Simulation and Implementation of an ECU for Electric Power Steering System

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ABSTRACT
This paper focuses on the simulation and development of the ECU for a electric assisted power steering system. This article begins by introducing the EPS (Electric Power Steering) system concept and comparing the technical and commercial benefits with existing technologies. This EPS system improves the engine efficiency, reduces the weight and there by reduces the fuel consumption, the electronic control unit is implemented using the freescale's S12X microcontroller and the responsiveness in the steering is achieved by providing different motor assistance at different vehicle velocities. This active steering is possible using intelligent fuzzy logic control mechanism in the ECU.

Keywords: **Active Steering, Fuzzy Logic, Electronic -control unit.**

1. INTRODUCTION
The recent researches in automotive technology mainly concerned with the reduction of fuel consumption and providing comfort driving, in recent times the hydraulic power steering were replaced by electric power assisted steering system. This change directly influences the fuel economy since the electric motor replacing the hydraulic actuator reduces the vehicle weight to a great extent. The hydraulic actuators are always coupled with the engine whereas in EPS that is not the case. The comparison of fuel consumption in EPS and hydraulic power steering (HYPAS) is shown in figure1.[1]

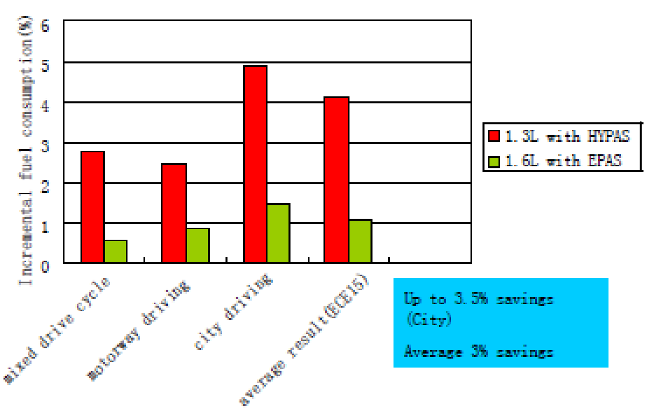

Figure 1. Fuel Consumption in EPS VS HYPAS

The EPS not only reduces the fuel consumption but also reduces the driver effort by providing torque assistance, the EPS system proposed in this paper is based on the concept of active steering where the steering assistance is provided on the basis of the vehicle's velocity.

2. ELECTRIC POWER STEERING SYSTEM
Electric power steering is fully electric system, which reduces the amount of steering effort by directly applying the output of an electric motor to the steering system. The key components of an EPS system includes a torque sensor, vehicle speed sensor, an actuator(electric motor),an electronic control unit(ECU) and control diagnostic algorithm. The typical EPS system is shown in the figure2.

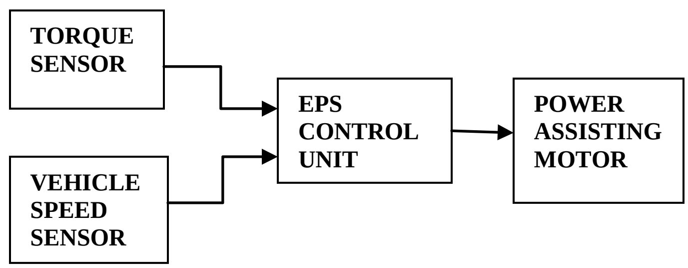

Figure 2. Block Diagram of an EPS System

2.1 Active Steering System
Active steering system is a type of steering wheel speed responsive method which varies the degree that the wheels turn in response to the steering wheel. At lower speeds, this technology reduces the amount that the steering wheel must be turned improving performance in situations such as parking and other urban area traffic maneuvers. At higher speeds, the performance is such that the normal increased responsiveness from speed is avoided and it provides improved directional stability, Safety is one of the prime objectives of this system. This responsiveness in the steering is smoothly achieved with the help of fuzzy logic control algorithm.

3. FUZZY LOGIC CONTROL
The term Fuzzy can be simply defined as imprecise way of expressing a quantity, In general fuzzy logic controller is used where the mathematical model of the system is too complicated and when there exist a nonlinear relationship between the variables. However in some cases the mathematical model do exist and lead to satisfactory result the fuzzy logic controller can be used to improve the performance of the system or for

simplifying the implementation, but for this fuzzy logic control a behavioral knowledge or predefined solution about the system is necessary. This fuzzy logic control is based on the natural language and experience of experts, as above said the fuzzy logic model is a very powerful tool for dealing quickly and efficiently with the imprecision and nonlinearity [2]. A typical fuzzy logic controller is shown in figure3. Which performs the three functions namely fuzzification, fuzzy reasoning and defuzzification.

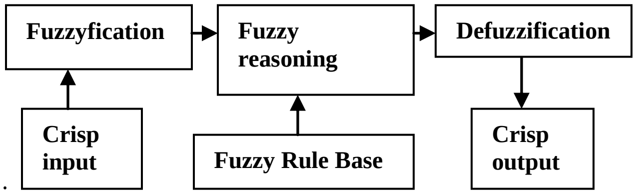

Figure 3. Fuzzy Logic Controller

3.1 Fuzzification

This is process in which the given crisp input is converted into fuzzified inputs, these fuzzified inputs were referred by the fuzzy linguistics with a degree of membership (DOM) associated with it. The input torque can be resolved into the different fuzzy linguistic sets:{VBIG,QBIG,BIG,MEDIUM,SMALL,VSMALL}.

For velocity the fuzzy sets can be set as:{VFAST,QFAST,FAST,MEDIUM,SLOW,VSLOW,ZERO}. In general a fuzzy set is represented as follows:

$$A=\{x,\mu(x)|X\square x\}.$$

were A is the fuzzy set , x is the crisp input ,$\mu(x)$ is the membership function and X is the universal set, In our case the torque and velocity are the universal set and resolved into many subsets as explained above. Input and output adopts the triangular and trapezoidal membership functions as shown in figure 4 and 5.

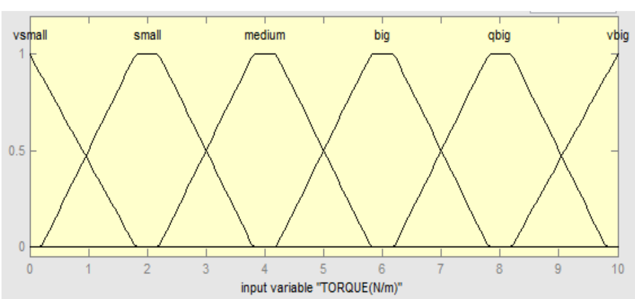

Figure 4. Membership Functions for Torque

The trapezoidal membership function is given by the following relation

$$\begin{aligned} \mu(x) &= a(b-x)/(b-c) \quad ; \quad b \geq x \\ &= a \quad ; \quad c \geq x \\ &= a(e-x)/(e-d) \quad ; \quad d \geq x \\ &= 0 \quad ; \text{ otherwise} \end{aligned}$$

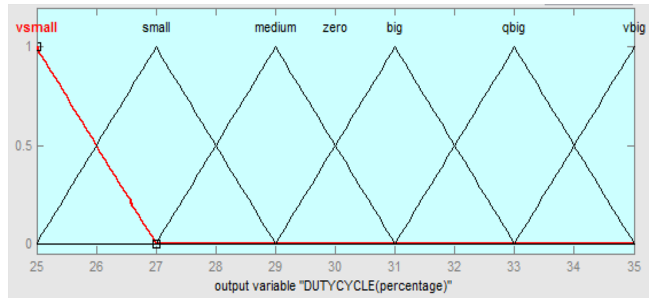

Figure 5. Membership Functions for PWM Dutycycle

The triangular membership function is given by the following relation

$$\begin{aligned} \mu(x) &= a(b-x)/(b-c) \quad ; \quad b >= x \\ &= a(d-x)/(d-c) \quad ; \quad c >= x \\ &= 0 \quad ; \text{ otherwise} \end{aligned}$$

3.2 Fuzzy Reasoning

The fuzzy reasoning is important process since this is decision making part of the algorithm. The fuzzy rule is commonly in the form IF-THEN statement. The fuzzy reasoning is done by applying the fuzzy rule base for the inputs. Fuzzy rule base is based on the expert's knowledge and experience. According to practical control experience, the linguistic variable of fuzzy control rules can be expressed as table I

Table 1.

		TORQUE						
		VBIG	**QBIG**	**BIG**	**MEDIUM**	**SMALL**	**VSMALL**	**ZERO**
VELOCITY	**VFAST**	VSMALL	VSMALL	VSMALL	ZERO	ZERO	ZERO	ZERO
	QFAST	SMALL	VSMALL	VSMALL	VSMALL	ZERO	ZERO	ZERO
	FAST	SMALL	SMALL	VSMALL	VSMALL	VSMALL	ZERO	ZERO
	MEDIUM	MEDIUM	MEDIUM	SMALL	SMALL	VSMALL	VSMALL	ZERO
	SLOW	BIG	MEDIUM	MEDIUM	SMALL	SMALL	VSMALL	ZERO
	VSLOW	QBIG	BIG	MEDIUM	MEDIUM	SMALL	VSMALL	ZERO
	ZERO	VBIG	QBIG	BIG	MEDIUM	SMALL	VSMALL	ZERO

The assist motor is controlled by pulse-width modulation, the duty cycle value for the discrete sets of velocity and torque is given in the above table.

$$\text{DUTYCYCLE=TORQUE } \Theta \text{ VELOCITY.}$$

For this aggregation the degree of membership (DOM) is determined by using the following relation

$$\mu_{Dutycycle}=\min[\mu_{torque}(x),\mu_{velocity}(x)]$$

3.3 Defuzzification

In this step the fuzzy linguistics were again converted into optimal crisp value. The defuzzification method used here is weighted average method.

Crisp output= $(\Sigma\, \mu(x).\, x) \;/\; (\Sigma \mu(x))$

Here x is the crisp value and μ(x) is the DOM value associated for the crisp input x. This weighted average method is used because it is found to provide better crisp output. The control algorithm is traced by giving a test input represented as flow chart in figure 6. For easy understanding.

4. HARDWARE IMPLEMENTATION

The electronic control unit is implemented with freescale's s12X microcontroller. According to the basic requirements of EPS, the range of steering torque is from 1 to 10 N/m and velocity ranges from 0 to 120 Km/h, based on this input the motor assistance is provided. The motor is controlled by the on-chip pulse width modulator in the controller. To control the D.C motor a 8-bit PWM is used, Here the motor is controlled by fixing the pulse period as constant and varying the duty cycle. Where the duty is the total percentage of 'ON TIME' in a single pulse period. In this the single pulse period is 1msec and the duty cycle is varied from 20% to 35%. The PWM pulse is captured using the digital CRO and shown in the figure 7.

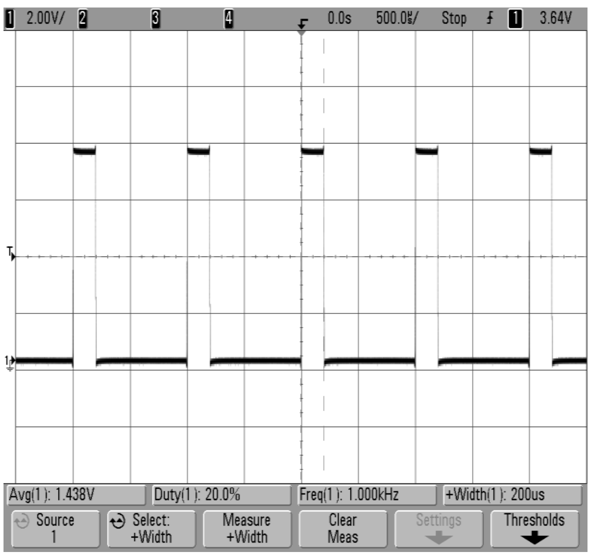

Figure 7. D.C Motor PWM wave form

The relation used for determining the PWM duty register (PWMDTY) value from duty cycle is given below

$$Duty\ Cycle\ \% = [PWMDTY / PWMPER] * 100\%.$$

4.1 Test signal generation

The ECU developed for the motor assistance is tested with the test signal generated from PC, the signals were fed into microcontroller through serial communication, based on the serial input values the controller actuates the motor. The test signal generator is a standalone application developed using the MATLAB's GUIDE (Graphical User interface Development Environment). The test signal generator is shown in figure 8.and the entire hardware setup is shown in figure 9.

Figure 8. GUI Based Test Signal Generator

5. SOFTWARE USED

The development tool used is FREESCALE CODE WARRIOR V5.0 [3] since the ECU was developed on Freescale's MC9S12XDT512 microcontroller. Free scale Code Warrior IDE was used to develop the software . The standard tools available in Code Warrior are Project manager, Editor, Search engine, Source Browser, Build System, Debugger. The tools we used in the development of smart car are Project Manager, Editor, Build System, and Debugger. CodeWarrior supports three main languages- C, C++, re-locatable assembly. It provides tools for rapid application development e.g., Device Initialization, Processor Expert. It supports ANSI level startup as well as minimal startup. CodeWarrior also provides single step execution for debugging. The simulation environment used for fuzzy logic simulation is MATLAB/SIMULINK fuzzy logic toolbox.[4].

6.SIMULATION RESULTS

The existed non-linearity between inputs and output is achieved and surface plot is found good which is shown in the figure 10.

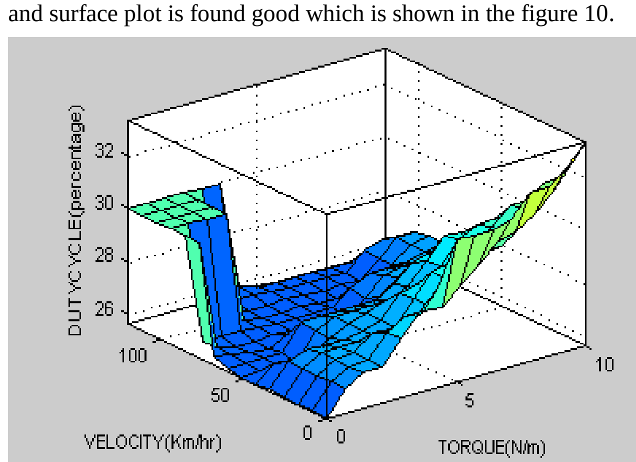

Figure 10. Velocity VS Torque Vs Dutycycle

The rules fired during the fuzzy reasoning and the respective input and output can be examined using the fuzzy ruler shown in figure 11.

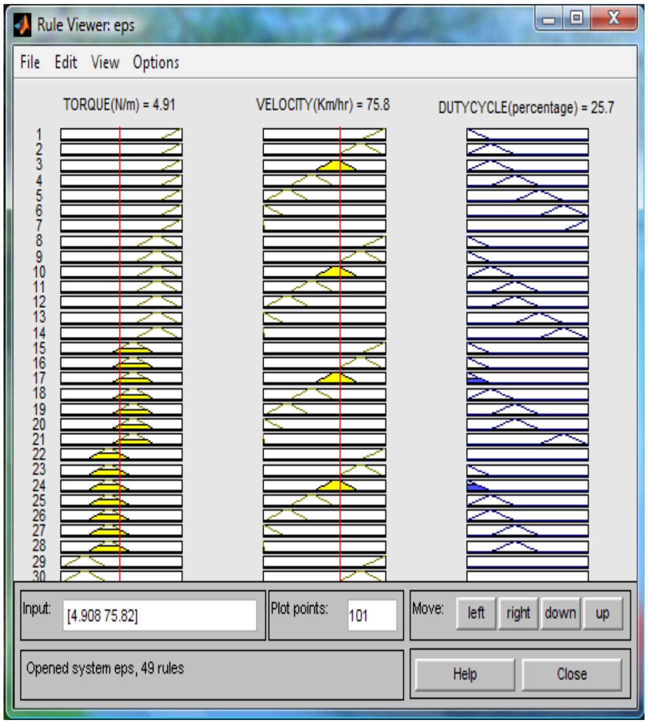

Figure 11. Rule Viewer

7. ACKNOWLEDGEMENTS

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8.REFERENCES

[1] Burton A.W innovation for electric power assisted steering control magazine,IEEE volume 23,Issue 06 30-39 Dec 2003

[2] Huijie Yao;Xiuhua Gao;ZHANG Xiao-Jiang.Fuzzy control strategy based on vehicle EPS power of analysis.Machinery Design and manufacturer,2008-07-006.

[3] Freescale CodeWarrior IDE, Version 5.0

[4] Mathworks.Building Systems with Fuzzy logic ToolBox,Version 2.1.3(R14),2007.

[5] Freescale MC9S12XDP512RMV2 Datasheet, Rev. 2.21, October 2009

[6] Ahmad .M.Ibrrahim-2004 Elsevier Science-“Fuzzy logic for embedded system application”.