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Analysis of Driver Position Control on Electronic Power Steering (EPS) Using PID

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Abstract

This research present about a steering control system on a vehicle whicgh is called Electrical Power Steering (EPS) that aims to observe and compare the position of EPS system with and without using PID controller. The EPS system has a state space order by 6x6 with one of the motor outputs to be controlled by a Proportional-Integral-Derivative (PID) controller and uses the MATLAB application as a simulation of the EPS system. The simulation is carried out in two stages, namely the simulation of an EPS system without controlling and simulating an EPS system using a PID controller. The results show ,that the position controller on EPS with the PID control method reaches the desired position with the parameter value Kp = 500, Ki = 500 and Kd = 200 while the input step is 1. The system output response has an overshoot value closes to 0, a rise time of 0.005 seconds. More over, EPS system which unutilized controllers, the output responseis can not reached the reference value.

Keywords : *Electric Power Steering* (EPS), *Proportional-Integral-Derivatif* (PID), *Simulation*.

1. Introduction

Direct current motors or DC motors are the most commonly used actuators. An automotif industry has been widely used DC motoris the use in the automotive industry. Industrial world the control of DC motorcycles is mostly done, such as DC motor position control. One of the implementations of DC motor position control Electric Power Steering (EPS) is mechanism that generates power to assist the operation of the steering wheel becomes light, stable and certainly provides comfortable. There are two types, power system which are hydraulic power steering (HPS) and electric power steering (EPS).

A stable system requires the right arrangement that is using a control system. Tuning the control parameters is done to be able to improve response characteristics such as reducing settling time, rise time, steady state error and reducing maximum overshoot. To realize an efficient setting, there is a control system method used, namely proportional, integral and derivative (PID) controllers [3]. The controller is used so that the EPS system output can be observed and compared to if the EPS system is not given a controller.

A stable systems requires accurate controlling which a control system is deployed which gain a stable system. An efficient controlling could increased respons varable such as setting time, rice time ; more over could reduced max overshoot. Thera three models that proposes to realize control system are effctively usage, such as P,I D. [3]. Those models has setup up by algiven controlling value so that EPS system could be monitored and compared by unloading controling value.

2. Research and Metode

2.1. Background

In general, the power steering begins with simple mechanical technology that is functioned as a simple aircraft to help ease the front wheel deflection on 4 (four) or more wheeled vehicles. Furthermore, it developed with the help of dc motor as a hydraulic pump drive and in the next development the power steering only uses dc motors directly without hydraulic, however, the existing EPS equipment is still considered uncomfortable for drivers and passengers, due to several factors, including uneven roads, engine vibration, sudden braking etc. From the problems mentioned above, the researcher wishes to try to solve the problem by giving the PID setting in Electrik Power Steering. This research aims to obtain the right PID parameter values to minimize the impact of the factors that cause the driver to feel uncomfortable.

2.2. Electric Power Steering (EPS)

Electric Power Steering (EPS) is one of the technologies in the automotive field that is very easy for vehicle users. This technology helps relieve the steering wheel which aims to improve the work efficiency of the vehicle by changing the power steering work process. This change switches the hydraulic system to electrically [1].

2.2.1. Principle and Architecture on EPS

Figure 1. shows an EPS works ungtion. There are two tupes signals are detected by the torque sensor when the vehicle is running, which are the torque and steering direction. Both signals are sent to the Electric Control Unit (ECU) where the ECU sends an instructions to motor controller which depends on steering torque, steering direction, vehicle speed and others. While the vehicle does not run the ECU does not send a signal to the motor controller so that the motor does not work [7]

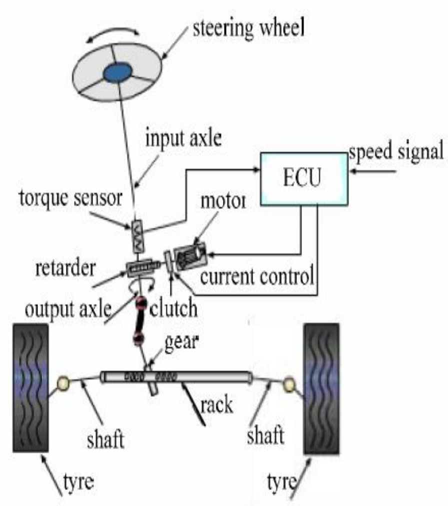

Fig.1. EPS System Scheme [7].

The ECU determines the steering direction and anauxiliary torque that is macth and sends the control signal to the motor and clutch. These signals will drive the motor with the power drive module and protection module. Retarder reduces motor speed to strengthen torque. Then torque can drive the gear to produce the appropriate torque. EPS can adjust the torque changes with the right algorithm and make the gear get the torque assisted by the driver [7].

2.2.2. EPS system Modelling

Mechanical and electrical parts.Mechanical components comprises of steering wheel; input axle; rack and pinion; retarder and gear.While the electrical parts include motors and electric control units (ECU). The process of modeling an EPS system . A controled EPS system, are discribes in state space model whice involviy are Eq. (6) has derivated from the eq. (1) which indicates of retarder as follow [7] :

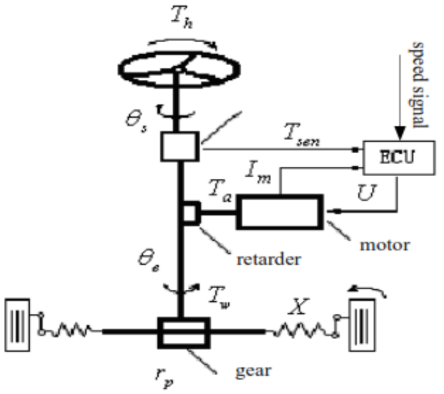

Fig.2. EPS System Modelling[7]:

According to the fig2. , Newton's law could be applied and the factors that are not needed is neglected. The moment of inertia from the steering wheel obtained in equation 1-16 [1]:

$$J_s \frac{d^2\theta_s}{dt^2} + B_s \frac{d\theta}{dt} = T_h - T_{sen} . \quad (1)$$

T_{sen}can be expressed in the equation as follows[1]:

$$T_{sen} = K_s(\theta_s - \theta_e) . \quad (2)$$

The motor used is a dc motor with a mathematical equation as follows :

$$U = L\frac{dI}{dt} + RI + K_b \frac{d\theta_m}{dt} . \quad (3)$$

The moment of inertia show as [1]: :

$$J_m \frac{d^2\theta_m}{dt^2} + B_m \frac{d\theta_m}{dt} = T_m - T_a . \quad (4)$$

EPS steering and motor power are obtained by the equation as follow [1]:

$$\begin{aligned} T_a &= K_m(\theta_m - G\theta_e) \\ T_m &= K_a \cdot I \end{aligned} . \quad (5)$$

While the retarder output has a moment of inertia and knowing and analyzing the gear in the EPS system can be seen in the equation below [1] :

$$J_e \frac{d^2\theta_e}{dt^2} + B_e \frac{d\theta_e}{dt} = T_{sen} + GT_a - T_w \quad (6)$$

$$m_r \frac{d^2x_r}{dt^2} + b_r \frac{dx_r}{dt} = \frac{T_w}{r_p} - F_{TR} \quad (7)$$

External factors has been considered on EPS system that can be a nuisance or noise for the EPS system so that it affects the output of the system itself, as for influencing factors such as air friction, tire friction with asphalt. These factors can be seen in the equation below [1]:

$$F_{TR} = k_r.x_r + F_\delta : \quad (8)$$

$$x_r = \theta_c.r_p \text{ [1]:} \quad (9)$$

Equations 1 through 9 could be simplified as follow [1]:

$$J_s \frac{d^2\theta_s}{dt^2} + B_s \frac{d\theta}{dt} + K_s\theta_s = T_h + K_s \frac{x_r}{r_p} \tag{10}$$

$$J_m \frac{d^2\theta_m}{dt^2} + B_m \frac{d\theta_m}{dt} + K_m\theta_m = T_m + GK_m \frac{x_r}{r_p} \tag{11}$$

$$M_r \frac{d^2x_r}{dt^2} + B_r \frac{dx_r}{dt} + K_r X_r = \frac{GK_m}{r_p}\theta_m + \frac{GK_s}{r_p}\theta_s - F_\delta \tag{12}$$

The value of M_r, B_r, and $K_r$could begained as follows [1]:

$$M_r = m_r + \frac{J_e}{r_p^2} \tag{13}$$

$$B_r = b_r + \frac{B_e}{r_p^2} \tag{14}$$

$$K_r = k_r + \frac{K_s + G^2K_m}{r_p^2} \tag{15}$$

Equations 11 through eq. 15are expresses in state space shownand parameters x, y, and u are shown as follow[1]:

$$\begin{gathered} \frac{dx}{dt} = Ax + Bu \\ y = Cx + Du \end{gathered} \tag{16}$$

$$x = \begin{bmatrix} \theta_s & \frac{d\theta_s}{dt} & x_r & \frac{dx_r}{dt} & \theta_m & \frac{d\theta_m}{dt} \end{bmatrix}^T,$$

$$u = \begin{bmatrix} T_h & T_m & F_d \end{bmatrix}^T,$$

$$y = \begin{bmatrix} T_a & T_{sen} & \theta_m & \frac{d\theta_m}{dt} & x_r \end{bmatrix}^T$$

The state space A, B, C, and D as below:

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ -\frac{K_s}{J_s} & -\frac{B_s}{J_s} & \frac{K_s}{J_s r_p} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ \frac{K_s}{M_r r_p} & 0 & -\frac{K_r}{M_r r_p^2} & -\frac{B_r}{M_r} & \frac{GK_m}{M_r r_p} & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & \frac{GK_m}{J_m r_p} & 0 & -\frac{K_m}{J_m} & -\frac{B_m}{J_m} \end{bmatrix}, B = \begin{bmatrix} 0 & 0 & 0 \\ \frac{1}{J_s} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & \frac{1}{M_r} \\ 0 & 0 & 0 \\ 0 & \frac{1}{J_m} & 0 \end{bmatrix},$$

$$C = \begin{bmatrix} K_s & 0 & -\frac{K_r}{r_p} & 0 & 0 & 0 \\ 0 & 0 & -\frac{GK_m}{r_p} & 0 & K_m & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}, D = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

2.2.3. Propotional Integral Derivative(PID)

This system is a closed loop control with the motor angle output as feedback. It will be compared with the input so that an error is obtained. The error is used as input for the PID controller thatmultiplied by each parameter Kp, Ki and Kd. The closed loop control system is shown in figure 3 as follow.

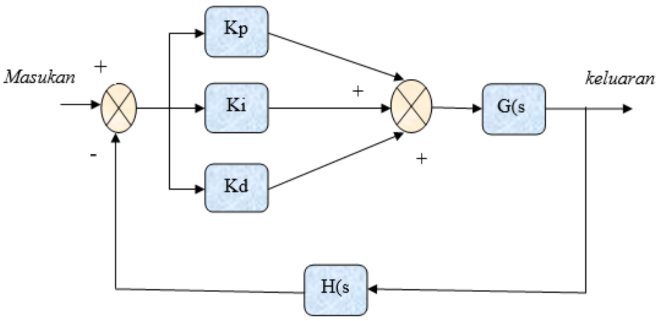

Fig.3. Diagram block control position on EPS system using PID

The values of Kp, Ki and Kd will be multiplied by the error value, this can be stated in the equation below[3]

$$u = Kp.e$$
$$u = Ki.\left(\int e(t)dT\right) \qquad (17)$$
$$u = K_d\left[\frac{de}{dT}\right]$$

Manual tuning is perform to abtained esired respons as shown in table 1.

Tabel 1. Parameter effect in PI controller[9]:

Closed Loop	Rise Time	Overshoot	Settling Time	Steady State Error
Promotional	Decrease	Increase	Small Change	Decrease/Increase
Integrative	Decrease	Increase	Increase	Eliminating
Derivative	Small Change	Decrease	Decrease	Small Change

2.2.4. EPS based on PID

The process of designing an EPS system with PID controllers are discussed. The PID controller used consists of two PID controllers without tuning and PID controllers with manual tuning. The PID controller is used as a position control system on EPS describesas follows:

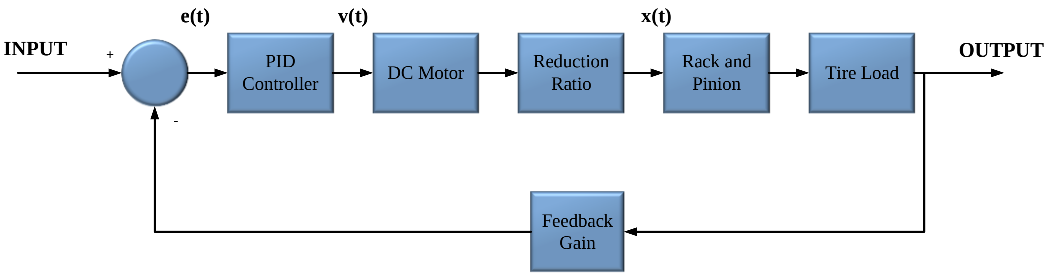

Fig.3. Block diagram system

The initial stage in the design of EPS system control are determining the mathematical model and EPS parameters. After EPS parameters, are defined the state space is perform as:

$$A=\begin{bmatrix}0 & 1 & 0 & 0 & 0 & 0\\ -90 & -20 & 180 & 0 & 0 & 0\\ 0 & 0 & 0 & 1 & 0 & 0\\ 1{,}28 & 0 & -149{,}10 & -1{,}93 & 7{,}14 & 0\\ 0 & 0 & 0 & 0 & 0 & 1\\ 0 & 0 & 71{,}43 & 0 & -20 & -8\end{bmatrix}, B=\begin{bmatrix}0 & 0 & 0\\ 100 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0{,}72\\ 0 & 0 & 0\\ 0 & 20 & 0\end{bmatrix},$$

$$C=\begin{bmatrix}0{,}9 & 0 & -208{,}8 & 0 & 0 & 0\\ 0 & 0 & -10 & 0 & 1 & 0\\ 0 & 0 & 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 0 & 0 & 1\\ 0 & 0 & 1 & 0 & 0 & 0\end{bmatrix}, D=\begin{bmatrix}0 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{bmatrix}$$

This state space is a plant that will be controlled by PID using matlab to obtain the values of Kp, Ki, and Kd. The parameter values Kp, Ki and Kd are obtained based on the output response on the system. The process of positioning control on the EPS system can be explained in the flowchart as follows:

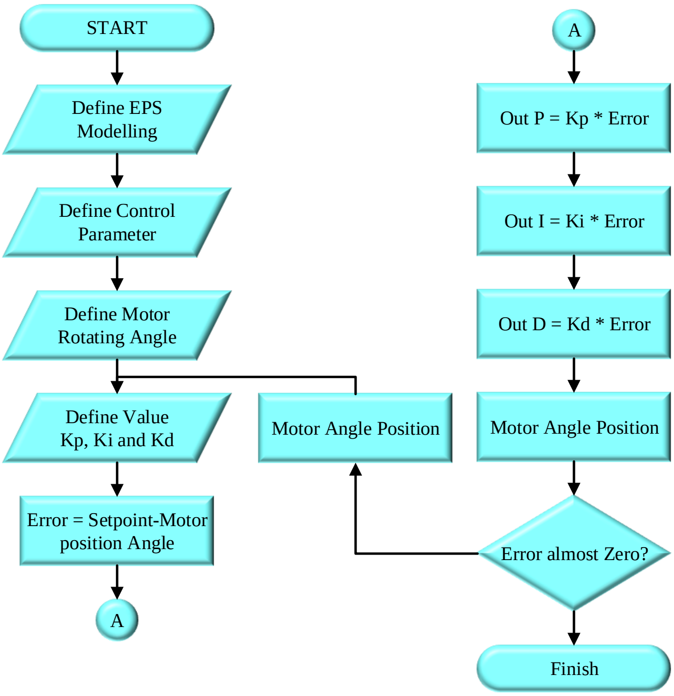

Fig.4.Flowchart system

3. Result and Data Analysis

The test is carried out by comparing the experimental results of the electric power steering system using a controller and without controllers. Experimental results that will be observed are the output response in the EPS system to achieve the desired position, the output observed in the form of a time of equilibrium, steady state error, and overshoot. The block used in Simulink can be seen in **Fig5**.

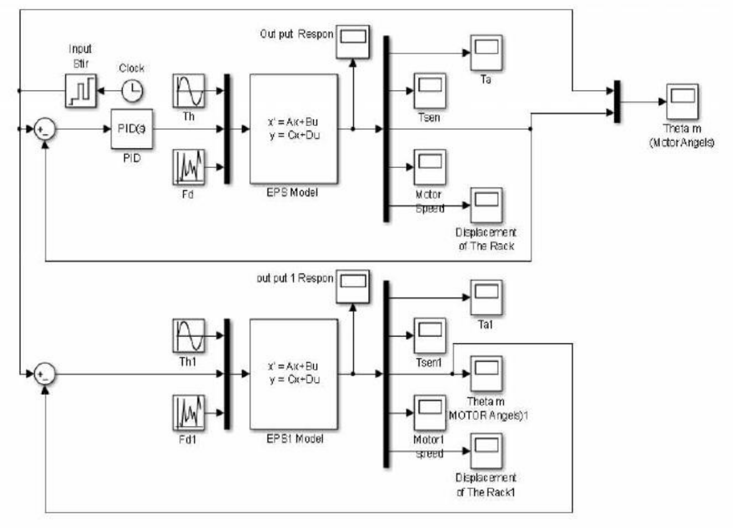

Fig.6. Block Diagram Simulink Matlab

By making two simulations the EPS control system with and without control based on Figure 8 on an EPS system without controllers produces response output as shown below.

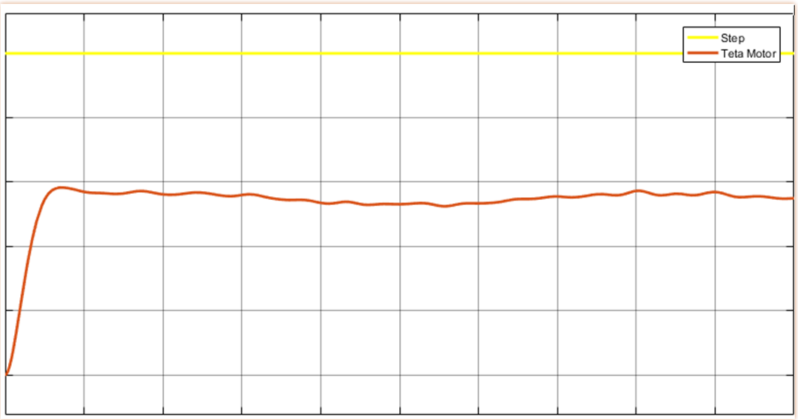

Fig.7.Output Responses without PID

For EPS control systems using PID controllers with parameters Kp, Ki and Kd. These parameters are obtained by manually tuning four times to get the best response output. Response output using PID control can be seen in the picture below.

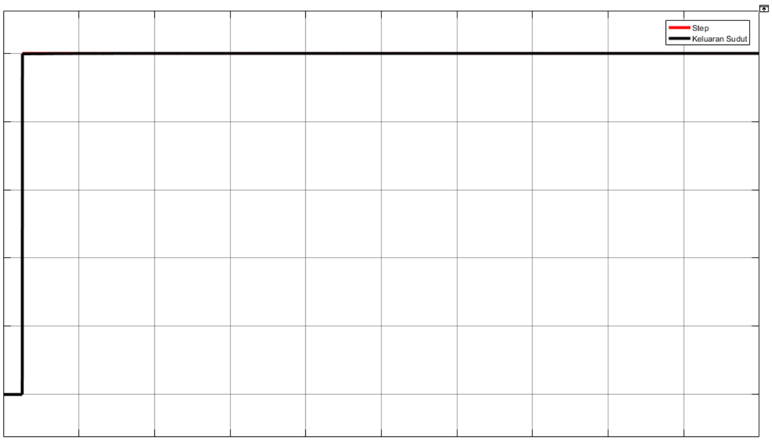

Fig.8.Output Responses with PID

The response output is obtained by the PID parameter values, namely the Kp value of 500, Ki by 500 and Kd by 200. So that the Overshoot value is 0% and the rise time is 0.0025. If both system output responses with and without controllers and given some input values will produce output as shown below.

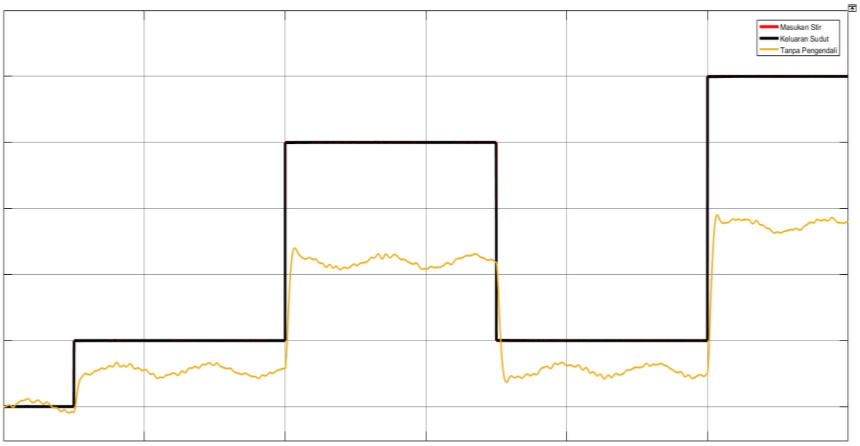

Fig .9.Output Responses With and without PID

The response can be seen in Fig. 9 that the response is very good so that it can follow the direction of movement of the steering input so that this response does not have zero overshoot, rise time is less than 1 second and the steady state error is zero. And the yellow line is an uncontrolled EPS system. So that it is proven that the EPS system works very well when given controllers rather than without controllers.

4. Conclusion

In this research, a simulation of the electric power steering system has been simulated, and the system was tested with the aim of providing a comparison between with and without using PID Controller. So, there is a conclusion as below.

[1]. The PID method successfully controls the position of the EPS system, proven when kp = 500, ki = 500, kd = 200 and input step = 1 obtained the output response: overshoot = 0, and a rise time of 0.005 dt is needed.

[2]. The PID controller produces an overshoot of 0%, and does not have a steady state error.

[3]. The EPS system works better with a PID controller than without a controller, because the controller is enabled so that the system output can be in accordance with the system input.

{4]. From the above explanation, it can be determined and concluded that by providing a better PID control method than without giving controllers to the Electric Power Steering (EPS) System.

Suggestion

It was realized that this study was still incomplete, in future, real parameter should be investigating in order to obtaining the correct EPS parameters. Therefore, to maintain the correct data, this real implementing should be conducted.

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