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Building ECUs for Electric Power-Assisted Steering Systems

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Abstract - *A system of servo control is EPS. This essay addresses the basic components of an electric power steering system and offers a valid justification for the development and controller correction techniques, taking into account the controller's major technical index. The respective control technique of the electrically powered steering system is created in line with the performance requirements of the vehicle steering system, and the necessary software and hardware is created to implement this control strategy and regulate each link in the vehicle steering process. Comparative studies are carried out on a vehicle outfitted with the produced EPS and the imported EPS, respectively, to confirm the viability of the control technique. The outcomes demonstrate that the generated EPS performs similarly to the imported EPS. The designed EPS can be employed in light-duty vehicles because it not only performs well but also has acceptable steering performance.*

Key Words: Electric power steering System, ECU building Fuzzification, fuzzilogic

1. INTRODUCTION

An increasing number of active control systems, including electric power steering (EPS), active suspension systems (ASS), and anti-lock brake systems (ABS), have been developed in an effort to further improve vehicle performance. Many of these systems have been in use on a commercial basis for almost forty years. An increasing number of individual control systems are being used because no single system can be effective across the whole range of vehicle operating conditions. These systems are made for specific purposes, so interference between them and a complex systematic control is inevitable, which limits and degrades the performance of the vehicle. It is well recognized that the coordinated efforts of multiple vehicle control subsystems are mostly responsible for improving the dynamics of the vehicle. As a result, there is a propensity to integrate the various subsystems in order to ensure and improve the functioning of the vehicle. This has become a research focus in the field of vehicle dynamics control.

The usage of electric power-assisted steering in automobile vehicles has increased significantly. Theoretically, there are two types: electro-hydraulic power steering (EHPS), which utilizes an electric motor to drive a hydraulic pump, and electric power steering (EPS), which uses the electric motor to directly assist the steering action (a pump similar to that used in conventional power steering). While EPS is forecast to grow dramatically over the next few years, EHPS penetration, which is presently estimated at approximately 8%, is expected to stay steady. It is projected that EPS, which presently has a 25% market share, will be standard equipment in every second car sold in the next ten years. In comparison to EPS, the EHPS system has additional parts since it also includes a hydraulic pump, a brushless DC (BLDC) electric motor, and the necessary electronic control unit (ECU). EHPS is preferable to conventional power steering because it can control and improve the hydraulic pump drive's energy efficiency. The pump does not need to build up pressure if little or no steering is required. This cannot be done (or can only be done extremely expensively and laboriously) with a standard power steering system since the pump is driven directly by the combustion engine. An EPS no longer has a hydraulic system. The electric motor directly assists the steering motion.

There are lower costs because the hydraulic system is not there. Nevertheless, the risk is increased in the event of failure since the electric motor directly affects the steering column. This has delayed the implementation of these systems and created a market opportunity for EHPS, which has a lower risk of failure. Nevertheless, this risk has been diminished by redundancy for crucial sub-components (similar to the aircraft industry) and thorough validation testing.

2. RELATED WORK

2.1 The Electric Power Steering System

e electric power steering (EPS) system greatly improves vehicle handling and stability, which completely transforms the driving experience. By directly applying an electric motor's output to the steering system, EPS lessens the physical effort needed to steer, improving overall control. The EPS system, which consists of the electrical unit and the mechanical structure, is a seamless addition to the contemporary automobile environment. Electronic parts including the steering column, torsion bar, reduction gear mechanism, power steering motor, and gear rack cooperate with mechanical parts like the wheel speed and torque sensors. The complex interaction between mechanical and electronic parts illustrates the high level of engineering that goes into an electric power steering system in a car. The design of this system, as shown in Figure 1, demonstrates the complex interplay between these elements, emphasizing the seamless integration of mechanics and technology for the best driving performance.

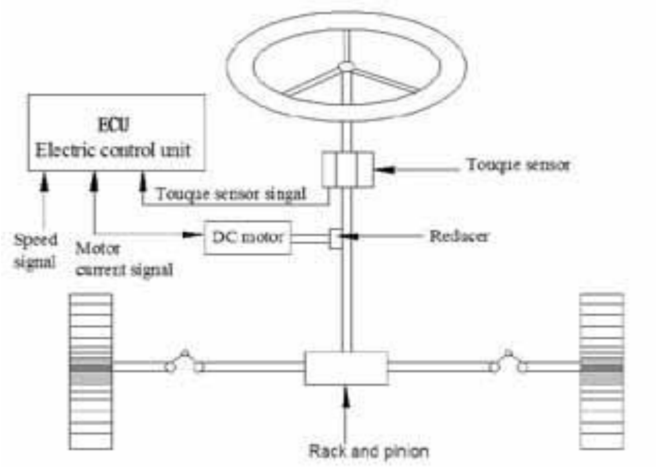

Figure 1. Vehicle Schematic

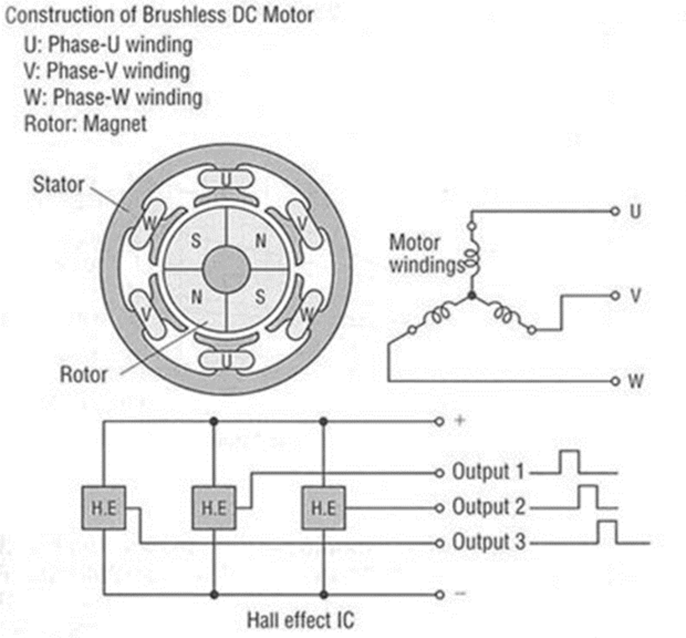

Figure 1.2. BLDC Motor

3. THE DESIGN FOR THE HARDWARE OF THE CONTROLLER

3.1 Power Vary Circuit

The primary characteristics of this brush dc motor are: rated voltage of 12 V, rated current of 30 A, and rated speed of 1180 RPM. We employ dc pulse width modulation (PWM) technology for power motor control. The modulation frequency generated by the MCU in this system, which operates on a set frequency width, is 21 KHz. The following are the main benefits of PWM speed: (1) the main circuit is simple, requiring fewer power components; (2) due to its high switch frequency, requiring only the filtering action of the armature inductance, we can obtain the smooth dc current, and its speed adjusting performance is good; (3) switching devices work only in switch condition, consuming little power in the main circuit, and the devices are highly efficient.. Power varies circuit shown in figure 2.

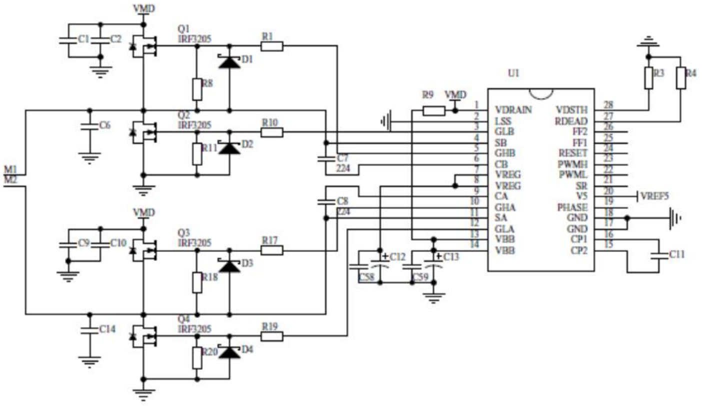

Figure 2 . Power Varies Circuit

3.2 The Overall Framework For Hardware Circuit

The microcontroller, power circuit, signal processing circuit, dc motor power driving module, fault diagnosis and display module, speed sensor, torque sensor, engine ignition signal, access processing circuit for current and current sensor, etc. are the main modules that make up the hardware circuit of the electric power steering system. Figure 3 below depicts the EPS system hardware's logical architecture.

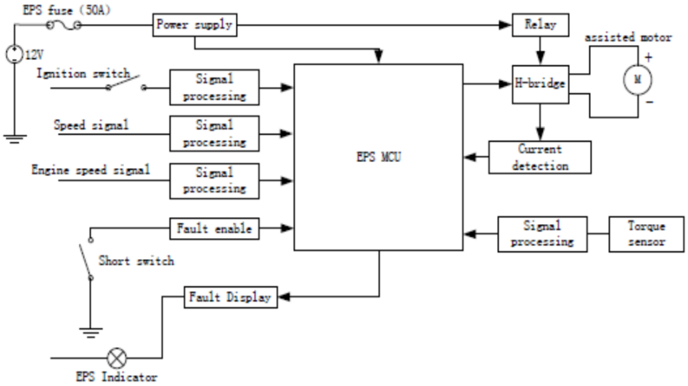

Figure 3 . Composition diagram for EPS Control System

The hardware design exhibits a few things: (1) we employ two distinct input roads for the circuit to increase dependability. The numeration chip automatically records the pulse number on one route. Two HSI ports on the MCU finish the job in the other route; setting a hardware watchdog to prohibit PWM output; and focusing on electromagnetic compatibility and strong and weak electricity separation while designing the PCB. (4) The heat dissipation of the power components needs to be noted in the structure's layout.

4. SOFTWARE DESIGN

Using the modular design concept and the C programming language. It can be separated into the main programme and the interrupt service procedure depending, interrupt input reflecting steering wheel rotation on its functions. The primary programme is for data acquisition and processing to achieve the high sampling rate requirements. Several control tasks, including serial communications information, setting the watchdog timer to a number, timing PWM output, and timer fault diagnosis, are completed via interrupts. The primary programme flow chart is shown in Figure 5(a). The algorithm for PID correction and PWM output interrupt service is shown in Figure 5(b). The software design additionally takes the following actions to guarantee the system's dependability on the anti-interference aspects:

(1) Digital filter: to average-filter the data gathered to guard against pulse interference. This entails sorting a continuous sample of a limited number of data, eliminating the two largest and smallest, and then average the remaining data. Moreover, use differential identification to account for the volume of data.

(2) Many "RST" directives that allow PC pointers to point to the program's beginning at 2080H are encoded in the routines. In addition, all programme modules have multiple "NOP" instructions added in advance of the crucial test, jump, and call instructions.

(3) Microcontroller software watchdog function is also utilised in addition to hardware watchdog. (4) To ascertain if the operating state is normal, it is necessary to conduct real-time tests on the main components, significant parameters (such as battery voltage, motor current, etc.), and significant storage units. (5) To write the EPROM with the fundamental system settings.

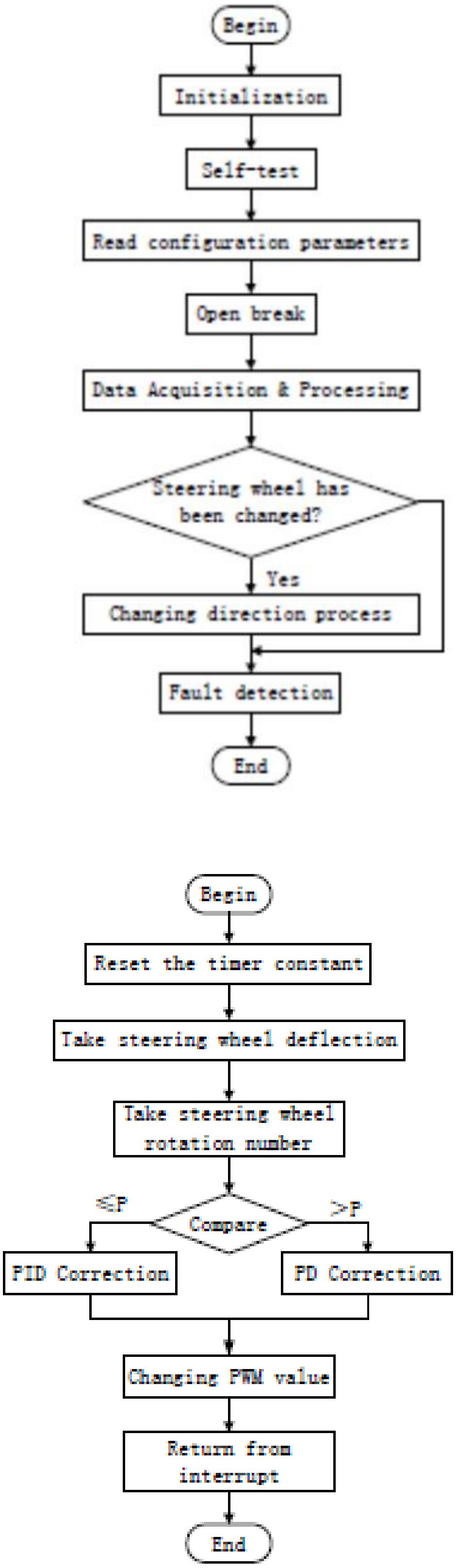

Figure 3.1. Working Algorithm

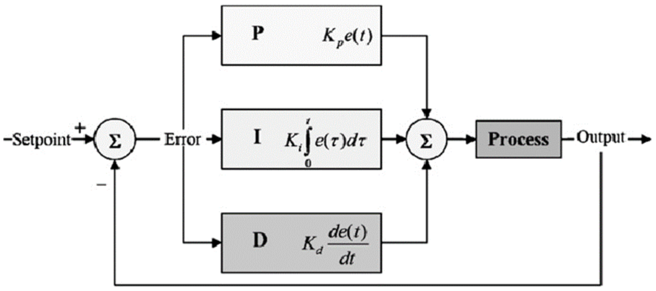

Figure 3.2. PID Control

4.1 Fuzzy Logic Control

Fuzzy logic controllers find their niche in applications where the mathematical model of a system is excessively intricate or when there exists a nonlinear relationship among variables. The term "fuzzy" denotes an imperfect representation of numbers, capturing nuances that classical binary logic might overlook. Employing a fuzzy logic controller becomes advantageous when either the system lacks a precise mathematical model, or the available model is too complex to yield practical results. This approach proves particularly valuable in scenarios where system performance improvement or simplified implementation is desired.

Despite its utility, fuzzy logic control necessitates behavioral information or a predefined solution for the system. It operates on the principles of natural language and leverages the expertise of domain experts. The fuzzy logic model emerges as a potent instrument for swiftly and effectively handling imprecision and nonlinearity [2]. In the realm of fuzzy logic control, Figure 4 illustrates a typical fuzzy logic controller, showcasing the seamless execution of three essential tasks: fuzzification, fuzzy reasoning, and defuzzification. This integrated process facilitates the translation of vague and imprecise information into a well-defined and actionable output, making fuzzy logic controllers' invaluable tools for navigating complex, real-world systems

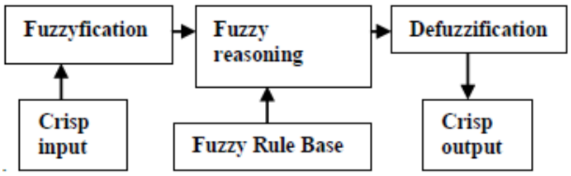

Figure 4. Fuzzy Logic Controller

4.2 Fuzzification

In the intricate process of fuzzy logic control, the pristine input undergoes a transformation into fuzzified inputs characterized by fuzzy linguistics and a corresponding Degree of Membership (DOM). These fuzzy inputs, represented by various fuzzy language sets such as VBIG, QBIG, BIG, MEDIUM, SMALL, and VSMALL, play a pivotal role in resolving input torque complexities. Each set possesses a distinct degree of membership, contributing to a nuanced understanding of input properties. Similar to velocity settings, fuzzy settings generate a dynamic spectrum adjustable from ZERO to VFAST, QFAST, FAST, MEDIUM, SLOW, and VSLOW. This adaptability empowers the system to dynamically respond to changing conditions, accommodating a diverse range of scenarios.

Exploring the theoretical underpinnings, a fuzzy set can be expressed as A=x, (x)|Xxx, where A is the fuzzy set, x is the crisp input, (x) is the membership function, and X is the universal set. In our example, torque and velocity define the universal set boundaries, within which subsets are constructed using the fuzzy language sets. This systematic breakdown facilitates a comprehensive analysis, enhancing the understanding of input characteristics and their broader implications.

To further elucidate these concepts, Figure 5 serves as a visual aid, illustrating the seamless integration of trapezoidal and triangular membership functions for input and output parameters. These graphical representations bridge the gap between abstract principles and real-world applications in the field of fuzzy logic and control systems, providing a tangible illustration of the discussed theoretical concepts. This visual approach aids in conveying complex ideas, making the theoretical foundations more accessible and applicable in practical scenarios.

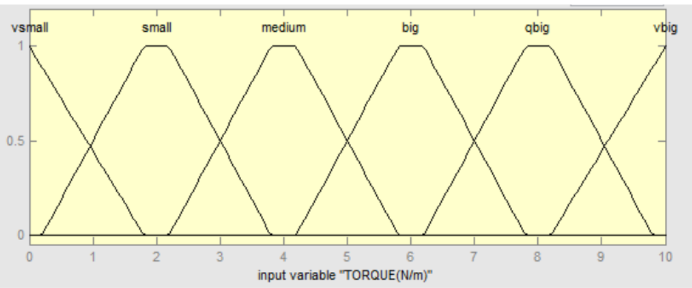

Figure 5. Membership Functions for Torque

4.3 Fuzzy Reasoning

Within the intricate realm of algorithmic decision-making, fuzzy reasoning emerges as a crucial and nuanced step, offering a means to navigate the complexities of imprecise or uncertain knowledge. This sophisticated method takes the form of fuzzy rules, often expressed with IF-THEN statements, providing a framework to capture the intricate nuances inherent in real-world scenarios. Fuzzy rules constitute the bedrock of fuzzy reasoning, and their formulation involves the amalgamation of extensive domain expertise and practical experience of the system's expert.

The architecture of fuzzy rules is a carefully crafted interplay of theoretical knowledge and hands-on control experience, as exemplified by the organized structure of Table I. This table serves as a comprehensive repository, encapsulating language variables and their corresponding fuzzy rules, all distilled from authentic control scenarios. Each rule encapsulates the expert's tacit knowledge, transforming it into a set of structured instructions that guide the algorithm in making nuanced decisions.

The richness of the fuzzy rule architecture not only contributes to the algorithm's flexibility but also underscores the symbiotic relationship between the designer's experience and the algorithm's prowess in navigating intricate decision spaces. These rules, expressed in a well-organized manner, serve as a bridge between theoretical constructs and practical applications. They embody the collective wisdom derived from real-world challenges, providing the algorithm with a robust foundation for effective decision-making.

Furthermore, the structured presentation of fuzzy control rules in Table I attests to the integration of theoretical knowledge and practical control experience. It showcases the depth of understanding required to distill complex real-world situations into a set of rules that an algorithm can utilize for decision-making. The mutual enrichment between the system designer's expertise and the algorithm's adaptability ensures that the decision-making process is not only theoretically sound but also finely tuned to address the intricacies of dynamic and unpredictable environments. In essence, fuzzy reasoning, as embodied in these rules, stands as a testament to the fusion of human expertise and algorithmic precision in the pursuit of effective decision-making in complex domains.

Table 1. Fuzzy logic

		TORQUE						
		VBIG	QBIG	BIG	MEDIUM	SMALL	VSMALL	ZERO
VELOCITY	VFAST	VSMALL	VSMAIL	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	VSMAIL	ZERO
	SLOW	BIG	MEDIUM	MEDIUM	SMALL	SMALL	VSMALL	ZERO
	VSLOW	QBIG	BIG	MEDIUM	MEDIUM	SMALL	VSMALL	ZERO

The duty cycle value for the discrete sets of velocity and torque for the aid motor is presented in the above table. The assist motor is regulated by pulse-width modulation. Torque velocity equals duty cycle. The following relation is used to calculate the degree of membership (DOM) for this aggregate. Torque=min[velocity(x)], dutycycle(x)].

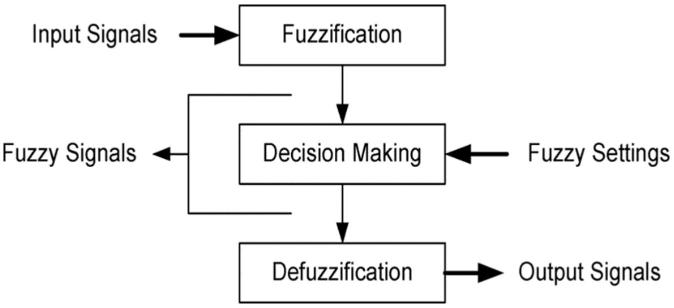

Figure 6. Fuzzy Reasoning System

4.4 Defuzzification

In this transformative phase, the previously nebulous languages seamlessly transition into a state of utmost clarity through the meticulous application of a weighted average approach for defuzzification. This intricate process culminates in a crisp output, represented by Crisp output = f(x), with (x) denoting the Degree of Membership (DOM) value corresponding to the crisp input x. The judicious implementation of the weighted average approach places precision at the forefront, ensuring not only accuracy but also a refined and distinctly clear outcome. The sophistication of this methodology lies in its ability to generate an output that is not only precise but also transparent, thereby enhancing the interpretability of the system's response.

The systematic refinement of fuzzy languages involves a thoughtful consideration of linguistic variables and their associated membership functions. Through this nuanced defuzzification process, the system navigates a multidimensional space of linguistic terms, allocating appropriate weights to different regions based on the degree of membership. This intricate precision ensures that the resulting output not only faithfully represents the input data but also optimally captures the underlying patterns, fostering a robust and reliable decision-making mechanism.

To vividly demonstrate the effectiveness of this approach, a test input is presented and comprehensively illustrated as a flow chart in Figure 6. This visual representation serves as a navigational guide, offering a step-by-step understanding of the control method and facilitating an intuitive comprehension of the system's behavior.

Furthermore, the adaptability of the weighted average approach is a notable feature, allowing for fine-tuning and customization based on specific application requirements. This adaptability, coupled with the inherent precision of the method, positions it as a versatile tool in various fields, including control systems, artificial intelligence, and decision support systems. Delving deeper into the intricate layers of this methodology, its elegance is not only rooted in theoretical foundations but also in its practical implications for solving real-world problems. The methodology emerges as a powerful and versatile solution, bridging the gap between theory and practical application in complex decision-making scenarios.

5. DESIGN STRATEGY FOR FUZZY CONTROLLER

Select a reasonable framework for the fuzzy controller:

Selecting a suitable framework for a fuzzy controller marks the initial phase in its development. This crucial step involves making informed decisions about the structure of the controller, beginning with the identification and definition of input and output variables. The careful determination of these variables serves as a fundamental prerequisite before delving into the specifics of the controller's architecture.

In the process of designing a fuzzy controller, the selection of an appropriate framework is akin to setting the stage for its subsequent functionality. The framework acts as a scaffolding upon which the intricate network of fuzzy logic, rules, and decision-making processes will be built. Therefore, the success of the fuzzy controller is inherently tied to the thoughtful consideration and definition of its input and output variables.

The choice of input variables involves identifying the key parameters or factors that will influence the controller's decision-making. These variables encapsulate the essential aspects of the system under control, providing the necessary input for the fuzzy logic to process. On the other hand, output variables represent the desired outcomes or control actions that the fuzzy controller will generate based on the processed input information.

By establishing a clear understanding of the input and output variables, system designers lay the groundwork for formulating the rules and logic that will govern the fuzzy controller's behavior. This systematic approach ensures that the fuzzy controller is tailored to the specific characteristics and requirements of the targeted system, enhancing its adaptability and effectiveness in managing complex and dynamic environments.

In summary, the meticulous process of choosing a framework for a fuzzy controller involves a strategic focus on defining input and output variables. This foundational step sets the stage for the subsequent development of the fuzzy logic, rules, and decision-making processes, ultimately contributing to the controller's ability to navigate and control complex systems.

Choose and separate the fuzzy control rules:

The foundational elements of a fuzzy controller reside in its fuzzy control rules. The process of generating these rules is a critical aspect of creating an effective fuzzy logic system, and it involves careful consideration of key factors related to specified performance requirements. Typically, a set of fuzzy rules is formulated, taking into account four crucial performance concerns, each contributing to the overall efficiency and reliability of the fuzzy logic system:

1. Rapid Response to Large Errors:

This performance concern emphasizes the need for the fuzzy controller to react swiftly when presented with significant errors in the system. Rapid response ensures that the controller can quickly adjust its output to bring the system back to the desired state, mitigating the impact of large errors on system performance.

2. Prevent System Overshoot:

Overshooting, where the system response extends beyond the desired setpoint, can lead to instability and undesirable outcomes. Fuzzy control rules are crafted to prevent or minimize overshooting, ensuring a controlled and stable response to changes in the input or setpoint.

3. Suppressing Oscillation:

Oscillations in the system's response can introduce instability and hinder smooth operation. Fuzzy rules are designed to suppress oscillations, providing a mechanism to dampen or eliminate undesirable fluctuations in the system output. This contributes to the overall stability and predictability of the fuzzy controller.

4. Zero Steady State Error:

Achieving zero steady state error is a critical performance goal, particularly in systems were maintaining a precise setpoint is essential. Fuzzy control rules are tailored to ensure that, over time, the system settles at the desired setpoint with minimal or zero deviation, enhancing the controller's accuracy and long-term performance.

By incorporating these performance concerns into the generation of fuzzy control rules, system designers aim to create a fuzzy logic system that not only responds effectively to dynamic changes but also operates with stability, precision, and minimal error. The careful consideration of these factors underscores the adaptability and reliability of fuzzy controllers across a wide range of applications.

Establish a control table and decide on fuzzification and defuzzification strategies:

When developing a fuzzy control system, all faults and error rates must first be converted from crisp inputs to fuzzy inputs. The crisp output for the control's execution will thereafter be created from the fuzzy set U of control rates.

Establish the fuzzy controller's parameters:

The phrase "basic universe of discourse of the quantized variables" refers to the useful range of error and error rate in a control system. It is necessary to ascertain the universe of discourse for each input and output while creating a particular fuzzy controller. The A/D and D/A converters in the fuzzy controller's voltage and current range will be specified by these control needs.. Nonetheless, the fuzzy logic controller's structure includes scaling units, which let the controller magnify the inputs and outputs to a desired range.

6. THE PACKAGING TECHNOLOGY

When designing and implementing electronic power steering (EPS) systems, packaging technology is essential to achieving the best possible performance, dependability, and space efficiency. The packaging process for EPS entails the fusion of multiple parts and subsystems into a sturdy, small unit. The following are important features of the electronic power steering systems' packaging technology:

1. Compact Design: Compared to conventional hydraulic systems, electronic power steering systems are made to be smaller. The packaging technology aims to reduce the amount of space needed, making it easier to integrate into contemporary cars, where space is frequently at a premium. The removal of large hydraulic parts makes this design more compact.

2. Integration of Electronic Components: Sensors, controllers, and actuators are just a few examples of the electronic components that must be integrated into the packaging of EPS. Together, these parts measure steering input, process data, and give the driver the help they need. These electronic components are placed inside the car correctly and are well-protected thanks to efficient packaging.

3. Heat Dissipation: During operation, electronic components produce heat, and efficient packaging technology takes care of this requirement. To keep electronic components from overheating and to prolong their lifespan, the design includes heat sinks, cooling fans, and other thermal management strategies.

4. Vibration and Shock Resistance: During operation, vehicles encounter varying degrees of vibration and shocks. EPS packaging technology considers these dynamic conditions and incorporates designs and materials that absorb shock to prevent damage or malfunction to delicate electronic components.

5. Environmental Protection: Electronic power steering systems are subjected to a variety of challenging environmental factors, such as temperature fluctuations, dust, and moisture. Long-term dependability is ensured by packaging technology, which uses weather-resistant materials, sealed enclosures, and protective coatings to shield the components from external influences.

6. Electromagnetic Compatibility (EMC): To avoid interfering with other vehicle electronics, electronic power steering systems are packaged with electromagnetic compatibility in mind. In order to control electromagnetic emissions and shield the system from outside interference, shielding techniques are used.

7. Serviceability: The ease of maintenance and repair is another aspect of packaging technology. In order to minimize downtime during maintenance, components that may need to be replaced or serviced, like sensors or electronic control units, are positioned and designed with accessibility in mind.

8. Cost Effectiveness: By maximizing the use of resources and production techniques, efficient packaging helps to lower overall manufacturing costs. Mass production, component standardization, and modular designs that can be modified to fit various vehicle models are all taken into account.

Conclusions

The controller and electric power steering system have undergone extensive testing and continuous development to deliver a high level of precision and responsiveness for drivers. The tactile sensation transmitted through the steering wheel enhances control, allowing drivers to achieve precise maneuvers with ease. The system's impact on power delivery is equally remarkable, contributing to a smooth and dynamic ride across various driving conditions.

As we approach the final stages of refining the software, our primary objective is to guarantee peak responsiveness and optimal performance. Leveraging advanced diagnostic tools, we are conducting thorough tests to identify and rectify any potential issues. A meticulous debugging process is being employed to address any faults, ensuring that the electric power steering system not only meets but exceeds the most stringent requirements for user satisfaction, safety, and dependability.

The commitment to achieving superior performance is reflected in the comprehensive testing protocols and ongoing development efforts. By focusing on refining the software, we aim to fine-tune every aspect of the electric power steering system to provide drivers with an unparalleled driving experience. The emphasis on user satisfaction extends beyond mere functionality, encompassing the creation of a driving environment that instills confidence and reliability.

In adhering to rigorous quality standards, we are not only meeting industry benchmarks but pushing the boundaries to set new standards for excellence. The integration of advanced diagnostics and meticulous debugging procedures underscores our dedication to delivering a product that not only performs exceptionally but also stands out in terms of safety, reliability, and user satisfaction.

As we approach the final stages of this refinement process, our goal is not only to meet expectations but to surpass them, ensuring that the electric power steering system sets a new standard for excellence in the automotive industry. Through continuous testing, development, and a commitment to quality, we are confident that drivers will experience a level of control and performance that exceeds even the most discerning expectations.

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