A Novel Design of Hybrid Energy Storage System for Electric Vehicles using Artificial Intelligence

Mr. Kuppireddy Krishna Reddy [1]

[1]Associate Professor, Department of Electrical and Electronics Engineering,
[1]Mother Theresa Institute of Engineering & Technology, Palamaner-517408, Andhra Pradesh, India.
ORCID:0009-0000-8855-7863

Mr. Bosubabu Sambana [2]

[2]Assistant Professor, Department of Computer Science and Engineering,
[2]Raghu Engineering College (A), Visakhapatnam, JNTU Kakinada, Andhra Pradesh, India.
ORCID: 0000-0002-8665-9441

***Abstract:*-To guarantee indicates a strong and the lowering of a minimization problem for EVs, we construct an unique hybrid power storage for an electric engine in this research. The Li-ion pack equivalent circuit is being used extensively owing to its convenience and usefulness in the realms of control and estimation. This research presents a way for controlling the power system by means of a power relationship limiting rule dependent on the amazingly capacitor (SOC). However, although having a significant influence on EV performance, the effect of temperature is seldom accounted for in existing comparable circuit models. Concurrently, the DC-DC converters of EVs have a low-pass filter added to them using magnetic integration technology that is of a lower order and hence more cost-effective. It is difficult to determine the relationship between temperature, state - of - charge (SOC), and comparable circuit properties. It's possible that the battery's total size may be reduced thanks to the dual energy storage, and power quality can be enhanced. To better depict lithium-ion batteries, we use fuzzy logic in this research. Using fuzzy rules, the effect of SOC and heat just on parameters is described in a clear and thorough way. The accuracy of the fuzzy model throughout a temperature range is confirmed by the simulation results.**

***Keywords: -electric vehicles, hybrid energy storage system, equivalent circuit model, integrated magnetic structure, fuzzy*logic.**

I INTRODUCTION

Li-ion batteries are often employed in integrated energy storage devices in modern electric vehicles because of their high energy density. These cars can now go far without needing to stop for fuel. Electrical current in electric cars is managed by a battery system (BMS) [1]. The difficulty in modelling the behaviour of Li-ion batteries is a major obstacle for BMS. A forecasting algorithm of the current battery behaviour is necessary for BMS to efficiently monitor and control a Li-ion battery pack. Li-ion batteries have a slower response time compared to supercapacitors [3,4]. In order to compete with gasoline vehicles in terms of rapid transient velocity, energy, and long-distance endurance [5], electric automobiles are fitted with a hybrid energy storage system (HESS) comprised of Li-ion batteries. When designing electric cars, it is crucial to strike a balance between expanding battery capacity and reducing vehicle size and weight so that charging can occur more quickly [6-8]. DC-DC converters, which are essential to hybrid energy storage systems, have seen tremendous development in recent years. Several distinct DC-DC converters are proposed, each of which makes use of a novel innovation. In [9], a new unidirectional DC-DC converters using a nil (ZVS) architecture is presented,It has been shown that a complexly organised, separated bidirectional DC-DC converter [10] may convert a significant quantity of power for transmission. After being proposed by S.Cuk in [11-12], the use of integrated magnetic technology to construct a nil switching DC-to-DC converter has shown to be very effective in actual applications. The isolated interlaced DC/DC converter [13] introduces the concept of three-winding connected inductors, however this type of converter is better suited for transmitting power. Hybrid energy storage solutions need careful consideration when selecting an energy management strategy. Many different strategies for energy management have been proposed and authored in recent years[14–17]. These include neural network models, fuzzy logic, vm control, the frequency disentangling method, on-line and offline optimised methods, nonlinear programming (DP), as well as battery power constraints. Most discussions of Li-ion battery types with similar circuitry are limited to a single temperature. It is also clear, however, that ambient temperature affects the Li-ion battery's characteristics [9-11]. Some scholars have just lately started writing on this phenomenon in detail. As described in [9], temperature has an impact on the model's parameters. Linear curves of SOC and temperature are shown for the model parameters in [10]. However, the functions used in the model make its parameters difficult to understand. We may put these strategies into two broad buckets: online global optimization and offline local optimization. Locating the best allocation of power across all inputs is a crucial aspect of off global optimisation problem. However, online local optimization requires accurate forecasting of driving conditions [11-15]. The authors propose an innovative DC-DC converter with an integrated magnetic architecture for use in electric vehicles. The proposed DC-DC converter describes its internal organisation, several modes of operation, and management of Li-ion supercapacitors in detail.According to the study's findings, a combination of a control algorithm as well as a power dynamic limitation rule may significantly improve energy management.

We provide a fuzzy logic circuit for Li-ion batteries in this study. Fuzzy rule bases, which are sets of fuzzy rules, may be used to model the behaviour of fuzzy systems [16-20] instead of using complex mathematical expressions. Therefore, fuzzy logic is used to characterise the impacts of SOC and heat just on model parameters [21-25]. In this study, we use fuzzy logic to build a model of a Li-ion battery that accounts for the influence of SOC & temperature. The impact of SOC or heat on model parameters is represented in a way that is both intuitive and accurate using fuzzy rules. The accuracy and flexibility of the new model across the full SOC and temperature gradient have been validated by simulation [26,27].Table1. Shows the advantages and disadvantages of isolated bidirectional DC-DC converters in HESS for EV

II TOPOLOGY OF HYBRID ENERGY STORAGE SYSTEM

The hybrid energy storage shown in Fig.1 consists of a DC/DC converter, supercapacitor, and a Li-ion battery. The 4 IGBT switches T1 through T4 and their corresponding diode (battery-adding) tubes D1 through D4 all have the same identities L1, L2, with inductance M, making up the basic coil of a DC/DC converter. The DC motor may run quietly since it is supplied by a reusable battery pack. The supercapacitor takes care of the temporary high-power demand. Power management systems in electric vehicles control the flow of energy by determining how much power is needed at any particular moment. The converter may be operated in five different main modes. Table 1 displays the energy flows or DC-DC converter operating mode to demonstrate the special functioning of the hybrid energy system.

TABLE I ADVANTAGES AND DISADVANTAGES OF ISOLATED BIDIRECTIONAL DC-DC CONVERTERS IN HESS FOR EV

Classification	Advantages	Disadvantages
Basic	●Simple structure ●Easy to control ●Easy to generate new topologies ●Low number of devices	●Large switching loss ●Low conversion efficiency ●Low power applications
DAB	●Wide voltage conversion range ●Low stress of switches ●Flexible control method ●High power density	●Complex structure ●Difficult to control ●Large volume and cost
Integrated magnetic structure	●High conversion efficiency ●Small startup current	●Complex structure ● a Less number of devices ●Difficulty to design

Classification	Advantages	Disadvantages
Interleaved	●Wide voltage conversion range ●Low current ripple ●High power density	● a Large number of switches ●Complex structure

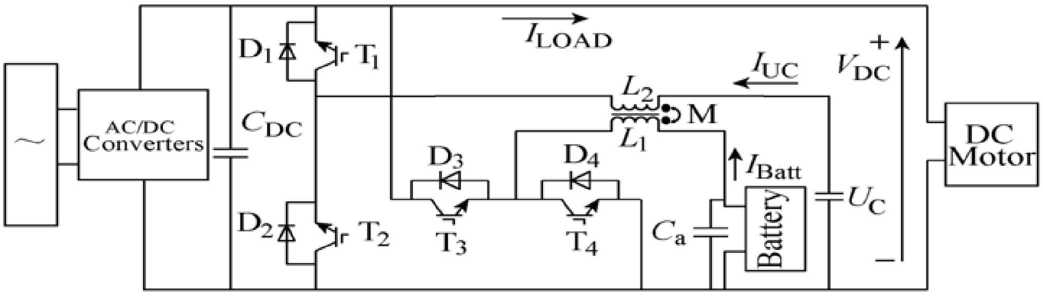
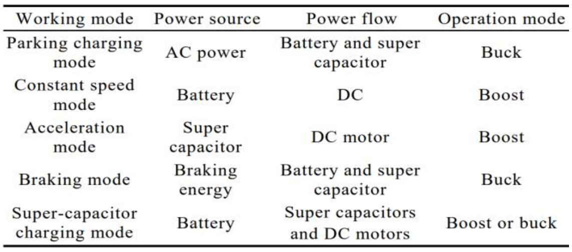


Fig.1.Topology of the hybrid energy storage system

Magnetic structural integration in the design of a direct current to direct current converterPower electronics rely heavily on magnetic elements like inductors for tasks including energy transfer, filtering, immunity to electromagnetic interference, and storage. The converter's physical dimensions and mass are mostly determined by the magnetic element's size. In this study, we employ an E-type iron flux to accomplish magnetic integration. To achieve this result, a linking inductance (L1 and L2) is being used. Fig.2 shows the output filtering inductor, L2, the external inductance, L1, and the supplementary capacitance, Ca. Ca's voltage, in the steady state, is equal to the sum of the voltages produced by L2 and L1 with no consideration to the ripple in the capacitor voltage. Four IGBT switches (T1 through T4) and four diodes (D1 through D4) make up the DC/DC converter shown in Fig.1. With a boost converter, you can choose between two different operating modes (L1, T4, D4 and L2, T2, D1), while a buck topology, the one with the oscillating electromagnetic structure has much less overall volume and weight. Using a DC/DC converter in an electric vehicle with a magnetic structure incorporated into it helps cut down on the vehicle's total bulk and weight. Finally, the output current fluctuation may be tamed thanks to the magnetic structure's integration. In section 4, modelling and experiment are used to verify the efficiency of the oscillating electromagnetic structure. converter can switch between three different modes (L1, T4, D4 and L2, T2, D1) (consisting of L1, T3, D4 or L2, T1, D2). Table 2 shows that when comparing two DC/DC converter.Table 2 shows the operation mode of the hybrid energy storage system

TABLE II. THE OPERATION MODE OF THE HYBRID ENERGY STORAGE SYSTEM



Working mode	Power source	Power flow	Operation mode
Parking charging mode	AC power	Battery and super capacitor	Buck
Constant speed mode	Battery	DC	Boost
Acceleration mode	Super capacitor	DC motor	Boost
Braking mode	Braking energy	Battery and super capacitor	Buck
Super-capacitor charging mode	Battery	Super capacitors and DC motors	Boost or buck

III THE FUZZY LOGIC-BASED MODEL FOR LI-ION BATTERY

The characteristics of the similar circuit model are affected by SOC and temperature, as shown in the prior discussion. Here, we develop a fuzzy logic model that takes into account SOC and temperature worldwide. Fuzzy logic may represent several antecedents in a single rule, allowing for a very precise estimate of nonlinear dynamic properties. Consequently, the variation in design variables to SOC or temperature, as given by fuzzy rules, may accurately mimic the battery dynamics. Our model's fuzzy rule coefficients are based on the SOC and temp values in an area around the partition sites

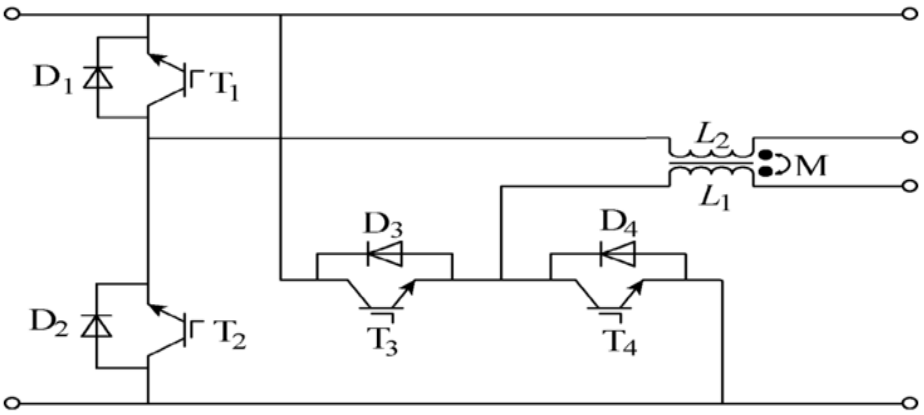


Fig.2.Topology of DC/DC converter with integrated magnetic structure

Fuzzy rules cannot be used to precisely describe a battery's capacity. Supposedly, the battery's capacity doesn't change much from room temperature on up. Capacity drops as the temperature drops below room norms. To describe this variation, we may use the given equations to get the fuzzy rule foundation of temperature for battery Cn.

Rule ^{l}: IF T is $(T \geq 23^{\circ}\mathrm{C})$, THEN $C_n = C_{n1}$;
Rule ^{2}: IFT is $(T \leq 15^{\circ}\mathrm{C})$, THEN $C_n = C_{n2}$;

in where Cn1 & Cn2 are the values found in the battery test. Methods for establishing fuzzy rules for design variables at low temperatures are similar to those outlined here. Combining these two criteria with the membership value () T represents the battery capacity inside the interpolate period 15 23 T °C. This means that the battery's capacity will change depending on:

$C_n(T) = \sum_{m=1}^{M} \mu_m(T) \cdot C_{nm}$ (1)
$0 \leq \mu_m(T) \leq 1$ and $\sum_{m=1}^{M} \mu_m = 1$ (2)

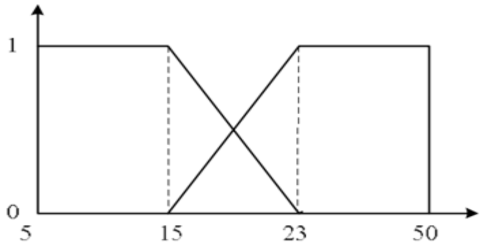


Fig.3.The membership function of temperature

The resistors inside the model need to have the pattern of fluctuation of the two influencing elements specified. First, individual consideration is given to SOC and temperature as independent variables. Trends in parameter fluctuation at a fixed temperature are used to assess SOC's impact on the model's settings. The relationship between temperature and Rs and SOC exhibits a consistent pattern of change (see Fig. 7). At each temperature, the Rs value fluctuates just little within the range SOC 0.2. Once SOC drops below 0.2, an uptick in Rs is seen. In the range SOC (0,0.1), Rs grows exponentially. The partition points and membership functions are chosen to reflect this trend in variation via fuzzy rules based on the Rs value so over SOC range. Existing fuzzy identification methods [15] may then be used to improve and validate the rules. High modelling accuracy is achieved over the whole range of the preceding SOC by adjusting the partition points to optimal subspace divisions. Trapezoidal and triangle membership functions are used, and partition points of (0.04, 0.06, 0.09, 0.2) of SOC is chosen because they maximise both model correctness and simplicity. The following elements form the foundation of the fuzzy rule base:

Rule : IF SOC is $(SOC \leq 0.04)$, THEN $R_s = R_{s1(soc)}$
Rule ^{2}: IF SOC is $(SOC = 0.06)$, THEN $R_s = R_{s2(soc)}$
Rule ^{3}: IF SOC is $(SOC = 0.09)$, THEN $R_s = R_{s3(soc)}$
Rule ^{4}: IF SOC is $(SOC \geq 0.2)$, THEN $R_s = R_{s4(soc)}$

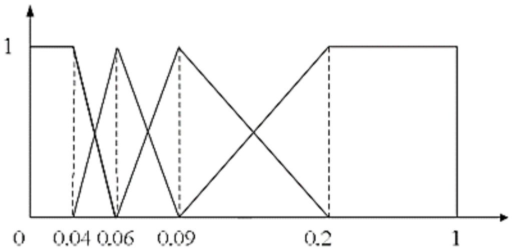


Fig.4.The membership function of SOC for Rs.

Similarly, to Rs, the trend of R1's temperature-dependent change is seen in Fig. 8. Since R1 differs from SOC in some way, that difference is also represented by a fuzzy set of rules. To further understand how the SOC's membership functions associate with the fuzzy rules, refer to Fig. 4. A same fuzzy rule basis is used for R2 in this case.

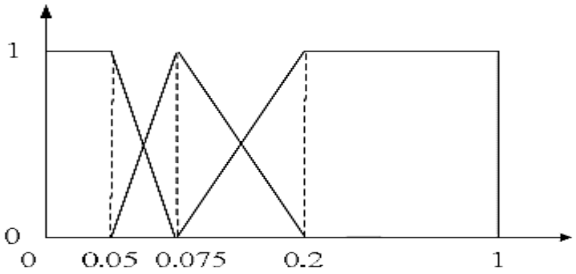


Fig.5. SOC membership functions for rings R1 and R2.

Assuming we have the fuzzy rules at hand that map SOC changes to model parameters, we can next account for the impact of temperature. Fig. 5 displays the values of Rs inside the area SOC 0.2 at a variety of temperatures. If the temperature drops, then Rs should rise. When the heat is beyond 35 degrees Celsius, there is not much of an influence on Rs. It is assumed, for the sake of this description, that beyond a certain temperature greater than 35°C, Rs remains constant. The change in Rs value between 15°C and 25°C is much bigger than the change in Rs value between 25°C and 35°C, demonstrating that Rs alters more dramatically when the temperature drops than room temperature. It is assumed that Rs is a continuous variable with respect to temperature between 15°C and room temperature in order to characterise this shift.

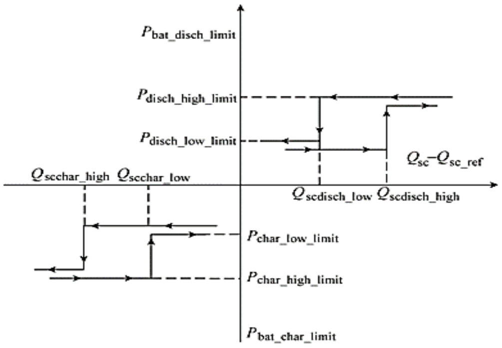


Fig.6.The diagram of Li-ion battery power dynamic limitation

If the supercapacitor's state-of-charge (SOC) falls below the lower limit Qsc char low, the Li-power ion's output cap drops to the lower limit Pchar low limit. The Li-ion battery's dynamic restriction may be expressed as:

If $Q_{\mathrm{sc}} - Q_{\mathrm{scref}} \geqslant Q_{\mathrm{scchar\_high}}$,

$P_{\mathrm{bat\_char\_limit}} = P_{\mathrm{char\_high\_limit}}$

If $Q_{\mathrm{sc}} - Q_{\mathrm{scref}} < Q_{\mathrm{scchar\_low}}$

$$P_{\mathrm{bat\_char\_limit}} = P_{\mathrm{char\_high\_limit}}$$

Mode 2: When the HESS is discharged, if the super-capacitor state-of-charge (SOC) is higher than the upper restriction Qscdisch high, the restriction of Li-ion energy is raised to Pdisch high limit; otherwise, the limitation of Li-ion strength is decreased to Pdisch low limit. The Li-ion battery's dynamic restriction may be expressed as:

If $Q_{\mathrm{sc}} - Q_{\mathrm{scref}} \geqslant Q_{\mathrm{scdisch\_high}}$,

$P_{\mathrm{bat\_dischlimit}} = P_{\mathrm{disch\_highlimit}}$

If $Q_{\mathrm{sc}} - Q_{\mathrm{scref}} < Q_{\mathrm{scdisch\_low}}$,

$P_{\mathrm{bat\_dischlimit}} = P_{\mathrm{disch\_highlimit}}$

Optimization algorithm and the Nelder-Mead simplex method may be used to form a hybrid technique that can be used to get the aforementioned control settings.

IVRESULTS

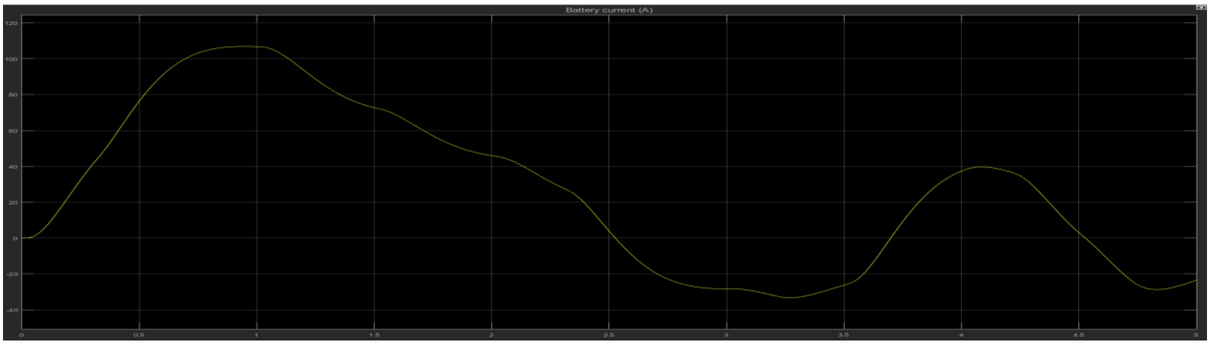


Fig .7. Battery current

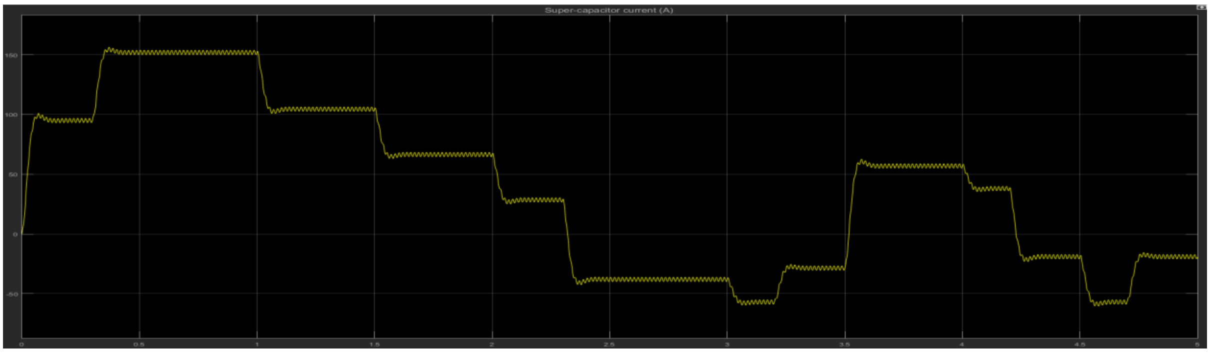


Fig.8.Super-capacitor current

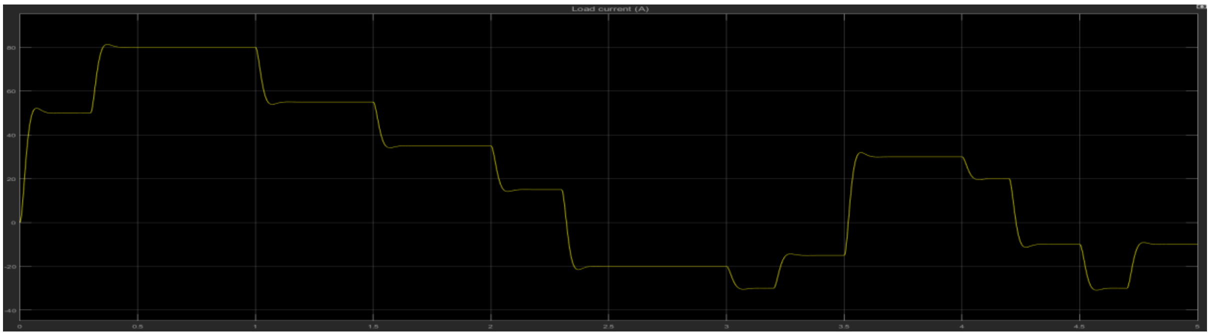


Fig.9. Load current

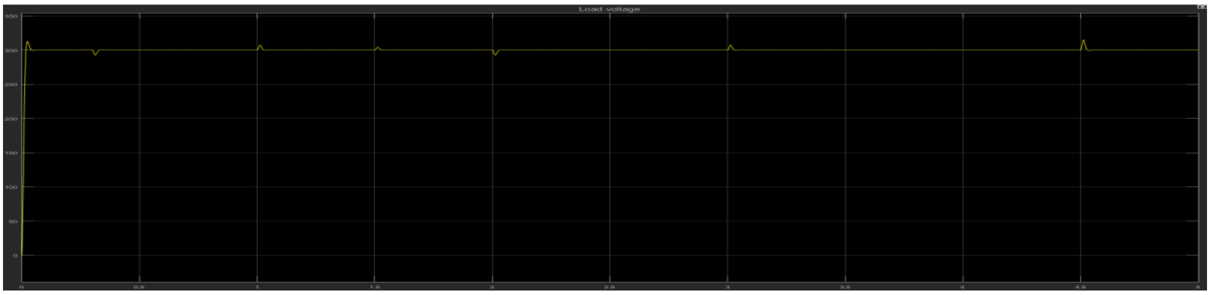


Fig .10. Load voltage

All Simulation results of the proposed HESS applied on electric vehicles.

TABLE III. COMPARATIVE PERFORMANCE OF THE USED CONTROLLERS.

arameter	**Controller**	**ettling Time**	**Peak Overshot**
C Voltage	PI	0.75 s	24%
	Fuzzy	0.25 s	24%
DC current	PI	0.85 s	33%
	Fuzzy	0.25 s	33%
ctive power	PI	0.76 s	30%
	Fuzzy	0.5 s	40%
active power	PI	1.2 s	450%
	Fuzzy	0.6 s	300%

Table 3 shows the comparative performance of the used controllers.

V CONCLUSIONS

To account for the effects of SOC and temperature, we create a unique fuzzy inference system of a Li-ion battery and verify its accuracy. A revolutionary hybrid energy storage (HESS) is built for electric vehicles using the power dynamic limitation rule of a Li-ion battery as the foundation for HESS power management as well as a newly created bidirectional DC/DC converter. The effect of state-of-charge and temperature on Li-ion battery model parameters is taken into consideration via global fuzzy rule bases. Along with extending the battery's life, this also reduces the ripple in the current output. The new model is demonstrated to be quite accurate across many testing environments. As a result, the unique fuzzy logic-based model serves Li-ion batteries well.

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