MODELLING AND ENERGY STORAGE MANAGEMENT SYSTEM FOR HYBRID ELECTRIC VEHICLES WITH FUZZY LOGIC CONTROLLER AND PMSM DRIVE

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Abstract:

Automobile power systems are increasingly in need of renewable energy resources. However, the conventional mechanisms failed to provide better energy management system (EMS) performance. Therefore, this article is focused on implementation of hybrid EMS system using solar photo voltaic (PV), fuel cells, super capacitor and battery storage system for permanent magnet synchronous machine (PMSM) drive of hybrid electrical vehicle with fuzzy logic controller (FLC). The PV fuel cell hybrid electrical vehicle is a model-based approach and delivers two major original contributions. A fuzzy logic control-based energy management strategy. Super capacitors and battery storage systems are used for rapid charging and different levels of battery state of charge.The power systems prove to work effectively and adaptively in different situations under the regulation of the EMS and demonstrate better fuel economy than using a widely-adopted power-following control strategy. The simulations conducted using Matlab/Simulink model showed that the proposed method outperformed as compared to state-of art approaches.

Keywords: solar photo voltaic, permanent magnet synchronous machine, fuzzy logic controller, energy management system.

I. INTRODUCTION

In order to establish an EMS in a HEV [1], the control method that is used is mostly rule- and optimization-based. A comprehensive analysis of the differences between the battery SC-based voltage compensator and its predecessor is provided [2]. In order to resolve the problems with the power quality, the compensator was wired in series with the grid-connected solar system [3]. The EMS is offered as a potential solution for the intelligent distribution of electricity. so that the direct current (DC) voltage may be maintained at a constant level. In addition to this, it protects the SC from receiving an excessive charge and improves both the health and performance of the battery. A supervisory EMS that is based on an adaptable FLC has been suggested [4-5]. The variance in the battery's current is kept to a minimum when the parallel active architecture is used. In addition to this, the efficiency of the system has been improved to its maximum potential, and the issues with the DC link voltage matching have been resolved [6-7]. The selection of the appropriate converter for hybrid electric vehicles and electric vehicles is a crucial problem. Researchers have previously addressed a variety of converters, including unidirectional, bidirectional, four-quadrant, and others. These converters can convert in either way. Every topology serves a distinct and specialized purpose, based on its unique arrangement. In [8-10], many kinds of converters for electric vehicles, together with their applications and potential drawbacks, are dissected. As a direct consequence of this, the negative impacts of converter losses have been mitigated. The type-III bidirectional SEPIC converter [11] is capable of transferring energy in either direction when it is put to use. This may be accomplished using the buck-boost mode, which results in the polarity of the output voltage being unchanged and costs less than the standard converter [12]. On the other hand, when the number of passive components increases, the cost increases and the losses increase as well. In [13], a comparison of a linked and uncoupled inductor in CCM was carried out for a SEPIC converter. This produces some ripple current, and it is efficient for the proportional integral derivative (PID) controller.

II. LITERATURE SURVEY

An inter-leaved bidirectional SEPIC converter operating in discontinuous conduction mode (DCM) was used in [14] in order to provide a smooth current for the purpose of charging the battery. As a direct consequence of this, the output voltage was successfully adjusted. On the other hand, as a result of the continual charging and discharging of SC [15], there were only small converter losses. Fuel cells are another alternative to internal combustion engines and batteries that are now in use. PEMFCs, or proton exchange membrane fuel cells, were used in the research described in reference [16], together with a lithium-ion battery and boost converters. A case study on the process of selecting batteries for electric vehicles (EVs) is presented in reference [17].

According to the findings of this study, electric vehicles would benefit most from using lithium-ion batteries. This is because, in comparison to other kinds of batteries, their performance is much higher. HEVs and plug-in HEVs both utilise a variety of energy storage systems (ESS), the most common of which being batteries and super capacitors (SCs). In addition, detailed illustrations of innovative charging strategies for the batteries may be seen in [18].

The article [19] presents a number of control techniques for HEVs as well as an in-depth analysis on EMS for the purpose of transforming a conventional vehicle into a plug-in hybrid electric vehicle (HEV). FLC is employed in order to effectively manage the motor and so limit the amount of energy that must be drawn from the battery in order to do so.

In [20] provides a very good introduction to fuzzy control as well as its extensive use in industrial applications. They also have a lot of different applications. There is provided an in-depth explanation about the mathematical concepts of fuzzy control and fuzzy relations. In addition, a representation of a collection of fuzzy rules, as well as non-linear fuzzy control, adaptive fuzzy control, and a few other things, are provided.

Chao Gao, Jian, and others [21] focused on improving the overall health of the battery as well as the discharge current of the battery. In order to maximize the effectiveness of the membership function of the FLC for HEV, the gold ratio cut-off method was used. In [22] authors contains representations of a number of fuzzy theories, including fuzzy classification, fuzzy diagnosis, and the applications of these ideas. Siemens, based in Germany, is currently working on a number of applications that are connected to fuzzy control. Examples of these categories are also described, including things like optimization theory, fuzzy data analysis, and fuzzy expert systems, amongst other things. The presentation also includes a variety of different optimization strategies for fuzzy controllers, such as generic algorithms (GA) and Rosen brok's algorithms. In addition, a comprehensive explanation of the multilevel qualitative optimization of fuzzy controllers may be found in [23].

FLC was employed for the rule-based approach that Hajer Marzougui et al. [24] developed. A control for flatness was used for either the fuel cells or the ultra capacitor. In HEVs, a rule-based algorithm was used to divide the power needs between the sources of power and the load, disregarding any losses that may have been caused by the converters. The cost of this EMS is significant despite its flexibility and the fact that it does not need any of the vehicle's trajectory to be known in advance. In [25], the current fluctuation of the battery was reduced as much as possible, and the Karush–Kuhn–Tucker (KKT) conditions were used to control the flow of power from the SC.

III. SYSTEM DESIGN

3.1 Proposed Model

The whole system's block diagram is shown in Figure 1, which may be seen here. In order to create a model of the system, mathematical equations are used in the Simulink/MATLAB environment. During the driving mode, SC provides assistance to the charge of the battery pack. There is an alternative method of putting energy storage devices to use in HEVs. A number of researchers make use of series combination in accordance with their methodology. Additionally, the parallel coupling of a fuel cell with a battery or SC was suggested; however, this would drive up the cost of the cars. The most common and desired configuration is a battery in parallel with SC. The use of these storage devices in series offers a vehicle a higher efficiency, but it also makes the car heavier and increases the amount of energy that is lost [36]. SC functions as a battery backup and safeguards the battery from inrush current. SC is capable of providing steady power and has a high power density. Despite having a low energy density, it can both provide and absorb peak current. It has the potential to improve the overall efficiency of the vehicle as well as the longevity of the battery life. The power production from a regenerative braking system is not a problem for it. An SC/battery HES for EVs is suggested and investigated in this paper as a result of the many benefits associated with this system.

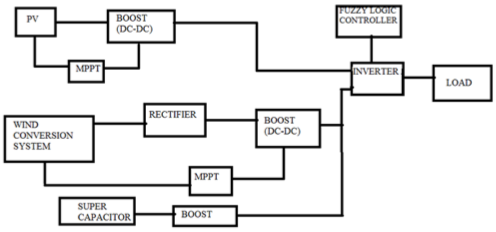


Figure 1. Proposed block diagram.

The functional architecture of the whole system is shown in figure 1, which may be seen at this location. In the context of Simulink and MATLAB, mathematical equations are utilized for the purpose of constructing a model of the system. During the mode in which the vehicle is being driven, SC contributes to the charging of the battery pack. There is another way of putting energy storage devices to work in HEVs than the one described above. Numerous researchers include series combination into their approach in order to get the best results possible. In addition, it was proposed to couple a fuel cell with a battery or a SC in parallel; but, doing so would drive up the price of the vehicles. The battery in parallel with the SC setup is by far the most popular and desirable combination. When used in series, these energy storage devices enable a vehicle to operate at a greater efficiency; nevertheless, this results in the vehicle being heavier and increasing the quantity of energy that is wasted . SC serves as a backup for the battery and protects the battery from inrush current. The power density of SC is very great, and it is able to provide constant power. In spite of the fact that it has a low energy density, it is able to both provide and absorb peak current. It has the ability to increase both the overall efficiency of the vehicle and the length of the life of the battery. [Case in point:] It is not an issue for it to produce electricity from a regenerative braking system because of its design. This research makes the suggestion of a SC/battery HES for EVs and investigates its viability as a consequence of the many advantages that are related with this system.

3.2 Fuzzy Logic controller

The FLC is a conventional structure, as shown in Figure 2. The inputs are the speed error (e) and the change in speed error, and the output is the change in the q-axis reference current. The membership function is employed, and the input and output scaling factors are computed. The FLC is responsible for carrying out the rule base, with the fuzzy variables e and ce serving as the inputs. The defuzzification unit is responsible for handling the number of iqs that are produced as the output.

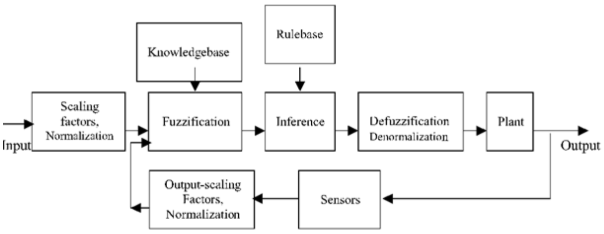
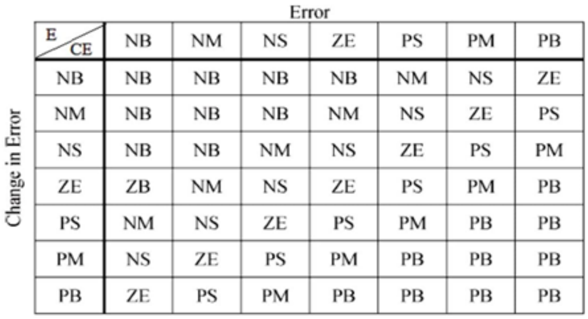


Figure 2. FLC controlling strategy.

By comparing the resulting speed response with that of the "standard design," the primary objective of the control system is to ascertain whether or not the "case design" for the high-performance PMSM drive is effective. The 'standard design' is the first thing that is developed, and this is done on the basis of the speed response to the step rated speed command (209 rad/s) when there is no load and the rated inertia is present. The specifications for the design are defined such that there is a speed overshoot of no more than 0.1 rad/s, and the rising time must be as short as possible taking into account the restricted current capabilities of the inverter. The scaling factors are selected both for fuzzification and for the purpose of obtaining the factors play an important role for the FLC and have an effect on the stability, oscillations, and damping of the system; as a result, they need to be selected with the utmost care [11]. Fuzzification is another reason why these scaling factors are selected. To normalize the speed error and the change in speed error, respectively.

The value of the factor has been determined in such a way that it is possible to get the rated current under the rated circumstances. It is via trial and error that the fine adjustment to the specification is accomplished. In order to get the best possible drive performance, the constants have been set to the following values: The next stage involves determining the membership functions of e, ce, and cu. These functions are crucial to the FLC's operation and are the primary subject of this particular piece of writing. The designs for the two distinct fuzzy sets that were created are seen in Figures 3 and 4, respectively. The geometry of the fuzzy sets on the two extreme ends of the universe of discourse is considered to be trapezoidal, but the shape of all other intermediate fuzzy sets is triangular, and the traditional method assumes that they overlap with one another. The breadth of the triangle membership function is split evenly in a range called the Universe of Discourse, and each section overlaps the next. Tables II and III, respectively, provide the fuzzy rule-base matrix for what is known as "standard design" and "case design." As was said before, the rules of the 'standard design' are defined by common criteria found in a large number of publications, but the rules of the 'case design' parameters are determined by a standard technique while simultaneously minimizing the number of fuzzy rule-bases. The linguistic components employed are identical to those found in the vast majority of published works. For the duration of the computing time period, the Fixed step mode will be used. The Dormand-Prince numerical approach and a Mamdani-type fuzzy inference are used in the process of solving differential equations numerically. In this particular investigation, the values of constants, membership functions, and fuzzy sets for input/output variables are determined via a process of trial and error.

Table I provides definitions for seven terms: NL, which stands for negative large; NM, which stands for negative medium; NS, which stands for negative small; ZE, which stands for zero; PS, which stands for positive small; PM, which stands for positive medium; and PL, which stands for positive large. It has designated three terms: N, which stands for negative; ZE, which stands for zero; and P, which stands for positive. Every fuzzy variable belongs to at least one of the subsets, with the degree of membership ranging from 0 to 1 for each fuzzy variable. As was noted before, the rules have been expressed in the form of a matrix for the sake of convenience, and they should be read as follows: If the "speed error is NS" and the "change in speed error is PS," then the "change in q-axis reference current is ZE," respectively. With the exception of the number of rules, all of the scaling factors, the form of membership function, the technique of fuzzification, and the method of defuzzification are specified and maintained at a consistent level throughout the study.



		Error						
	E CE	NB	NM	NS	ZE	PS	PM	PB
Change in Error	NB	NB	NB	NB	NB	NM	NS	ZE
	NM	NB	NB	NB	NM	NS	ZE	PS
	NS	NB	NB	NM	NS	ZE	PS	PM
	ZE	ZB	NM	NS	ZE	PS	PM	PB
	PS	NM	NS	ZE	PS	PM	PB	PB
	PM	NS	ZE	PS	PM	PB	PB	PB
	PB	ZE	PS	PM	PB	PB	PB	PB

Table 1. FLC control rule table.

IV. RESULTS

This section gives the detailed analysis of simulation results, which are implemented by using Matlab/Simulink Tool. Figure 3 shows the Simulink model of proposed hybrid EMS system, which contain the various blocks such as PV panel, fuel cells, super capacitor and battery storage system for PMSM drive of hybrid electrical vehicle with FLC. Further, Figure 4 shows the proposed Simulink model, which is equipped with super capacitor. Figure 5 shows the output voltage generated from EMS. Figure 6 shows the PMSM output response, which is measured in rad/s.

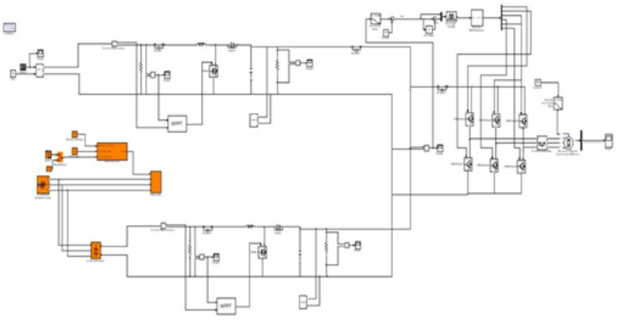


Figure 3.Simulink model.

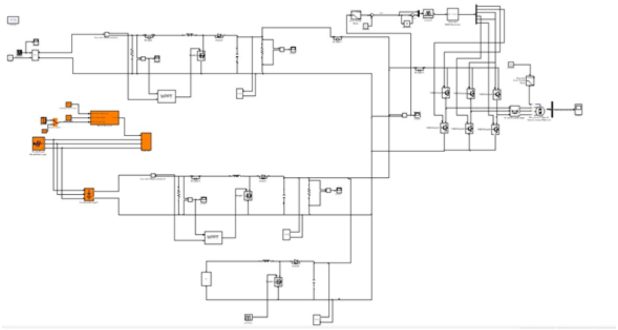


Figure 4.Simulink model with super capacitor.

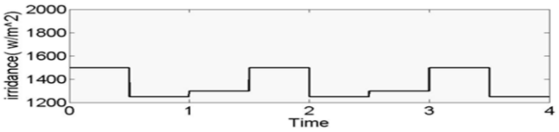


Figure 5. Solar irridation.

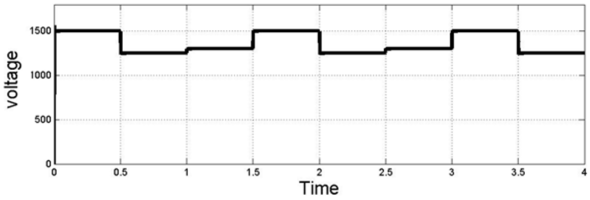


Figure 6. solar dc-dc converter input volta.

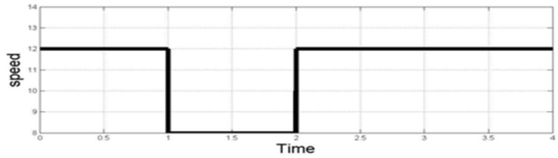


Figure8. Window input speed.

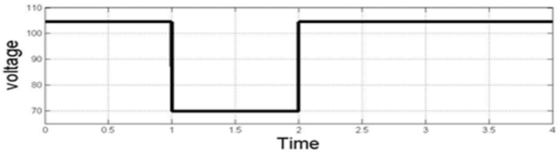


Figure9. Wind dc-dc converter input voltage.

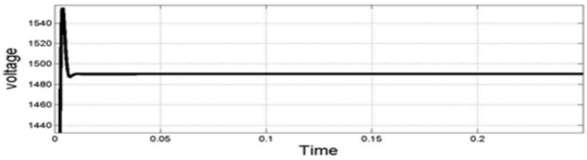


Figure10. Wind dc-dc converter output voltage.

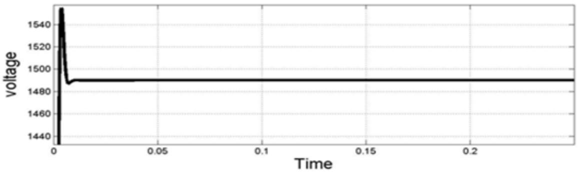


Figure11. Super capacitor output voltage.

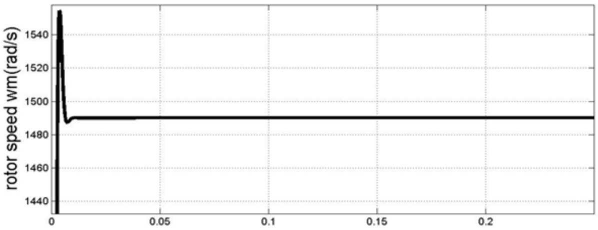


Figure 12. PMSM output response.

V. CONCLUSION

This work focused on implementation of hybrid EMS system, which contain the various blocks such as PV panel, fuel cells, super capacitor and battery storage system for PMSM drive of hybrid electrical vehicle with FLC. By using FLC method for operation of the system by solving the elements and make it simple for operation of PMSM drive of HEV. Further, the buck converter is used for step up voltage as per the speed and torque characteristics. In addition, the super capacitor is added for fast charging of battery and for good performance. The simulation results showed that the proposed method resulted in EMS system. This work can be extended with deep learning convolutional neural network controllers for better performance with low complexity.

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