Artículo de investigación

Reducing the time delay of input torque to the electrical motor of EPS system

Reducción del tiempo de retardo de los pares de entrada al motor eléctrico del sistema EPS
Redução do tempo de retardo dos pares de entrada ao motor elétrico do sistema EPS

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Abstract

An Electric Power Steering (EPS) system will be considered in this report. The electric power steering systems have some benefits over old and traditional hydraulic power steering systems in engine efficiency, space efficiency, and environmental compatibility. According to this system, the researchers will study an electro-hydraulic steering system. In this system, all functional components have been removed in the previous systems and have been made up of an electric motor, speed sensors, torque and electrical control unit. The simplest difference between these systems and last systems is to lower the weight of the vehicle than to the hydraulic systems. The simulation results show that the torque of the motor in the two simulation modes has the same behavior as the input torque, but this torque has a time delay compared to the input. In the vehicle's steering system, it is necessary to minimize the torque associated with the motor to reduce damage to the engine and system, which is also appropriate in simulation results, so that the wave can be ignored. Comparison of simulation results showed that the control system function is much more convenient than when the torque is acted stepwise and suddenly when the input torque is inputted to the system.

Keywords: Electric Power Eteering (EPS) system, permanent magnet synchronous motor, Torque sensor, power steering (auxiliary)

Resumen

En este informe se considerará un sistema de dirección asistida eléctrica (EPS). Los sistemas de dirección asistida eléctrica tienen algunos beneficios sobre los sistemas de dirección asistida hidráulicos antiguos y tradicionales en cuanto a la eficiencia del motor, la eficiencia del espacio y la compatibilidad ambiental. De acuerdo con este sistema, los investigadores estudiarán un sistema de dirección electrohidráulica. En este sistema, todos los componentes funcionales se han eliminado de los sistemas anteriores y se han formado por un motor eléctrico, sensores de velocidad, par y unidad de control eléctrico. La diferencia más simple entre estos sistemas y los últimos sistemas es reducir el peso del vehículo que los sistemas hidráulicos. Los resultados de la simulación muestran que el par del motor en los dos modos de simulación tiene el mismo comportamiento que el par de entrada, pero este par tiene un retardo de tiempo en comparación con la entrada. En el sistema de dirección del vehículo, es necesario minimizar el par de torsión asociado con el motor para reducir el daño al motor y al sistema, lo que también es apropiado en los resultados de la simulación, para que la onda se pueda ignorar. La comparación de los resultados de la simulación mostró que la función del sistema de control es mucho más conveniente que cuando el par se actúa paso a paso y repentinamente cuando el par de entrada se ingresa al sistema.

Palabras claves: sistema eléctrico de Eteering (EPS), motor síncrono de imán permanente, sensor de par, dirección asistida (auxiliar).

Resumo

Um sistema de direção assistida elétrica (EPS) será considerado neste relatório. Os sistemas de direção elétrica têm alguns benefícios em relação aos antigos e tradicionais sistemas de direção hidráulica na eficiência do motor, eficiência de espaço e compatibilidade ambiental. Segundo este sistema, os pesquisadores estudarão um sistema de direção eletro-hidráulico. Neste sistema, todos os componentes funcionais foram removidos nos sistemas anteriores e foram constituídos por um motor elétrico, sensores de velocidade, torque e unidade de controle elétrico. A diferença mais simples entre esses sistemas e os últimos sistemas é diminuir o peso do veículo em relação aos sistemas hidráulicos. Os resultados da simulação mostram que o torque do motor nos dois modos de simulação tem o mesmo comportamento que o torque de entrada, mas esse torque tem um atraso de tempo comparado à entrada. No sistema de direção do veículo, é necessário minimizar o torque associado ao motor para reduzir os danos ao motor e ao sistema, o que também é apropriado nos resultados da simulação, para que a onda possa ser ignorada. A comparação dos resultados da simulação mostrou que a função do sistema de controle é muito mais conveniente do que quando o torque é acionado em etapas e subitamente quando o torque de entrada é introduzido no sistema.

Palavras-chave: Sistema Eteering de Energia Elétrica (EPS), motor síncrono de ímã permanente, sensor de torque, direção hidráulica (auxiliar).

1. Introduction

A steering system is one of major subsystems for vehicle operation. The Hydraulic Auxiliary Steering Command, though extremely sophisticated in the last two decades, was invented in 1927, and for the first time in 1951, Chrysler installed the system on mass production vehicles (Engelman, 1994).

Power steering systems need substantial assist gain level and bandwidth to maintain passable steering efforts for a wide range of diver steering inputs and vehicle operational conditions. A number of articles perform dynamic and stability analysis of power steering systems (Ferries & Arbanas, 1997; Mukai, Noro & Hironaka, 1998) and attempt to quantify driver steering feel (Badawy, Bolourchi & Gaut, 1997). A torque map is the main element of an EPS controller; it determines how much steering torque is assisted by the motor. The shape of the torque map determines how the steering feels for the driver, the slope of the torque map is the steepest when the velocity is zero, and then decreases with an increase in speed, because the torque that is needed to steer is the largest when the vehicle is parked, and the steering needs to feel heavier for the driver when a vehicle is going fast to achieve stability (Crandall, 1978). A high level of controller gain at low velocity and the nonlinearity of the torque map can be a source of instability and vibration in the system (Baxter, 1988); therefore, the stabilizing compensator is required in addition to the torque map to complete the EPS controller. (Zaremba & Davis, 1995). However, designing a proper controller for an EPS has become a challenging problem for a number of reasons (Marouf et al., 2012). The controller needs to be robust in case that there are any unmodeled dynamics and parameter uncertainty. The parameter adjustment can be challenging, because even for the same type of vehicle, each car can have some variation in its system parameters (Zaremba, Liubakka & Stuntz, 1998). In addition, because the steering system interacts with human hands, which can be sensitive, a good controller design should eliminate undesirable vibrations. There have been many studies suggesting various forms of EPS controllers to make the system stable. Reference (Kurishige, Nishihara & Kumamoto, 2010) suggested stable conditions based on an EPS model and utilized a fixed-structure compensator to stabilize the system and minimize the torque vibration. Reference (Franklin, Powell & Emami-Naeini, 2014) used a frequency-weighted damping compensator to increase the phase margin of the system, but the increased range of the phase margin was restricted. Reference (Marouf, Sentouh, Diemai & Pudlo, 2011) employed a H-infinity control to assist torque, improve the steering feel, and enhance the closed-loop robustness. The limitation is that the proposed H-infinity control has a very high order and cannot eliminate vibrations. Reference (Braess & Seiffert, 2013) suggested a robust integral sliding-mode controller to generate the assist torque, stabilize the system, and improve the EPS damping characteristics. Reference (Chabaan & Wang, 2001) proposed an optimal linear quadratic regulator controller for a dual-pinion EPS.

The main advantages of the EPS compared to the HPS are the lower energy consumption and the resulting lower emissions of pollutants (McCann, 2000). For electric and hybrid vehicles, the EPS also offers the advantage that a steering assistance can be provided in the vehicle’s electrical operation mode with an inactive internal combustion engine. However, this potential is associated with a high overall system complexity and consequently a high development and validation effort (Shi, Zhao & Min, 2012).

Before the introduction of automobile engines, there was no need for an electric control unit in the car. Because all the operations in the car from the start and engine start up to the moment it was stopped in all conditions mechanically. But in the case of injectors, it felt that the center would be the main motor vehicle command to issue the necessary commands in different conditions for the ideal engine operation. At the moment, the electric steering control system on the car is mainly divided into two types of electric hydraulic systems (EHPS) and an electrical control system (EPS), the type of EPS being more environmentally friendly and economically feasible. Be In the EPS method, two types of motor are mainly used, which include a non-brushless DC motor and a permanent magnet synchronous motor (PMSM). In this study, we examined and simulated different parts of the system, including mechanical steering system, PMSM engine and ECU. In this chapter we will describe the results of the research. Also, a series of suggestions for researchers who are interested in the continuation of the topic will be presented (Shi, Zhao & Min 2012).

The smallest move in the steering wheel by the driver makes the torque that is detected by this sensor. As soon as the steering wheel is detected by the driver, the sensor through the "ECU" of the special part intended for this purpose transmits the steering command in the proper direction to an electric motor. The engine is connected to the rocket shaft and the power generated by it is transmitted to the rock. The transmission of this force may be via a shoulder gear system or spiral axis. As long as the torque is applied by the driver to the car, the electric motor also works and helps the driver to rotate the steering wheel (Li, Zhao & Chen, 2009).

The steering wheel (EPS) nowadays replaces auxiliary cyphers in a large number of new vehicles. This type of command is similar to the hydraulic model, but it is completely different from a different structure. This system was first introduced in the mid-1970s, but its construction and production. In the first years of the system, the system was the same as the electromechanical steering system, and the problems with the previous systems in the system were still intact. In this system, the problem of the continuity of the service was resolved by HONDA, which means that the electrical system worked when the rotation was in command, or in other words torque.

EPS components include several pars like (i) torque sensor, (ii) speed sensor, (iii) electric motor, (iv) control unit (ECU).
The electric steering system uses an electric motor to provide the necessary steering force. At the moment, the electric motors used in the control system of the electric system (EPS) which are divided into two main categories: 1. Direct current DC motor and 2. Synchronous permanent magnetometer.

The permanent magnetism of the synchronous magnetic field is divided into two groups according to the current and the waveform:

1.Direct and Brushless Power Supply (BLDC) motor and square waveform; 2. Synchronous Permanent Magnetic Motor (PMSM) with Intermittent Power Supply and Cyclic Waveform

The electric motor is converted from electrical energy to mechanical energy. In fact, electric motors are power transmission machines. Today, various engines are in use, including BLDC motors that have high performance and excellent control capabilities and Extensively used in many applications.

The purpose of this research is to design and simulate an EPS system based on the permanent magnet synchronous motor.

2. Method

The centerpiece of this circuit is the 8-bit microprocessor. The microprocessor is an electric chip made of a large number of transistors whose function is to: 1. Perform arithmetic operations such as addition, subtraction, etc. 2. Make new decisions based on existing orders. 3. Place information from part of memory to another.

Microprocessors have two measurement units. The first is the longitudinal unit of the transistors, called the musfet, and the longer the unit of the transistors is. The second unit of microprocessor control is the pulse frequency per hour, which is naturally lower, the lower the response speed of the logic. An 8-bit analog / digital converter with 256-bit memory is also used. The input of this microprocessor is a torque sensor signal and an engine current signal, all of which are converted via analog / digital converters into ECUs. When the torque signal inputs to the microprocessor via an analog / digital converter, the microprocessor acquires the amount of flow required by the engine.

The steering wheel (EPS), even when the engine is off, provides auxiliary power for steering the steering wheel. The system has lower fuel consumption, due to its lower weight than the hydraulic system, and its motor (DC) It only helps us when it's needed.

The system (EPS) works by a 12-volt motor and hence does not depend on the engine's engine power supply, so the steering sensitivity is not affected even when the engine is off.

)EPS) can produce a lot of power when the cars are moving at a slow pace and reduce the ability to drive at high speeds. The guidance with the software system makes the steering precision, moderation, and accuracy of the steering wheel higher. The electric steering system (EPS) was first used on the NSX Acura [Honda, S2000, Toyota Opirus, Toyota RAV4, plus a number of GM models (2009 to 2004), Chevrolet and Pontiac (2009 to 2002)

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Although some of the old electric steering systems were actually electro-hydraulic, so that an electro-motor was used to propel the hydraulic pump, but the new generation of electric commands (EPS) is generally electrical and electronic. The operation of this system is such that when the driver moves the steering wheel, the steering torque sensors get the steering wheel speed and steering speed, and this information through the inputs of the torque input (TORQUE) mounted on the steering shaft is fed to the control unit The command system is sent.

This section, after receiving the inputs for rotation to the correct value to the command engine, and the sensor on the motor, feeds the amount of rotation of the motor into the control unit, indicating that the ECU also monitors the engine position. Gives.

To examine and understand the characteristics of each system, mathematical modeling and then system simulation are required. By describing the system in mathematical language, its theorems and its symbols, and simulating it in the Simulink Matlab environment, we examine the performance and characteristics of the system for various inputs.

Consequently, the simulation and design of an electric steering system (EPS) is based on a permanent magnetometer (PMSM)

Considering the moment of inertia of the steering wheel and ... the torque equation is as follows:

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

Where, J_s is moment of inertia, $\beta_s$is Input axis adhesion range, θ_s is steering input angle, $T_h$is Torque input command, T_{sen} is Force opposite steering torque.

The opposite force of the torque of the steering wheel is equal to the difference between the angle of the inlet axis and the output axis, the equation being as follows:

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

Where θ_s and θ_e are inner axis angle and output axis angle, respectively.

The EPS engine is a permanent DC motor. The motor voltage is:

$$V = L\frac{di}{dt} + RI + K_b \frac{d\theta_m}{dt} \quad (3)$$

Where, L, R,K_b $\frac{d\theta_m}{dt}$ and $I$are inductance, armature Resistance, electromotor recursive force and Engine speed, respectively.

Electromagnetic torque (Tm) was generated by the motor and its formula is written as a coefficient of flow in which the torque coefficient of the motor is in this equation:

$$T_m = K_a I \quad (4)$$

The engine power is also obtained from equation (2):

$$J_m \frac{d^2\theta_m}{dt^2} + \beta_m \frac{d\theta_m}{dt} = T_m - T_a \tag{5}$$

Where, J_m, β_m , $\theta_m$are motorcycle moment inertia, Engine's coefficient of adhesion and Engine angle and T_m is Engine active torque T_a is Engine torque.

Also, the torque is a multiplier of the difference between the angle of the motor and the angle of the output axle.

A simulation of this model is designed to understand and understand the reaction of the system to the sine wave input and input inputs. This simulation is designed in the Simulink software environment and consists of three parts .

The implementation of the mechanical subsystem is based on the following equations in which the torque is entered:

$$J_s\theta_s = T_d - K_s(\theta_s - \theta_r) - B_s\theta_s \tag{5}$$

$$\text{mx} = \frac{1}{r_p}\left[k_m(\theta_m - i_m\theta_r)i_m + k_s(\theta_s - \theta_r)\right] - B_r x - k_r x$$

We need two of the sub-system outputs of the mechanical part, which is: 1. The torque supplied to the magnetic-torque generator part of the magnetic constant. 2. Output of torque to the regulator part.

The torque of our steering is sinusoidal torque.

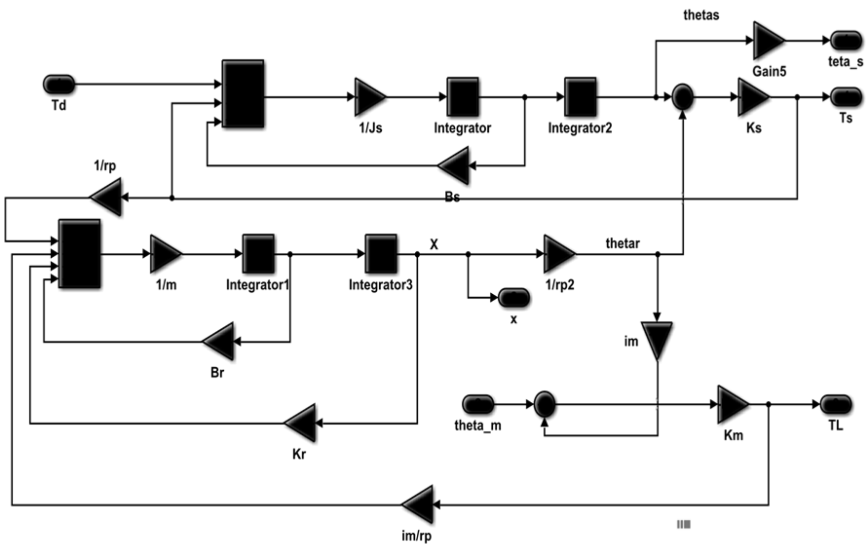


Figure 1 - The steering torque in the form of a sinusoidal torque

The second part is the simulation of the electrical control section. This part consists of a duplex simulation which is the flow regulator (regulator and the inverter section.

In the flow regulator, the torque Ts is the output of the mechanical subsystem and the speed set as input to this section. Using this information, the current regulator estimates the flow of the q axis. This subsystem consists of a data table and an output filter.

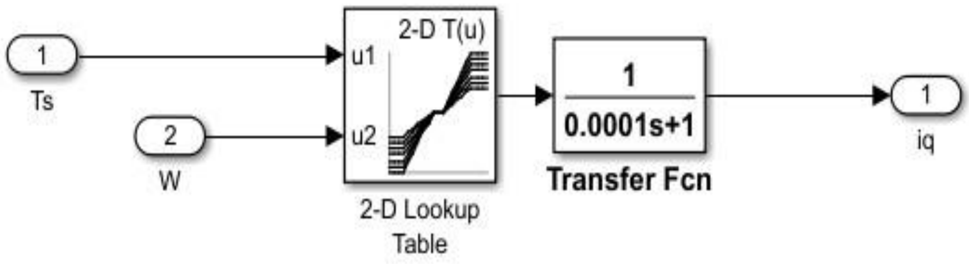


Figure2. The relationship between flow and torque

The data table shows the relationship between flow and torque. How much is the flow rate in different torques? From this subsystem, we obtain the flow of the axis q as the reference current, and along with the reference current, the d axis, which is considered zero, is In addition, the outputs of the motor are fed to the inverter.

The inverter block uses these inputs (reference currents of the q and d angles and output currents) to provide the necessary voltages to propagate the permanent magnet synchronous motor, and then transmit the output voltages to the inputs of the permanent magnet synchronous motor.

The third part is the simulation of a permanent magnetism synchronous motor, which absorbs the torque from the outlet of the mechanical subsystem along with the inverter output voltages.

In the output of this block, we can have values such as motor output speed, output torque and angle + currents of the d, q axis.

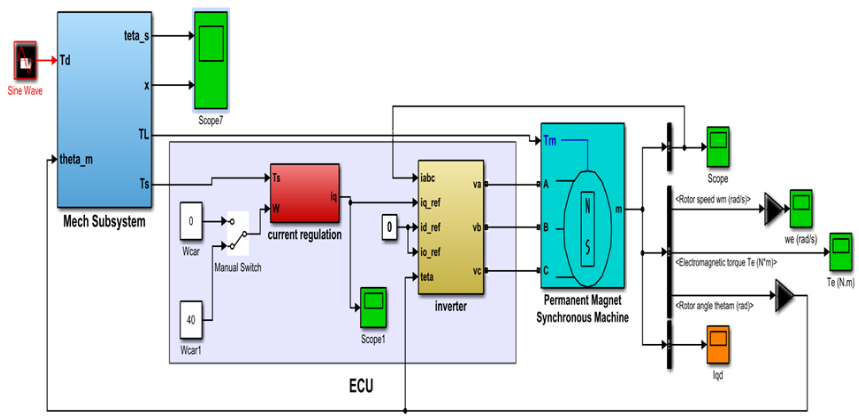


Figure 3 - EPS structure simulation

3. Results and Discussions

In this section, after simulating the different parts of the system, including the mechanical steering system, the PMSM engine and the ECU, we examine the simulation results for two different modes. In the first case, the operation of the control system is investigated for the input of the sinusoidal wave. In the latter case, the performance of the simulated system for the step input and the sudden application of torque to the mechanical control system are checked. It should be noted that all simulations are performed in the MATLAB software environment.

Table 1 - PMSM engine parameters used in research

Parameter	Size
Phase number	3
Number of pair of poles	4
Moment of inertia (kg.m2)	0.0004704
Induced Flux Produced by Magnet (V.S)	0.0175
Stator phase resistance (Ω)	0.1
Stator phase inductance (mH)	1

In the following parts, the simulation results are analyzed for different inputs and in different modes.

3.1 Analyzing the simulation results

In this study simulation results are considered for the following modes:

Mode 1: The steering torque (input of the mechanical part) is a sinusoidal function with a range of 8 and an angular frequency corresponding to the shape.

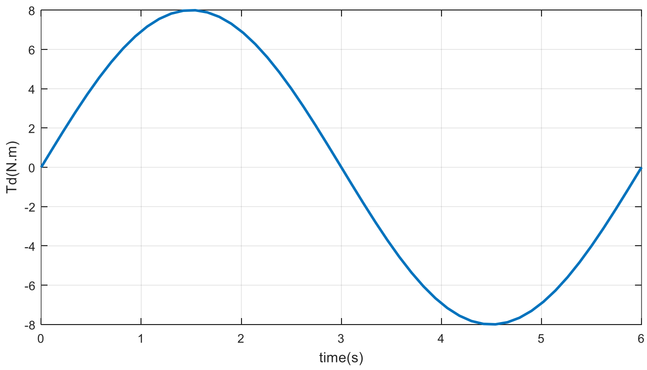


Figure 4 - Sample input torque applied to the simulation system

The steering torque (input of the mechanical part) is a static function with a final value of 8 Nm in accordance in Fig. 5.

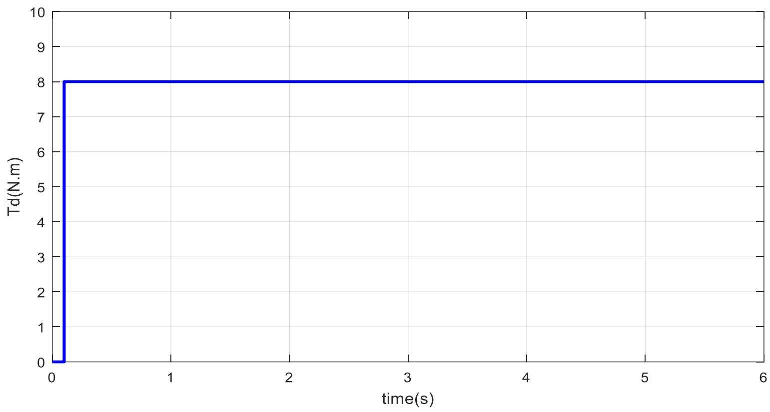


Fig. 5 shows the step input torque applied to the system

The following simulation results are considered for the above two situations.

3.2 Checking the results for the first mode

In this case, the effect of the ECU controller will be investigated by applying the vertically torque sinusoidally. Figure (6) shows the flow curve of the reference iq from the flow controller.

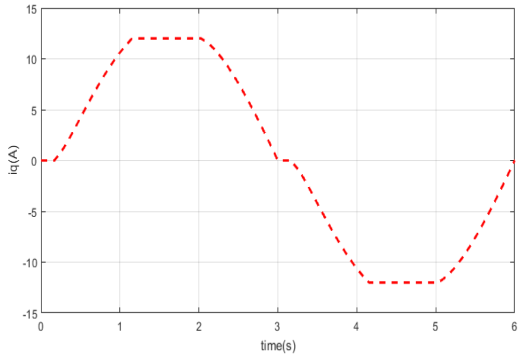


Figure 6: Current reference curve iq obtained from the flow controller (first mode)

Now, for the proper operation of the engine for proper control, the iq motor current must follow the reference value (Fig. 7). Figure 7 shows the curve of the axis flows of the motor d and q.

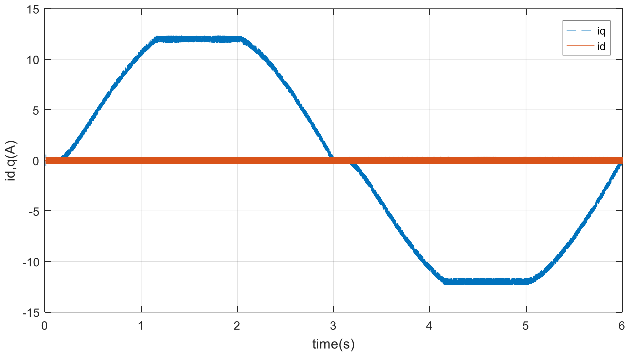
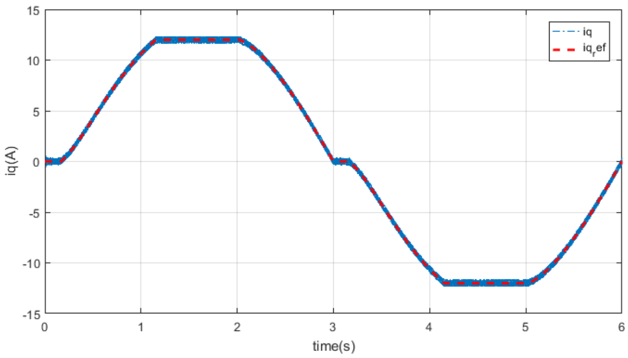


Fig. 7 - Flow curves of motor axis d and q (first mode)

It should be noted that the flow of the motor d axis is considered zero. Now, if we compare the two reference and actual flow rates of the engine related to the q axis, it is quite evident that the controller b works well and the two curves are very close together (Fig. 8).



Total 8 curves for iq current reference and iq motors (first mode)

Figure 9 also shows the torque input curve and motor output torque.

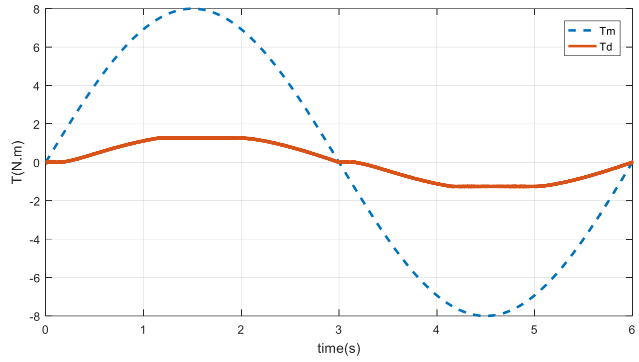


Figure 9 - Motor Output Torque Curve (First Mode)

Figure 10 shows the curve of the sinusoidal input torque to the system and the control torque input of the ECU section, which clearly indicates that the controller functions well and is very close together.

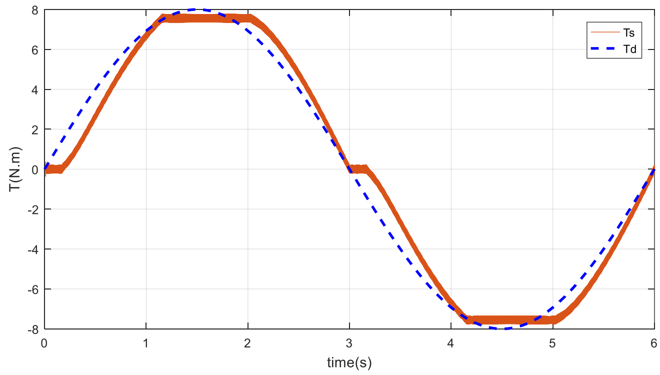


Figure 10 - Input torque curve for the ECU control unit (first mode)

As the curves of torque are known, the torque of the motor is similar to that of the input torque. The only point that exists is that this torque has a delay of less than 0.2 seconds in relation to the input, which can be ignored. Be However, if the ECU controller was not set up properly or was inadequate, this could have been a larger delay and could disrupt the system.

Another point to be noted is that the torque of the ripele is much lower in this case, the less damage to the engine and system, which is also very well suited to the simulation results in this case. Which can be ignored by the amount of ripple?

3.3 The results of the second mode

As stated in the elementary sections, here is a stepped input torque applied to the system to verify that the controller will function in the event that the steering torque suddenly increases.

Figure (11) shows the flow curves of the axis d and q of the motor in this state. In this case, the flow of the axis d is zero.

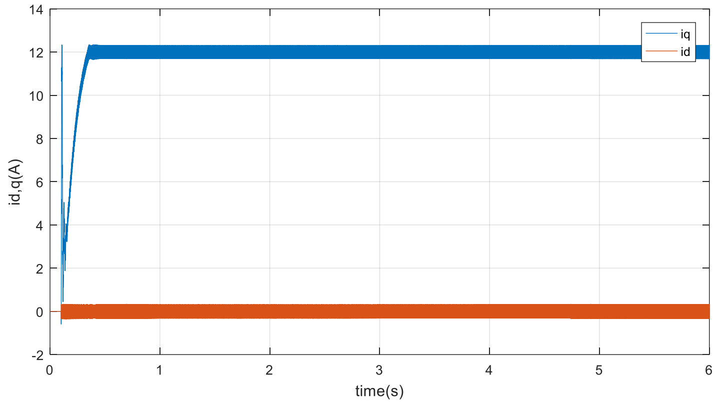


Figure 12 - Curve for reference iq current and motor iq (second mode)

As it can be seen, due to the mechanical parts and the high mechanical inertia of the inertia relative to the electrical energy, the intake torque increases steadily, the engine can not follow it promptly and has a delay in When the torque is raised, it is also in practice. In this case, the current also has a greater amount of ripals than the first one. Figure (13) also shows the torque curve of the engine.

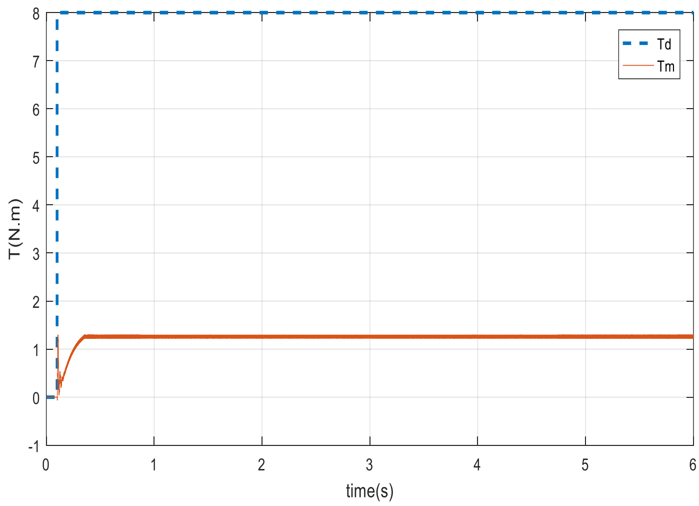


Figure 13 - Motor Output Torque Curve (Second Mode)

As can be seen, in the curve of the above figure, the existence of a delay in tracking the stepped intake torque by the engine is clearly evident due to the presence of mechanical parts and time delays. Figure (15) shows the torque curve input to the ECU control section.

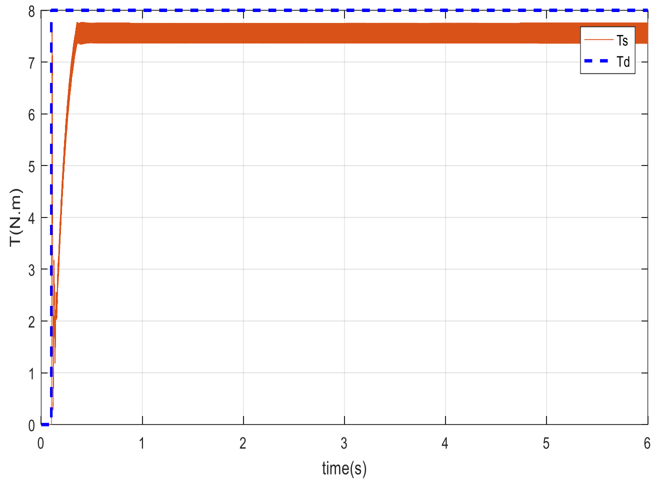


Figure 14 - Input torque curve for ECU control unit (second mode)

As the torque curves are specified, in this case, the torque of the motor is similar to the torque input, but this torque has a delay time than the input and can be neglected. The point to be made here is that the torque of the torque of the motor is less in this case, less damage to the engine and the system, which is also very well suited to the simulation results, in such a way that You can ignore the amount of ripple.

4. Conclusion

In this paper, the EPS model is based on the PMSM engine to complete the PMSM and EPS control simulation, which results in the proper functioning of the control system for controlling the PMSM engine in different modes. The results show that here are two significant points: first, torque should follow the reference value. The amount of current and motor torque should not be too high, as it can lead to a lot of damage to the system.

The main and important results obtained from the present study are:

The steering wheel (EPS) now replaces the hydraulic command, in a large number of new vehicles. One of the advantages of EPS is the removal of a hydraulic hydraulic pump, which consumes 8 to 10 horsepower from engine power. It also removes hydraulic fluid, hoses, leaks, and the need to check them out for the advantages of this system. This system also works more smoothly than the hydraulic command. Because there is no pump sound, no liquid inside hoses and valves, but the most striking difference is the steering and regularity of the steering wheel.

The electric steering system is adjusted to extremely precise measurements, which are difficult to adapt to for hydraulic controls. This system can provide a direct drive by checking the steering inputs, vehicle speed and other dynamic factors. At the same time, because it is driven by the software system, it increases the accuracy of the steering wheel and its moderation and sensitivity.

One of the key parts of the electric steering system is the ECU or ECU. The ECU in the vehicle is a vehicle made using electronics and computer science. The importance and economic role of the ECU, and especially the structure of that day, are on the rise.

Due to the expansion of the use of PMSM engines in the car system, it is necessary to use suitable controllers to control the speed of such engines.

The simulation results show that the torque of the motor in the two simulation modes has the same behavior as the input torque, but this torque has a time delay compared to the input. In the vehicle's steering system, it is necessary to minimize the torque associated with the motor, in order to minimize damage to the engine and system, which is also appropriate in the simulation results, so that the ripple can be ignored. Compare simulation results It says that the control system function is much more convenient than when the torque is acted stepwise and suddenly when the input torque is inputted to the system. Due to the mechanical steering and mechanical part of the mechanical part, the engine is very slowly following the reference value of the control system, which is also the case in practice.

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