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A Novel Design on Hybrid Energy Storage System for an Electric Vehicle using NNFF Technology

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Abstract: ***As each day passes, we, humans, are attracted towards more and more technology for the easiness of our day to day life. One such technology, which has a very high scope in future and in the aspect of reducing pollution and providing clean environment, is the use of electric vehicles. Moreover, the electric vehicles provides long distance endurance and it is really minimizes the cost. This paper mainly discusses about the use and benefit of hybrid energy storage system for electric vehicle with the help of Neural Network Fitting Function technology, which is based on a controller. At last, comparison between graphs of a base model and the proposed model is also shown, which clearly shows reduction in variation of the battery current, super capacitor, load current and dc voltage graph.***

Keywords: Battery, Electric Vehicles, Hybrid Energy Storage System, Neural Network Fitting Function, Ultra Capacitor.

I. INTRODUCTION

Due to an increasing pollution and an effort to provide a clean environment, the government and the automobile manufacturers are focusing their works on the development of electric vehicles which uses greener propulsion solutions. In this paper, we will be discussing about Hybrid Energy Storage System (HESS) of Electric Vehicles (EV). HESS uses one or more energy storage mechanism with supplementary operational characteristics [2]. Many technologies have been invented in recent years to reduce the use of fuels in vehicles which leads to pollution and one such technology is the usage of energy storage system in electric vehicles. These EV uses Li-ion batteries because of its advantages. In this paper, we will be discussing about HESS containing Li-ion batteries and Ultra Capacitors (UC) in electric vehicles to make it comparable to fuel vehicles with respect to long distance endurance, fast transient acceleration and energy. While developing the electric vehicles, it is necessary to make sure to reduce the size and weight of battery used in order to extend the charging rate and capacity of the battery.

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In Hybrid Energy Storage System (HESS), DC/DC converters plays an important role. For the HESS, it is very important to select a satisfactory energy management (EM) strategy. And the one we used in this paper is the Neural Network Fitting Function technology.
The main objective of this paper is to compare the base paper model which used PI controllers to detect and correct errors in the graph and the proposed model which uses Neural Network Fitting Function technology which used layers to reduce the errors and thus provides a smooth and accurate waveform by reducing the glitches. The difference in the waveform of both the base model and the prosed model is also shown in this paper.
Our government and the automobile manufacturers are more focused on the adoption of electric vehicle as a way to cut down on greenhouse gas emissions. As the scope for the electric vehicles are increasing in the future, there are different technologies invented for the best use of electric vehicles and one such technology is the use of NNFF controller.

II. HYBRID ENERGY STORAGE SYSTEM TOPOLOGY

By the term hybrid means combination of two or more things. In this case, Hybrid Energy Storage System (HESS) refers to the useful coupling of two or more than two energy storage technologies with the supplementary in operation characteristics. The topology of hybrid energy storage system used in the base paper is shown in fig 2.1[1]. The below figure explains the working of HESS for electric vehicle. By the term electrical in electrical vehicle means we need dc output. The term hybrid in hybrid energy storage system means we are taking storage from more than one system in order to store the energy.

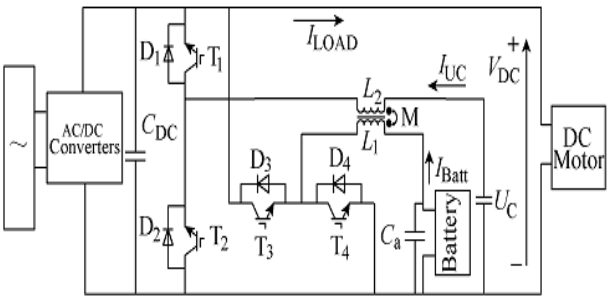


Fig 2.1 : Topology used in Hybrid energy Storage System[2]

This topology consists of DC/DC Converter, Lithium Ion battery and Super Capacitor. The DC- DC Converter consists of 4 transistor(IGBT) switches named T1, T2,T3 and T4 which acts as IGBT switches along with 4 corresponding diodes D1.D2.D3 and D4 and an integrated magnetic circuits composed of self inductance L1,L2 along with mutual inductance M which shares a common core inductor. These magnetic elements like inductance are the main source of electrical energy conversion. They mainly helps in energy storage, filtering and electrical isolation. Here, an E-type magnetic core used in order to achieve the magnetic element's integration. The battery connected provides power the DC motor. The super capacitor is dealing with the instantaneous state of peak power supply. As discussed in the figure above, the energy management system decides the flow of electrical energy to the load as per the demand. Different modes of operation of hybrid energy storage system is shown in the table below [1]. In the base paper, L1 and L2 acts as a coupling inductor. L1 is the external inductor, L2 is the output inductor and C_a acts as an additional capacitance.

Table 1: Different modes of operation of HESS

Working mode	Power Source	Power Flow	peration Mode	
Constant Speed Mode	Battery	DC	Boost	
Super Capacitor Charging Mode	Battery	Super Cpacitor and DC Motor	Boost or buck	
Parking charging mode	AC Power		Battery and Super Capacitor	Buck
Braking Mode	Braking energy		Battery and Super Capacitor	Buck
Acceleration Mode	Super capcitor		DC Motor	Boost

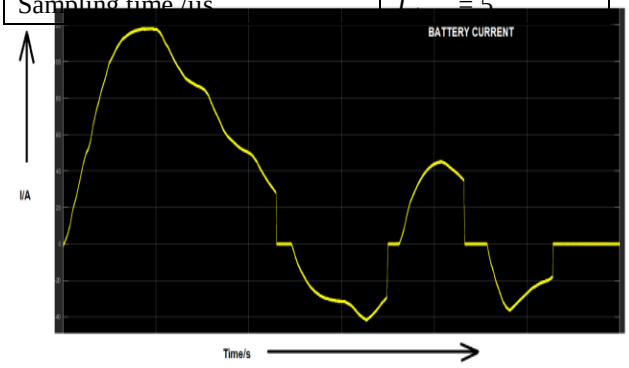
The same topology has been used in the proposed model but the difference is the usage of neural network fitting function controller instead of PI controller. Thus it clearly shows the best result with very less variations and error as compared to the base model.

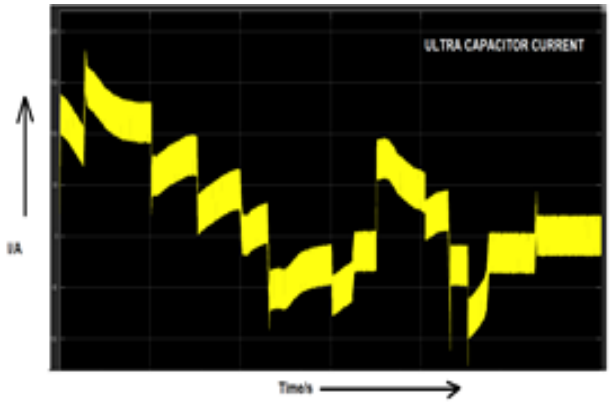
III. BASE MODEL

The simulink model can be derived from figure 2.1. The important part is the controller which we used here is PI controller. Initially an AC supply is given to the AC/DC Converter which converts AC into DC and then it is filtered out with the help of a capacitor (CDC). A transistor technology is used here which consists of 4 transistors (IGBT). An Ultra capacitor is also used here. The combination of Transistors along with Battery and the AC System form the hybrid energy storage for the DC Motor. Simulation specifications are shown in table 2 [1]

Table 2 : Simulation Specifications

Detailed Simulation Parameter	
DC side voltage /V	$V_{DC\text{-}nom}$ = 300
Rated Voltage of the Battery Pack/V	$V_{batt\text{-}nom}$ =144
C_{DC}/µF	4400
Rated Voltage of theSUper Capacitor/ V	$V_{UC\text{-}nom}$ =125
L_1/mH	10.12
L_2/ µH	580
M/ µH	580
Switching frequency/kHz	f_s = 15
Sampling time /us	T_s = 5





The results obtained by implementing the simulink model is shown in the figure 3.1.a to 3.1.d

(a) Battery Current
(b) Super Capacitor Current

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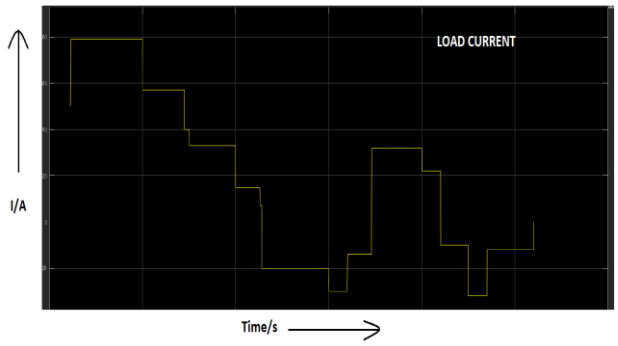
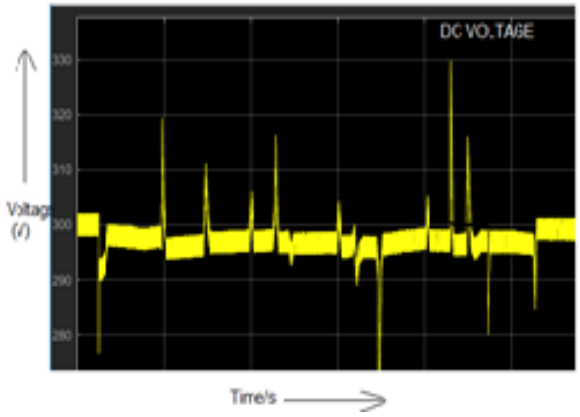


(c) Load Current



(d)DC Voltage

Fig 3.2: Simulation result of the base model of electric vehicle using PI controller

From the graph, it is clear that apart from the load current graph which is very smooth without any ripples, all other 3 graphs has a big variations and is not ripple free. The load current graph uses a staircase generator which produces graph in the form of stair cases and it is used to compare the resuts when the vehicle is in the charging state, discharge state, in the off mode or in the standby mode.

In the graph of load voltage, the voltage should be 300V but it is varying between 300 to 320V in the upper side of the graph and between 260 to 300V in the lower side of the graph. And also a thick graph is obtained with more flickers and fluctuations. Our aim is to make these graphs a smoother one with less variations and error free one. For that we are using the neural network fitting function controller. The coming session will explain about how it works. Also, compared to the super capacitor current, the battery current variations are smoother with minimal ripple content. This can help in the extension of battery life and also helps to reduce the loss due to current ripples caused due to the DC motor. Sudden change in the load current is normal because of the high frequecy fluctuations due to the presense of super capacitor. There will be a variation in the load voltage also which is caused by the accleration or breaking of the vehicle but again with the help of super capacitor, the voltage can be quickly restored to 300 V which is the reference voltage.

IV. PRPOSED MODEL

As discussed, our government took an initiative along with several automobile manufacturers to manufacture more electric vehicles as a result of reducing the pollution caused due to the excessive use of fossil fuels which is used in vehicles. The best technology inorder to achieve a clean and pollution free environment is the usage of Electric vehicle which uses batteries instead of internal combustion engines. Even though, many inventions are made to get a better results of using electric vehicle, the one we are proposed in this paper is the usage of electric vehicles with the help of the Neural Network Fitting Function Controller. The one which is used in the base paper is the PI controller and results have been shown below. We are using the same elements as in the base model but the one we are replacing here is PI controller and using Neural Network Fitting Function controller in the place of that. With the help of this, a much, accurate and smoother results have been obtained.

The same topology has been applies here but with a different controller to get an accurate result. This topology consists of DC/DC Converter, Lithium Ion battery and Super Capacitor. The DC DC Converter consists of 4 transistors(IGBT) switches named T1, T2,T3 and T4 along with its corresponding diodes and an integrated magnetic circuits composed of self inductance L1 and L2 which ultimately form a mutual inductance These magnetic elements like inductance are the main source of electrical energy conversion. They mainly helps in energy storage, filtering and electrical isolation. Here an E-type magnetic core used in order to achieve the magnetic element's integration. The battery connected provides power to the DC motor. The super capacitor is delaing with the instantanoeus state of peak power supply. As discussed in the figure above, the energy management system decides the flow of electrical energy to the load as per the demand.

Initially an Ac supply is given to the bridge converter which is basically AC to DC converter which converts the incoming AC current to the DC current. The capacitor parallel to the converter is used for the filtering purpose. 4 transistors are connected across it which receives gate pulses from G1,G2,G3 and G4. A mutual inductance is also connected there. The output from the transistors are connected to the battery and the super capacitor. Finally this configuration helps to run the dc motor which is used in vehicles.

Function Fitting can be explained as the process of forming neural network on a group of inputs in order to generate an associative group of targeted outputs. This uses layers and provides error free or minimized error outputs. For NNFF, the signal is send first along with the error (i.e, change with respect to time=du/dt). Here, the input is divided into 2 parts- one is the normal input and the second input is error in input. Both of these inputs are given to a multiplexer which produces a single output.The output goes to NNFF as its input. The block diagram of Neural Network Fitting Function is shown is Fig 4.1:

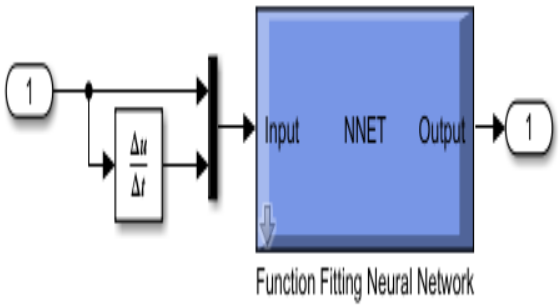


Fig 4.1 : Block diagram of Neural Network Fitting Function.

The proper working of NNFF is shown in fig 4.2. From the above figure, we can see that the input received by the NNFF block is processed and then it is given to layer 1.

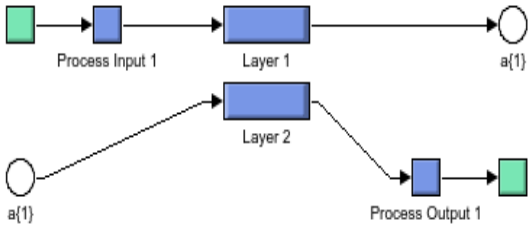
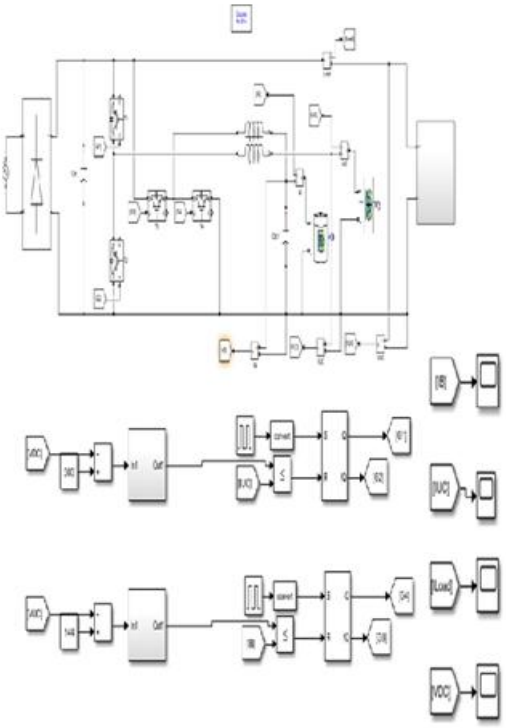


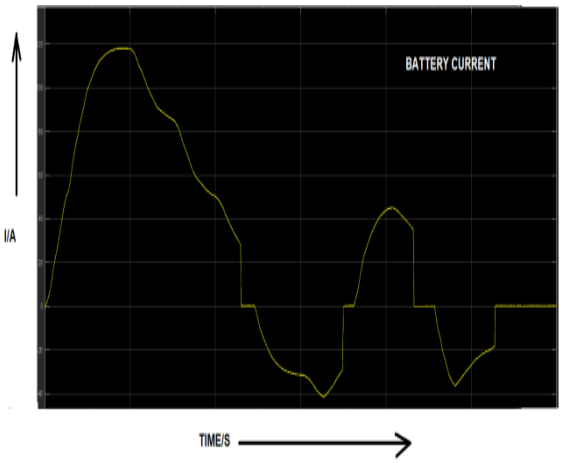
Fig 4.2 : Working of NNFF

The NNFF is divided into layers and these layers will helps to reduce the errors. We need to check how much layers needs to be used to get an error free output. An output is produced from layer 1. If the error is not reduced then the output is passed through layer 2 as its input and produces another output. This process goes on till the error is reduced nearly to zero. And the last reduced output is the final one. This is the main technique of NNFF. So, 2 inputs-VDC and reference voltage 300 V is given to add or subtract block and an output is produced. This output will act as an input to the NNFF subsystem. The output from the NNFF subsystem is given to the comparator and another gate pulse is given to the converter. The output from which is given to the SR flip flop (which is used to store the element

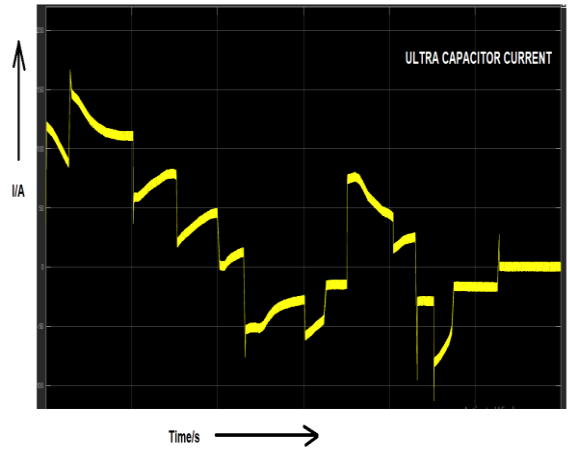


temporarily) which finally produces 2 complimentary outputs and these outputs are used as gate pulses G1 and G2. Similar case is with the ultra capacitor as well. Thus the improvement is brought from the one used in base model. The Simulink model of proposed one is shown in fig 4.3.

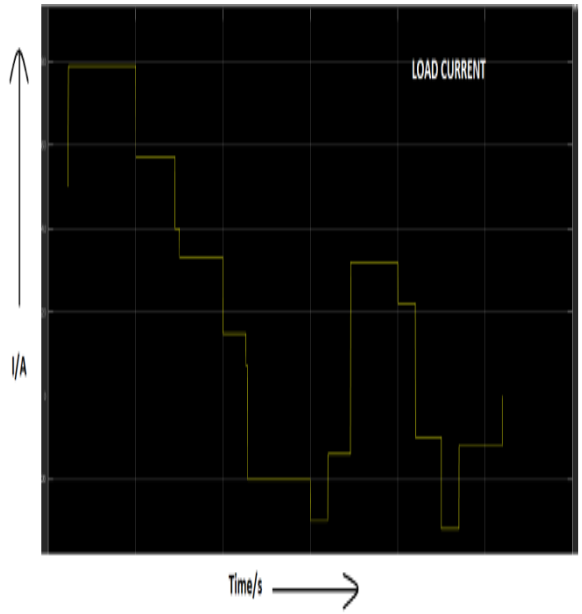
The result obtained from the proposed model is shown in fig 4.4:



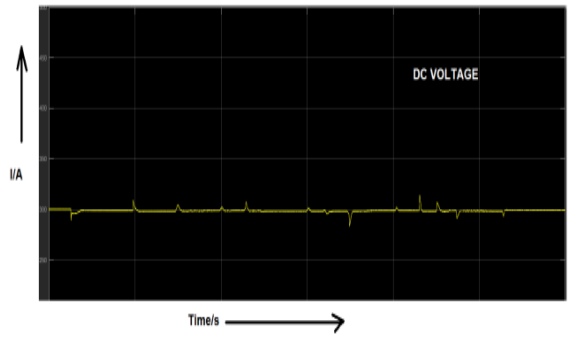
(a) Battery Current



(b) Super Current Current



(c) Load Current



(d) Load Voltage

Fig 44 : Simulation result of the proposed model of electric vehicle using Neural Network Fitting Function controller.

From the above results, we can see that comparing to the base model, the battery current became smooth and of less ripples than the base model battery current. The variations and error in the super capacitor is also drastically changed. There would be any changes in the waveform of the load current. That will remain the same. In the case of load voltage, comparing it with the base model waveform, it is observed that the error and the variations are reduced and is reaching the reference voltage of 300V with less ripple We can see that, it is almost ripple free one.

From the above analysis, it is clearly visible that using Neural Network Fitting Function, a better, accurate and smooth results are obtained. So, if we continue to use this method while making the electric vehicle, it leads to efficient usage of energy and also provides a way for a clean environment.

V. CONCLUSION

Electric vehicles have a bright future ahead. There are several schemes by our government which encourages citizens to use the battery packed electric vehicles instead of internal combustion engine vehicles. This helps to provide a clean environment and more positively helps humans to breathe clean air. The batteries used in the electric vehicles are rechargeable batteries which just needs a charging stations. As discussed throughout this paper, the hybrid electric cars are more environmental friendly with the long life batteries. If we continue the usage of Hybrid electric cars , as per the usages, we can access it more economically also.

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