MODELLING AND PERFORMANCE ENHANCEMENT OF HYBRID ELECTRICAL VEHICLE USING ANFIS

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ABSTRACT

To improve the controlling behaviour of hybrid electric vehicles, robust controllers (e.g. ANFIS) are admired for their ability to achieve performance comparable to that of a conventional automobile while significantly enhancing fuel economy and tailpipe emissions. The SPHEV configuration is a combination of the parallel and series Hybrid electric vehicle configurations. The MATLAB (Simscape/Simdriveline/Simulink) simulation tool is used to discover the possibilities of advanced hybrid power train architectures and energy storage system designs in order to improve the accuracy of modelling. Despite their complex architecture, SPHEVs are favoured over simple powertrains due to their technological advances and advantages. The work can be analysed using various energy sources, such as fuel cells, thereby reducing the use of fossil fuels. To initiate the design of the controller using the ANFIS scheme, a simulink model of the motor plant and a mathematical model of the controller are required, both of which can be used for simulation purposes.

Keywords: Electric Vehicles, Hybrid, Fossil Fuels, emission , Electrical Propulsion, Energy Storage Device

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1.0 INTRODUCTION

The power train consists of all components used to convert stored potential energy into mechanical energy. Power trains propulsion may utilise chemical, solar, nuclear, or kinetic energy, or make use of them. The oldest example is the sail- and oar-powered galley. The electric bicycle is a common modern example. [1] Hybrid electric vehicles combine a battery with an internal combustion engine that can either recharge the batteries or power the vehicle.

As of 2016, only electric/ICE hybrids were commercially available among the various hybrid vehicle types. Parallel operation of a single variety to provide power from both engines Another operated in series, with one source providing power exclusively and the other supplying electricity. Either source may serve as the primary source of propulsion, with the other serving to supplement the primary. One is a split power hybrid, which uses both parallel and series connections. Generally, hybrid electric drives fall into the following categories [2].

Parallel hybrid

Differential gears are represented by the grey squares. Both the internal combustion engine and the electric motor in parallel hybrid systems are capable of driving the vehicle independently or in tandem [3]. As of 2016, this is the most prevalent hybrid system. If they are joined along an axis (in parallel), the speeds along this axis must be identical, and the torques supplied must sum. (The majority of electric bicycles are of this variety.) When only one of the two sources is in use, the other must rotate, be connected by a one-way clutch, or be freewheeling [4]. Parallel hybrids can be further classified based on the proportion of motive power provided by the various motors: the internal combustion engine (ICE) may be dominant (with the electric motor only engaging under certain conditions) or vice versa. Parallel hybrids rely more on regenerative braking, and the internal combustion engine can also act as a generator for supplemental recharging[5]. This makes them more efficient in stop-and-go urban traffic. They utilise a battery pack that is smaller than other hybrids. The hybrid versions of the Honda Insight, Civic, and Accord are examples of production parallel hybrids [6]. Series Hybrid The composition of a series hybrid vehicle. The square in grey represents a differential gear. A different configuration (not shown) involves electric motors on two or four wheels. Extended-range electric vehicles (EREV) and range-extended electric vehicles (REEV) are alternative names for series hybrids [7]. The California Air Resources Board classifies series hybrids with specific characteristics as extended-range battery-electric vehicles (BEVx). This series-hybrid configuration is common in diesel-electric locomotives and ships (the Russian river ship Vandal, launched in 1903, was the world's first diesel-powered and diesel-electric powered vessel), and Ferdinand Porsche used it successfully in early 20th-century racing cars, including the Lohner-Porsche Mixte Hybrid. In a series-hybrid system for road vehicles, greater flexibility, higher efficiency, and lower emissions at the point of use are realised when an intermediate electric battery, acting as an energy buffer, is positioned between the electric generator and the electric traction motors [8].

2.0 LITERATURE REVIEW

In this section, a comprehensive writing overview of research on crossover electric vehicles is introduced. The review focuses on vehicle presentation and reproduction, power and energy management, energy storage devices, propulsion systems, and the impact of driving cycle on overall efficiency and mileage. The investigation also focused on financial and emission analysis. *Karen et al. (1999)* presented V-Elph 2.01, a simulation and modelling tool developed at Texas A&M University. V-Elph was developed using the MATLAB/Simulink language for graphical simulation and is compact for most PC stages. They also discussed the planning philosophy for vehicle drivetrains using the V-Elph package. Using the recreation package, an EV, an arrangement HEV, a similar HEV, and a conventional internal combustion engine-powered drivetrain were designed. Every vehicle's reproduction outcomes, including fuel consumption, vehicle emissions, and complexity, are evaluated. *Ma Xianmin (2002)* promoted an innovative impetus framework configuration for electric vehicles requiring a high force thickness. Initially, the hypothesis examination of numerical models of EV is established based on the vehicle's dynamic properties. Subsequently, the entire framework is partitioned into seven capacity blocks according to power flow, and the reenactment models are developed in the MATLAB programming language. The reproduction results are validated in a PDM AC-AC converter, demonstrating that the proposed strategy is suitable for EVs. *Brian (2007)* created a MATLAB and ADAMS model to demonstrate the vehicle's superior efficiency. He utilised the Honda IMA (Integrated Motor Assistant) design, in which the electric engine functions as a motor force supplement. He demonstrated that the engine unit acts as a generator during regenerative braking. He employed the board's calculation of the force the executive regulator intended for the vehicle was straightforward. *Cuddy and Keith (2007)* characterise and evaluate hybrid vehicles that are likely to be feasible in the next decade based on their design and configuration (ADVISOR). The fuel economy of two diesel-powered, half-and-half vehicles is compared to that of a diesel-powered, forward-ignition automobile. The described equal mixture is 24 percent more efficient than an internal combustion engine vehicle and 4 percent more efficient than an arrangement crossover.

The viability of fuel utilisation depends on both the vehicle's configuration and the control method employed. The control system provides robust control of the vehicle to ensure optimal utilisation of locally available energy resources under the given working conditions. Therefore, the energy management strategy is essential for determining how and when energy will be supplied by various PHEV sources. In 1999, AVL Company proposed a hybrid framework that combined a 50 cc carburetted lean-consumption two-cycle engine with a 0.75 kW electric engine mounted on the motor's driving rod to provide increased force during speed increase. *Markel and Simpson (2007)* discussed the battery force and energy requirements for lattice-charged, equal-momentum electric vehicles with different operating methods. First, they considered the conventional all-electric reach-based working concept and demonstrated that the synchronous requirement for high energy and force necessitates a larger, more expensive battery. They then proposed an elective electric-assistance working concept for lattice-charged HEVs to enable the use of a smaller, less expensive battery. Nevertheless, this procedure is necessary to reduce the vehicle's productivity during both charge-draining and charge-supporting operations. *Zhangcheng et al. (2007)* presented a novel technique for addressing the issue of the force control system of the arrangement mixture electric vehicle. They characterised three activity methods and an expense method. To determine which activity mode should be selected during driving cycles, a support vector machine classifier was developed (SVM). They claimed that their method did not require any device models and required less computational time. The control system relied on contributions from street-level information.The condition of the battery's charge and the vehicle's speed. Their reproduction tests demonstrated the practicability of the method. *Daniel (2007)* designed, developed, and manufactured a hybrid electric vehicle. Despite proposing the engineering as a hybrid electric vehicle design, he demonstrated that the vehicle operates well in the electric mode and left the hybrid transformation as a future extension. Before fostering the equipment component, he performed a reenactment using PSCAD/EMTDC and approved the re-created results using the equipment he created. *Gonder and Markel (2007)* dissected the energy the executives' method for the operation of crossover electric vehicles. They summarised three potential energy management procedures and analysed the repercussions of selecting one method over another in terms of the force and distance of the duty cycle over which the vehicle will likely operate. The specific operating system utilised during the charge-depletion mode will have a significant impact on the part credits and the value of PHEV technology. *Andrea et al. (2005)* depicted the energy planning for the EV and the HEV, which demonstrates that the HEV is currently a more aggressive option than the ICE vehicles. On a model, a half-and-half innovation is constructed and evaluated.

The reach extender and the power-help technique were tested, and the results were disclosed. The arrangement was designed to meet low production costs without sacrificing much productivity. The cost of the likewise required is also necessary. *Rajeswari et al. (2006)* investigated the limit of the energy storage system, such as the battery, in a hybrid vehicle. Different tests on the discharge qualities, including investigation of Ohmic protections under various conditions, were performed on a different battery and a battery used in a hybrid vehicle, and the former was found to have a higher impedance during cycling. The significance lies in battery selection and research, charging methods, and innovations.

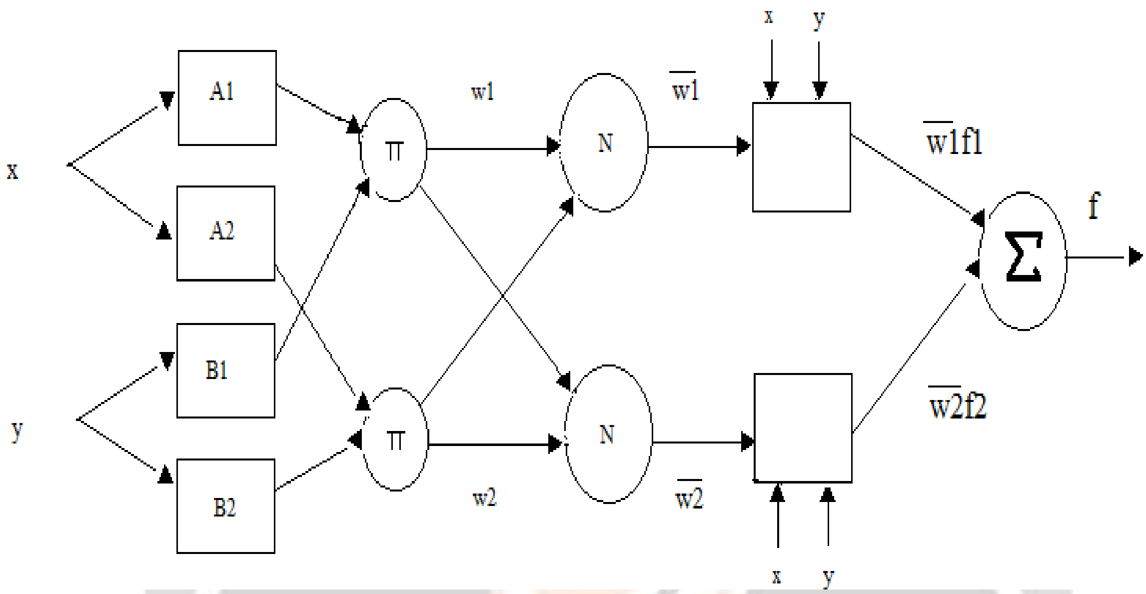


Figure 1 Structure of the ANFIS network

3.0 METHODOLOGY

The electric motor is a 450 Vdc, 50 kW permanent magnet synchronous machine with a corresponding drive. This motor has eight poles and buried magnets. To achieve a maximum motor speed of 6,000 rpm, a flux weakening vector control is used. The generator is a 450 Vdc, two-pole, thirty-kilowatt PMSM with a corresponding drive. A vector control is utilised to achieve a maximum motor speed of 13,000 revolutions per minute. The battery is a Nickel-Metal-Hydride battery with a capacity of 6.5 Ah, 200 Vdc, and 21 kW. The boost DC/DC converter is voltage-regulated. The DC/DC converter adapts the low battery voltage (200 V) to the DC bus, which supplies the 500 V AC motor.

3.1 MATLAB

For computing and analysing the entire system, MATALAB, a versatile tool for technical simulation and computing, is required. MATLAB is widely utilised in all areas of applied mathematics, as well as in university education and research, and in the business sector. The software is based on vectors and matrices, as MATLAB stands for matrix laboratory. This makes the software especially useful for linear algebra, but MATLAB is also an excellent tool for solving algebraic and differential equations as well as numerical integration.

MATLAB's performance on Windows is comparable. On Windows computers, 64-bit Windows and the 64-bit version of MATLAB should be used in the majority of cases, as it can access the larger amounts of memory in modern computers and 32-bit Windows support will be discontinued within the next couple of years. Computers with a larger number of CPU cores can outperform those with a smaller number of cores, but the results will vary depending on the MATLAB application. Computer performance may degrade due to thrashing if MATLAB and other concurrently running programmes use more physical memory than is available, requiring the computer to resort to virtual memory. MATLAB requires a minimum of 4 GB of memory to function properly. Simulink is an environment for block diagram-based multidomain simulation and Model-Based Design. It facilitates embedded system design, simulation, automatic code generation, and continuous testing and verification. Simulink offers a graphical editor, block libraries that can be customised, and solvers for modelling and simulating dynamic systems. It is integrated with MATLAB®, allowing you to incorporate MATLAB algorithms into models and export simulation results for further analysis in MATLAB. With Simulink, you can explore realistic nonlinear models that incorporate friction, air resistance, gear slippage, and other parameters that characterise real-world phenomena. Simulink enables you to view the development environment as a laboratory for simulating and analysing systems that would not otherwise be possible or practical. Whether you are interested in the behaviour of a vehicle's clutch system, the flutter of an aeroplane wing, or the impact of monetary supply on the economy, you can find the information you need here.

3.2 P-D CONTROLLER

The P-D controller is utilised to increase the system's stability by enhancing the control system. The PD controller has the capacity to predict future system response error. To avoid the effects of the rapid change in the value of the error signal, the derivative is calculated from the output response of the system variable rather than the error signal. In this instance, D mode is intended to prevent the abrupt changes of the output variable in the control output that lead to abrupt changes in the error signal. D mode is utilised when calculation of the error can improve control or when stabilisation of the system is essential. Based on the frequency characteristic of the D element, its phase lead is 90 degrees. To avoid the effects of a sudden change in the reference input that would cause a sudden change in the value of the error signal, the derivative is derived from the output variable rather than the error signal. Changes in the error signal will result in changes in the output control. To avoid this, it is necessary to design D mode proportional to the output variable's change [34].

PD controller is primarily utilised for the control of moving objects such as submarines, ships, and rockets.

3.3 P-I CONTROLLER

The P-I controller's primary function is to reduce steady-state error. Therefore, it has a negative effect on the speed of response and overall stability of the system. This controller is typically used in locations where system speed is not a concern. Since the P-I controller is incapable of calculating future system errors, it is unable to reduce the rise time and eliminate oscillations.

PI controller will decrease oscillations and steady-state error caused by on-off controller and P controller operation, respectively. However, integral mode negatively impacts the system's speed response and stability. It is estimated that the PI controller does not predict what will occur when an error approaches. This issue can be resolved with the derivative mode, which is able to predict what will occur with the error in the near future and thus decrease the controller's reaction time. A PI controller is frequently used in industries where response time is not a concern[35]. A non-D mode control is used when:

a) Rapid system response time is not required.

b) Significant disturbances and noise are present during the process's operation.

c) There is only one energy storage mechanism in operation, namely capacitive or inductive.

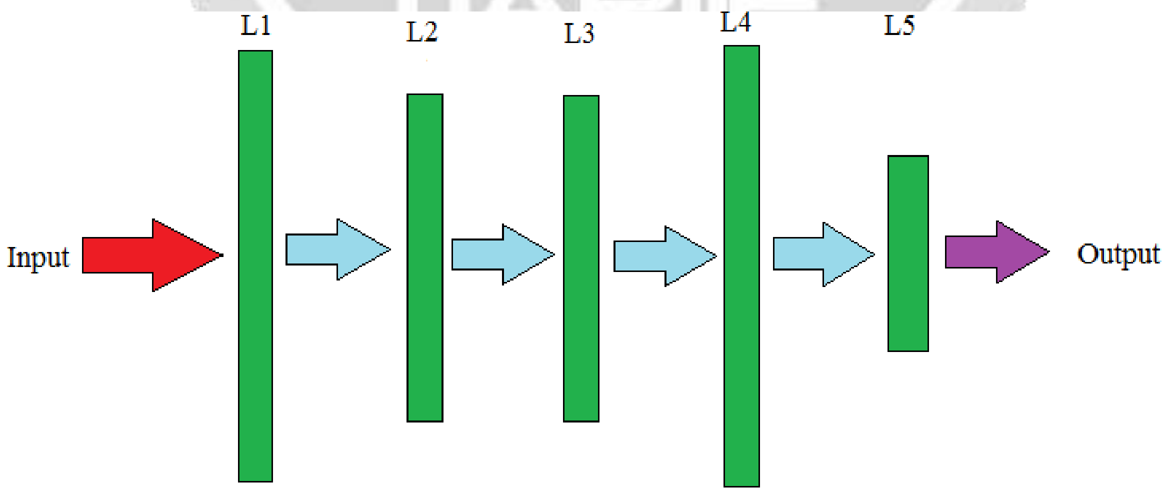


Figure 2: ANFIS Architecture

4.0 RESULTS & DISCUSSIONS

This section discusses the simulation results obtained by implementing the algorithm described in the previous section to solve our problem statement. All simulations were performed using MATLAB R 2014b on a computer with 4GB RAM and a core i3 processor.

4.1 SIMULATION AND RESULTS IN MATLAB

At t = 0 s, the HEV is stopped and the driver accelerates to 70 percent of maximum speed. So long as the required power is less than 12 kW, the HEV will move using only the battery-powered electric motor. Both the generator and the ICE are powerless. After applying the ANFIS controller depicted in figure 4, rotor current can also be plotted. The motor section implements this controller.

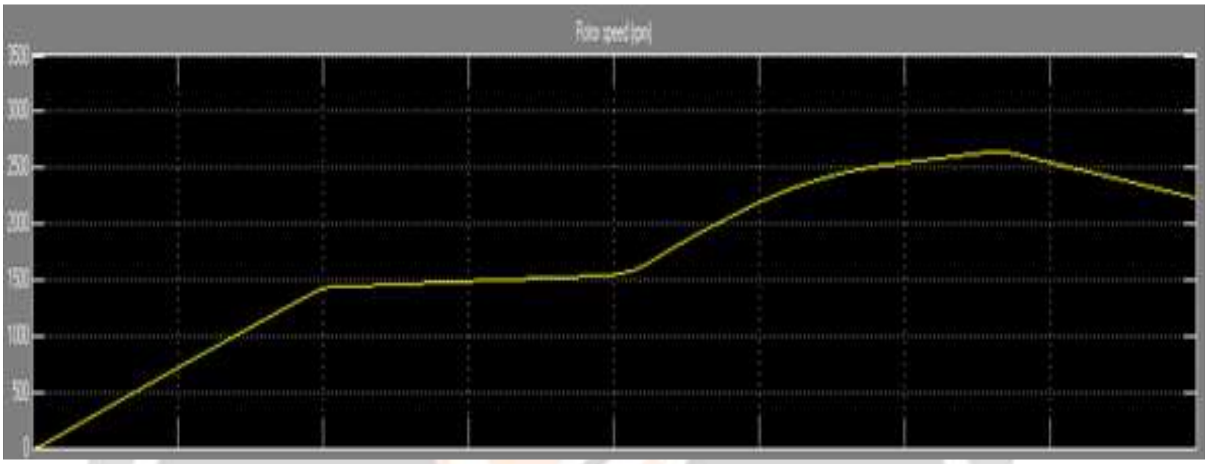
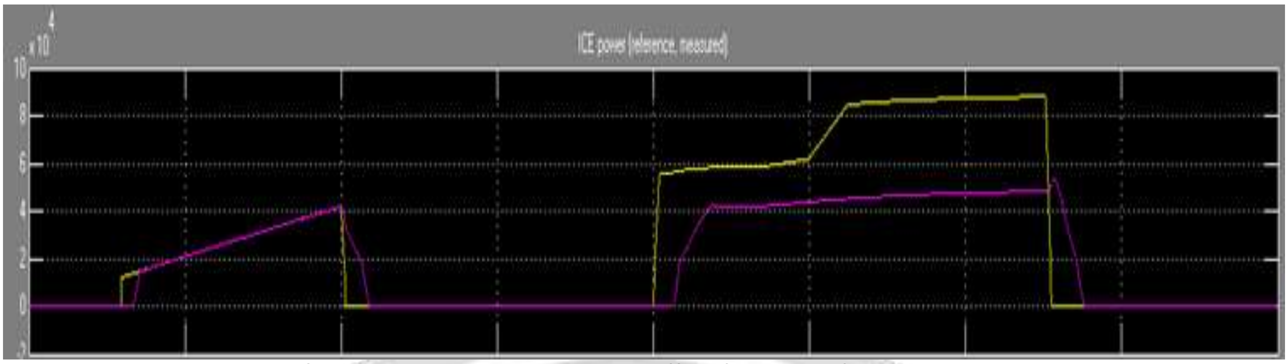


Figure 4: Plot of rotor current incorporated with ANFIS

Figure 5 Torque development with ANFIS controller

At t = 4 s, 10% of the accelerator pedal travel is released (cruising mode). As the ICE is unable to reduce its power instantly, the battery absorbs the generator's power to reduce the required torque. At t = 4.4 s, the generator is entirely shut down. The only source of required electrical power is the battery. At t = 8 s, 85 percent of the accelerator pedal is depressed. The ICE is restarted to provide the additional power required. The generator-ICE assembly response time prevents the total electrical power (generator and battery) from reaching



the required power. Therefore, the measured drive torque differs from the reference

Figure 6: ICE measured and reference power

At t = 10 s, the battery SOC falls below 40% (it was initialised to 41.53 percent at the start of the simulation), indicating that the battery must be recharged. The generator provides energy to both the battery and the motor. Observe that the battery power begins to decrease. This indicates that the battery is charged by the generator while the HEV is accelerating. Currently, the required torque cannot be met because the electric motor has reduced its power demand in order to recharge the battery. At t = 13 s, -70 percent of the accelerator pedal is depressed (regenerative braking is simulated). This is accomplished by turning off the generator (it takes 0.5 seconds for the generator's power to drop to zero) and commanding the motor to act as a generator driven by the vehicle's wheels. The HEV's kinetic energy is converted into electrical energy and stored in the battery. The required torque of -250 Nm cannot be achieved at this pedal position because the battery can only absorb 21 kW of energy. At t = 13.5 s, the generator is turned off entirely.

In each scope, some intriguing observations can be made. Throughout the duration of the simulation, the DC bus voltage of the electrical system is observed to be well-regulated at 500 V. Throughout the entire simulation, in the planetary gear subsystem, the Willis relation is equal to -2.6 and the planetary gear's power law is equal to 0.

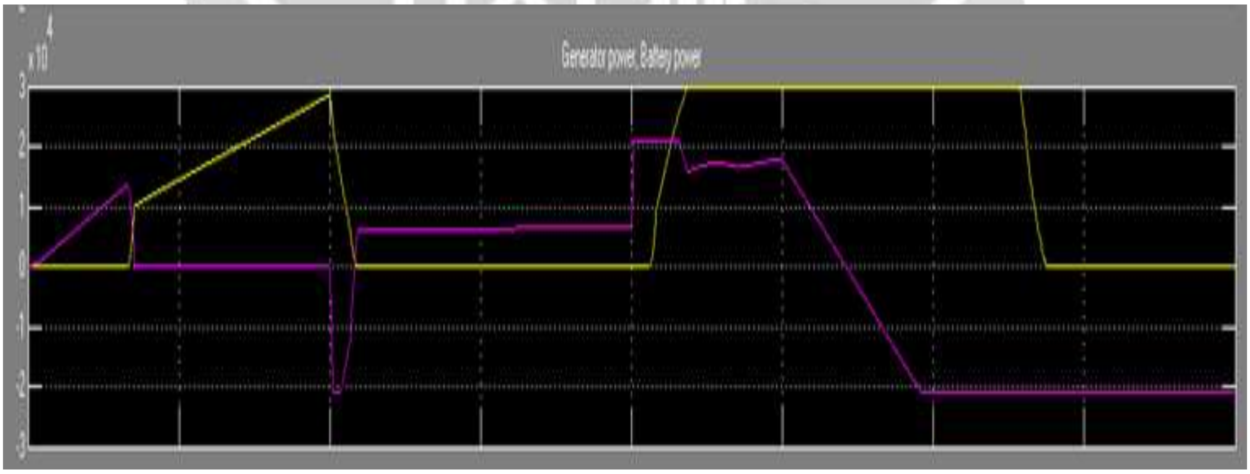


Figure 7: Generator Power and Battery output power

Observing the magnitude of current and power at each time point, as depicted in the preceding figures, improves the effectiveness of HEV control.

5.0 CONCLUSIONS

a hybrid electric vehicle (HEV) frame designed with a robust controller, i.e. ANFIS, provides superior response in comparison to biological controllers. In the modelling and feedback control of any dynamical system, a controller is required for the plant because it eliminates all disturbances and returns the system to its initial state within a few seconds. To initiate the design of the controller using the ANFIS scheme, a simulink model of the motor plant and a mathematical model of the controller are required, both of which can be used for simulation purposes.

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