Design of control system for Electric Power Steering in vehicle

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Abstract— **Electric power steering system (EPS) uses an electric motor to provide essential control to the driver. The EPS system uses variable assist, that provides more assistance as the speed of a vehicle decreases, on the contrary, it provides less assistance. This paper introduces the basic composition of the electric power steering system, and the correction methods of controller, given the main technology index of the controller. According to the performance requirements of cars steering system, make the relevant control strategy of the electric power steering system and through the design of related software and hardware to realize this control strategy and it can control each link of the automobile steering process. In this paper, a multi-agent system method was introduced to deal with the control problem of EPS system. The multi-agent system control strategy shows the advanced nature, superiority and feasibility of the theoretical analysis and engineering application of EPS control system.**

Keywords— multi-agent system; vehicle; Electric Power Steering; control strategy.

I. INTRODUCTION

Nowadays due to new advancement in electric machine, sensors, and control systems, system of electric guidance replaced to hydraulic guidance system. In EPS system, electric motor connects to steering rod turn via a gear mechanism. Sensors measure the transmitted torque and the edge position of the steering rod. Control system, receive sensor information, speed of the vehicle and the regulation scale and then after, send the application order to the electric motor so that the auxiliary torque will be generated. Electric guidance system has some advantages due to hydraulic direction system. These advantages are included in improvement in fuel efficiency, change in auxiliary torque by change of vehicle speed, ability in generating the auxiliary torque even if the automobile motor is off. Some other benefits to this system are Simpler and less auxiliary and additional instrumentation, adjustable guidance specification and elimination of the hydraulic liquid. One hydraulic system continuously give small load on motor even when the auxiliary torque is not needed, but as the EPS system applies only when this auxiliary torque is required, no additional energy will be consumed. so the fuel efficiency will be improved. Gear box is one section of EPS system included in gears which are connected from one side to the car wheels via a long

shaft, and to the electric motor from the other side. EPS system is a complex non-linear dynamics containing different working conditions. The requirements of vehicle steering are high and involve many factors and it's difficult to adopt a single control strategy to coordinate the conflicts between the performance requirements under different conditions[1,2]. In this paper, a multi-agent system method was introduced to deal with the control problem of EPS system. First, the architecture and working principle of EPS system was introduced. Then, through the control requirements in EPS system, the MULTI-AGENT SYSTEM -based EPS control strategy and architecture was discussed and the basic function and behavior of every agent was represented. And according to the different working conditions, EPS system was divided into assist control model, return-to-center control model and damping control model, and corresponding Flexible-PID control algorithm, Fuzzy-PID control algorithm, Bang-Bang-PID control algorithm were designed. It has practical engineering significance to the design of EPS motor control strategy, to the improvement and optimization of EPS function and to the steering manipulation safety and provides an effective control method for EPS system.

II. SYSTEM MODEL

Electric power steering system (Fig.1) is designed to use an electric motor to reduce effort by providing steering assist to the driver of a vehicle. It consists of a torque sensor, which senses the driver's movements of the steering wheel as well as the movement of the vehicle; an ECU, which performs calculations on assisting force based on signals from the torque sensor and vehicle sensor; a motor, which produces turning force according to output from the ECU; and a reduction gear, which increases the turning force from the motor and transfers it to the steering mechanism. By incorporating electronic stability control electric power steering systems can instantly vary torque assist levels to aid the driver in evasive man oeuvres and allow varying amounts of assistance to be applied depending on driving conditions.

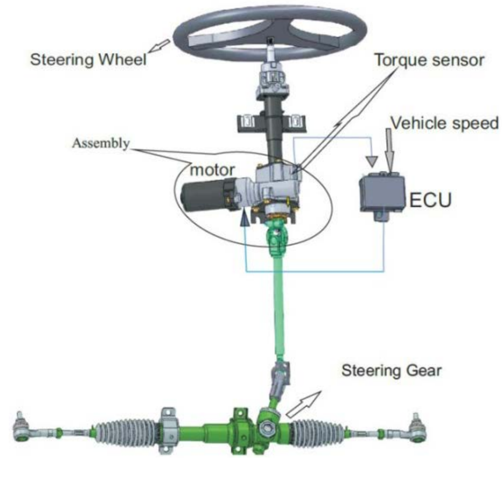

Fig.1. A column-type EPS system.

EPS system has a slight advantage in fuel efficiency because it is no belt-driven hydraulic pump constantly running, whether assistance is required or not, and this is a major reason for their introduction. Another major advantage is the elimination of a belt-driven engine accessory, and several high-pressure hydraulic hoses between the hydraulic pump, mounted on the engine, and the steering gear, mounted on the chassis which greatly simplifies manufacturing and maintenance [3].

The motor for EPS is a permanent magnetic field DC motor. Attached to the power steering gear assembly, it generates steering assisting force. Fig.2 illustrates the construction of a DC motor, consisting of a stator, a rotor, and a commutation mechanism [4,5].

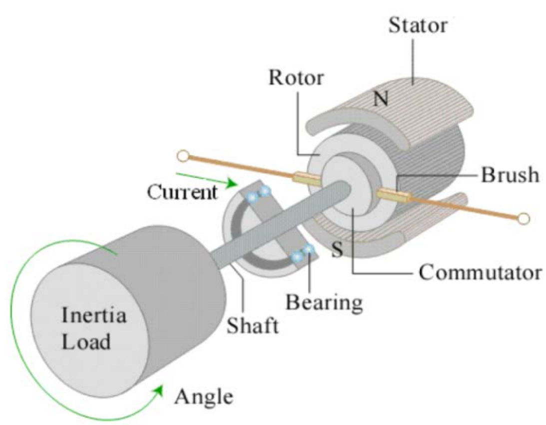

Fig.2. DC motor construction.

The stator consists of permanent magnets, creating a magnetic field in the air gap between the rotor and the stator. The rotor has several windings arranged symmetrically around the motor shaft. An electric current applied to the motor is delivered to individual windings through the brush-commutation mechanism, as shown in the figure. As the rotor rotates the polarity of the current flowing to the individual windings is altered. This allows the rotor to rotate continually. Fig.3 is the schematic of the electric circuit, including the windings resistance R and inductance L.

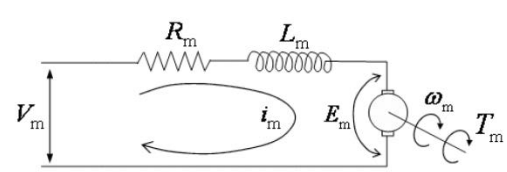

Fig.3. Electric circuit.

We can get the transfer function of a DC motor, and the mathematical model is given by

$$\begin{cases} V_m = R_m i_m + L_m \frac{di_m}{dt} + e_m \\ T_m = K_t i_m \\ T_m = T_L + T_f \\ e_m = K_e \omega_m \end{cases} \tag{1}$$

The mathematical model in the frequency domain are

$$\begin{cases} V_m(s) = R_m I_m(s) + L_m s I_m(s) + E_m(s) \\ J_m s \omega_m(s) = -B_m \omega_m(s) - T_L(s) + T_m(s) \\ E_m(s) = K_m \omega_m(s) \\ T_m(s) = K_m I_m(s) \end{cases} \tag{2}$$

If set $T_L = 0$ and relate V_m to T_m , there is

$$T_m^{(1)}(s) = \frac{K_m(J_m s + B_m)}{(L_m s + R_m)(J_m s + B_m) + K_m^2} V_m(s) \tag{3}$$

If set $V_m = 0$ and relate T_L to T_m , there is

$$T_m^{(2)}(s) = \frac{K_m^2}{(L_m s + R_m)(J_m s + B_m) + K_m^2} T_L(s) \tag{4}$$

There is the matrix transfer function as following

$$T_m(s) = T_m^{(1)}(s) + T_m^{(2)}(s) = \begin{bmatrix} \frac{K_m(J_m s + B_m)}{(L_m s + R_m)(J_m s + B_m) + K_m^2} \\ \frac{K_m^2}{(L_m s + R_m)(J_m s + B_m) + K_m^2} \end{bmatrix}^{-1} \begin{bmatrix} V_m(s) \\ T_L(s) \end{bmatrix} \tag{5}$$

III. MULTI-AGENT SYSTEM CONTROL STRUCTURE

As is known to all, EPS system is a complex non-linear dynamics containing different working conditions. The requirements of vehicle steering are high and involve many factors and it's difficult to adopt a single control strategy to coordinate the conflicts between the performance requirements under different conditions. An agent is a computer system that is capable of independent action on behalf of its user or owner, that is, which figures out what needs to be done to satisfy design objectives, rather than constantly being told. And a multi agent system is one that consists of a number of agents, which interact with one-another. In the most general case, agents will be acting on behalf of users with different goals and motivations. To successfully interact, they will require the ability to cooperate, coordinate, and negotiate with each other, much as people do. A multi-agent system method should be introduced to deal with the control problem of EPS system.

multi-agent system control structure consists of Data Acquisition Agent, Condition Monitoring Agent, Controller Selection Agent, Flexible-PID Control Agent, Fuzzy-PID Control Agent, Bang-Bang-PID Control Agent, PWM Drive Agent and Stability Control Agent which is shown in Fig.4.

Data Acquisition Agent is used to obtain the EPS system's data and stored in the database for Condition Monitoring Agent and Controller Selection Agent calls for determining the choice of controller. Stability Control Agent is used to monitor and ensure that all controllers and the whole EPS system's stability. PWM Agent is used to adjust the PWM duty cycle to obtain the magnitude and direction of the motor [6,7].

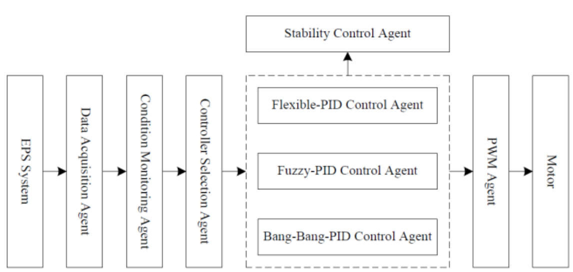

Fig.4. multi-agent system control structure.

The block diagram of control strategy of EPS system is shown in Fig.5. The assist characteristic unit determines the reference current to the motor based on the driving conditions, and the controller computes the control signal which minimizes the error between and the actual current. The EPS controller conducts a search for data according to a table lookup method based on the signals input from each sensor and carries out a prescribed calculation using this data to obtain the assist force.

Another important technology is the generation of Pulse width modulation (PWM) signal which is employed in a wide variety of applications, ranging from measurement and communications to power control and conversion [4,5] .

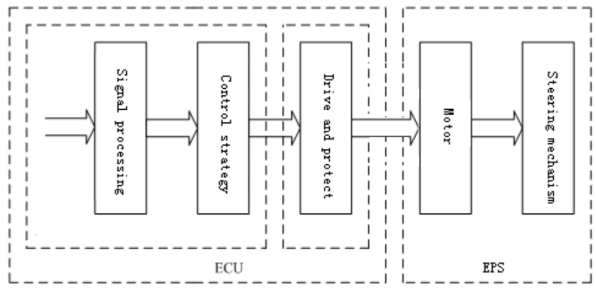

Fig.5. EPS control strategy

In the assist control model and for Flexible-PID Control Agent, the target motor current which is proportional to the motor assist torque is determined from the signal output from the torque sensor, and the Flexible- PID controller is performed so that there is no difference between this target current value and the value detected through feedback from the current sensor (Fig.6).

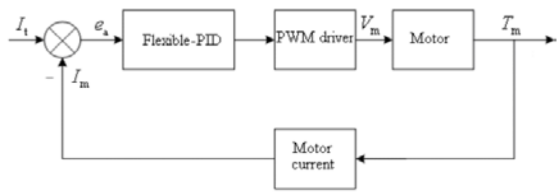

Fig.6. Flexible-PID controller.

In the return-to-center control model and for the Fuzzy-PID Control Agent, the vehicular control requirements are when at low speed the return curve must pass back to the starting point, and when at high speed the allowed residual angle was not allowed to exceed 5° (Fig.7).

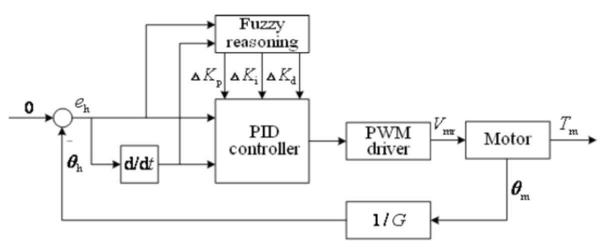

Fig.7. Fuzzy-PID controller

In the damping control model and for the Bang-Bang-PID Control Agent, the control structure was adjusted between the Bang-Bang controller and PID controller so as to make the error reduced by using the shortest optimal control problem (Fig.8).

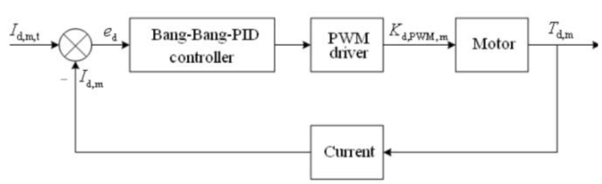

Fig.8. Bang-Bang-PID controller.

IV. CONCLUSIONS

For EPS system, assist motor, torque sensor and Electronic Control Unit are the three key components. The core of the controller is control strategy which not only reflects the EPS control functional requirements, the level of adaptive capacity and intelligence as well as the key bottleneck and technology of independent research and development.

The multi-agent system control strategy shows the advanced nature, superiority and feasibility of the theoretical analysis and engineering application of EPS control system. In different control model, the switching and function of each controller were effective and could meet the real-time control demand under different working conditions. It has practical engineering significance to the design of EPS motor control strategy, to the improvement and optimization of EPS function and to the steering manipulation safety and provides an effective control method for EPS system.

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