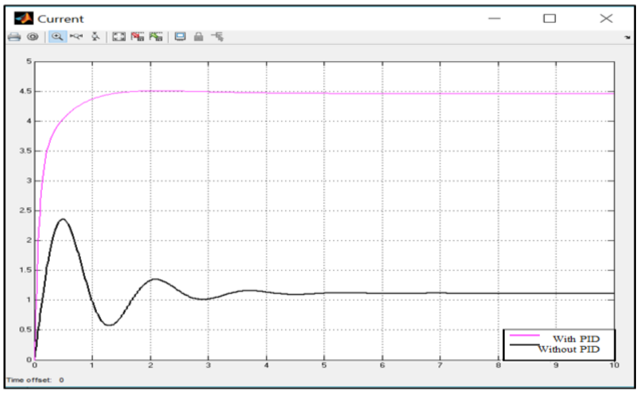


Fig. 7. Current of no load without PID

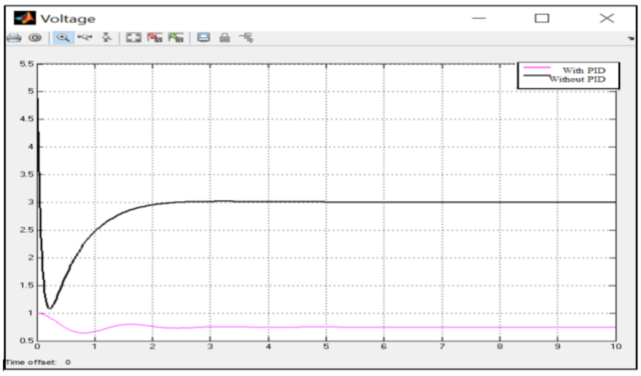


Fig. 8. Voltage of no load without PID

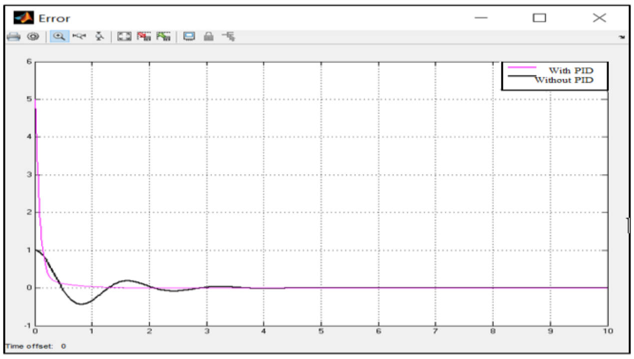


Fig. 9. Error of closed loop system at no load

The results for the first case, no-load, are shown in Fig. 5 to Fig. 9. Fig. 5 shows the speed response at the no-load condition, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and overruns above and below, where the performance was clear by improving performance using the control unit. Fig. 6 shows the torque response at no-load condition, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear through improving performance using the control unit. Fig. 7 shows the current response at the no-load condition, and we note the difference between the presence and absence The control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear by improving performance using the control unit. Fig. 8 shows the voltage response at no load, and we notice the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below where it was the performance is clear by improving the performance using the control unit. Fig. 9 shows the error response at the no-load state, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear by improving performance using the control unit.

B. Simulation results at constant load

When DC servo motor operation at constant load, the characteristics and simulation responses are shown in Fig. 10 to Fig. 15, Speed of DC servo motor at constant load in Fig. 10. Torque of DC servo motor at constant load as show in Fig. 11. Current of DC servo motor at constant load as show in Fig. 13. Fig. 13 Voltage of DC servo motor at constant load. Fig. 14 Error of closed loop system at constant load.

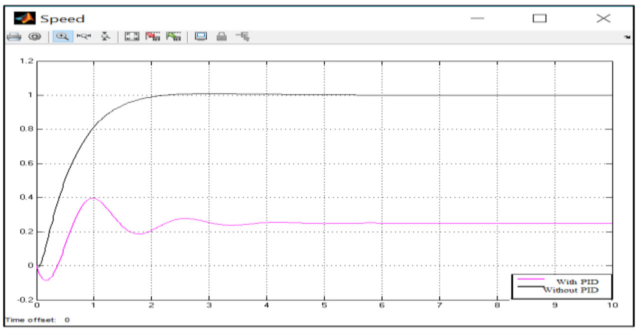


Fig. 10. Speed of constant load without PID

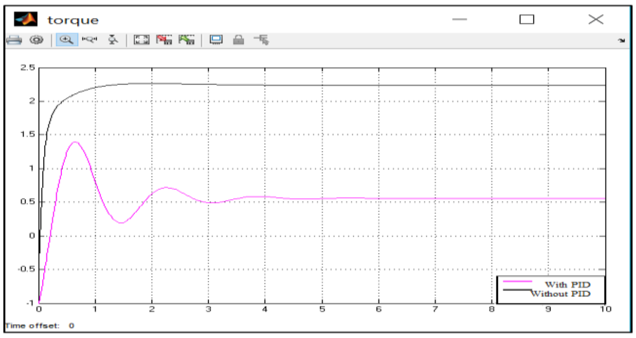


Fig. 11. Torque of constant load without PID

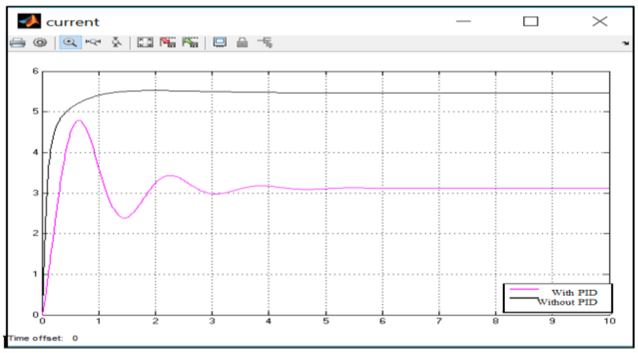


Fig. 12. Current of constant load without PID

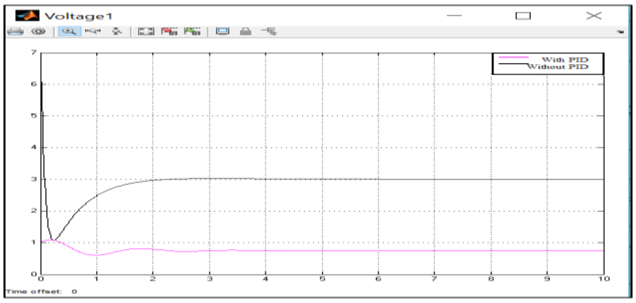


Fig. 13. Voltage of constant load without PID

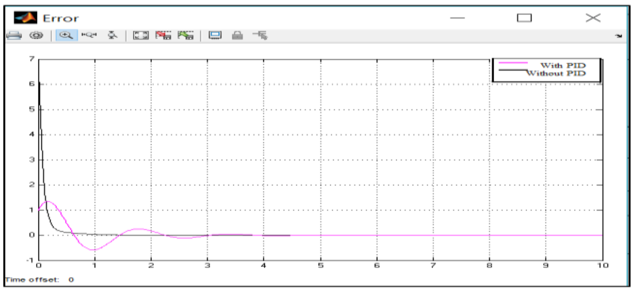


Fig. 14. Error of closed loop system at constant load

Results for the second case, static loading, in Fig. 10 to Fig. 14. Fig. 10 shows the speed response at the static load condition, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear by improving performance using the control unit Fig. 11 shows the torque response at the constant load condition, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear by improving performance using the control unit. Fig. 12 shows the current response at constant load condition and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear through improving performance using the control unit. Fig. 13 shows the voltage response at the constant load state, and we note the difference between the presence and absence of the control unit in response, stability time, and override above and below, where the performance was clear by improving performance using the console. Fig. 14 shows the error response at the constant load state, and we note the difference between the presence and absence of the console with terms of speed response and stability time, and override above and below, where the performance was clear from by improving performance using the console.

C. Simulation results at variable load

At variable load condition for DC servo motor, the performance characteristics and simulation responses can be shown in Fig. 15 to Fig. 19. Speed of variable load without PID as show in Fig. 15. Torque of variable load without PID as show in Fig. 16. Current of variable load without PID as show in Fig. 17. Voltage of variable load without PID as show in Fig. 18. Error of closed loop system as show in Fig. 19.

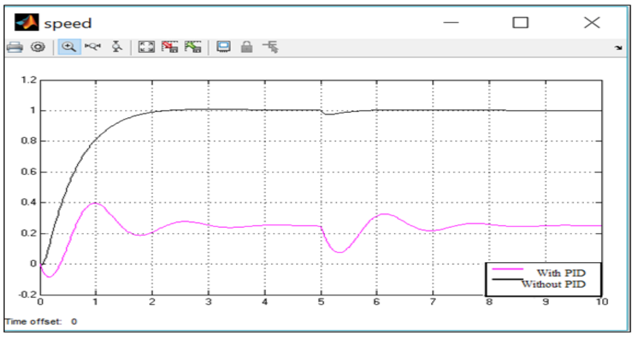


Fig. 15. Speed of variable load without PID

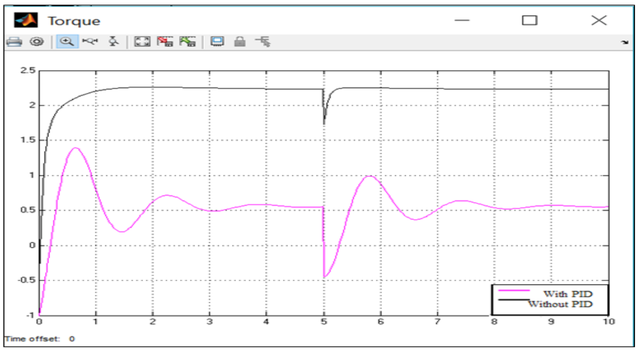


Fig. 16. Torque of variable load without PID

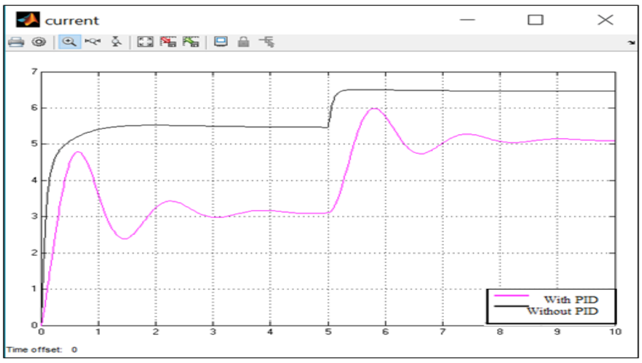


Fig. 17. Current of variable load without PID

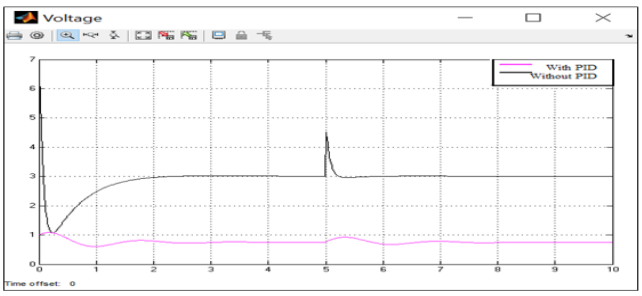


Fig. 18. Voltage of variable load without PID

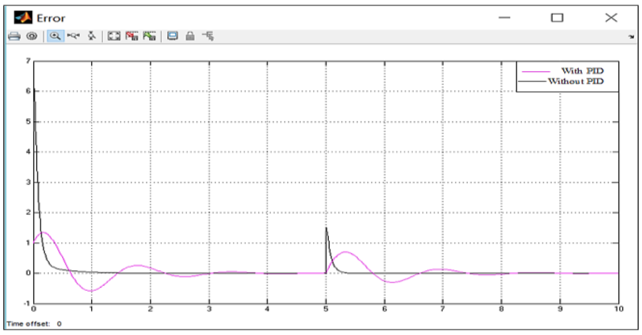


Fig. 19. Error of closed loop system

The results for the third case variable load in figures from Fig. 15 to fig. 19. Fig. 15 shows the speed response at the case of variable load and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system and stability time and override above and below where the performance was clear by improving performance using the control unit. Fig. 16 shows the torque response at the state of variable load, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear by improving performance using the control unit. Fig. 17 shows the response of the current at the state of Variable load, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear by improving performance using the control unit. Fig. 18 shows the voltage response at the state of variable load, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below, where the performance was clear by improving performance using the control unit. Fig. 19 shows the error response at the state of variable load, and we note the difference between the presence and absence of the control through the criterion of the rate of settling time and the rate of speed of rise time and response of the system, stability time, and override above and below where the performance was Obviously by improving performance using the console.

V. CONCLUSION

Tests were conducted for the proposed system, which enabled the development of a suitable design for a conventional controller. The simulation results proved the possibility of improving the performance of the electric motor according to different operating conditions (no load, constant and variable loads). The results indicated the quality of performance using the traditional controller for the absence of the controller. Through the results that were observed above, it is clear that the use of the traditional controller led to better results compared to the state without controllers in terms of improving the performance and operation of DC servo motor under different operating conditions at different states of loads (no load-constant load-variable load), as the mechanical properties of the servo motor were improved and smoothing by reducing overshoot and settling time, All of this leads to better and get good results in real time.

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