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Integration Methodology of Ultra Capacitor-Battery Based Hybrid Energy Storage System for Electrical Vehicle Power Management

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ABSTRACT: Improving the vehicle's performance in terms of single range coverage is necessary given the demand for electrical vehicles today and the improvements made in the industry. A resourceful energy storage system used to increase the enactment and efficiency of an Electric Vehicle. The utilization of sources with high energy and power densities is necessary due to the dynamic nature of EV power requirements. One supplier cannot fulfill this need. Therefore, by combining different energy storage sources, the efficiency of an EV can be boosted. This paper discusses how to use a sliding mode controlled connecting the battery source with a bidirectional DC-DC converter. There are numerous driving modes available for electric vehicles, including normal, cruise, and acceleration/deceleration. To fully utilize both bases, a rule-based EMS is created, with the rules being centered on specific realistic values. The hybrid power source can handle both the transient (peak) and average load demands of an electrical vehicle. In a MATLAB/SIMULINK environment, the full Electric vehicle simulations have been conceded using a real-time drive cycle in an Indian metropolis, pulse load conditions, and the vehicle as load. The results demonstrate that an ultra capacitor completely and effectively regulates the pulse load current.

KEYWORDS: Ultra capacitor, Hybrid Energy Storage System (HESS), Electric Vehicle (EV).

I. INTRODUCTION

EVs are being formed in high amount quantities these days as a result of the rising price of petrol and environmental anxieties. EVs have healthier fuel efficiency and adhere to current emanation limits than gasoline-powered ICE vehicles [1]. A battery serves as the main power source for electric cars currently on the market. EVs are subjected to various time-varying power demands brought on by rapid acceleration and deceleration. Battery 1's performance is significantly impacted by the fact that it cannot be charged and drained at a higher rate during the regeneration phase. The limitations of EVs are their low power density, brief lifespan, and limited range of operation. We can meet both the short-term peak power requirements for ultra capacitors and the long-term average power requirements for batteries through hybridization. Because of its long lifespan substantial power density and advantageous charge and discharge efficiency, ultra capacitors are anticipated to be employed as a supplementary energy storage technology in conjunction with batteries [3]. An ultra capacitor, a double-layer electrochemical capacitor, has a 1,000-fold more energy storage capacity than a typical capacitor. It has characteristics shared by traditional capacitors and batteries, and has an energy density 10% higher than batteries. Comparing to the few thousand charge and discharge cycles of a typical battery and the capacitor, ultra capacitors have a higher number of cycles. 100000 or so [4]. An ultra capacitor's fast delivery and even uptake of significant passing pulse power helps ensure that the load's supplies are satisfied during hasty

acceleration, deceleration, and regenerative period of drive [5]. Since the battery and ultra capacitor's essential characteristics (voltage level, charging/discharging, etc.) differ, a sufficient interface between both sources is required for an electric vehicles (EV) efficient operation. A power electronics chopper come across the requirement for enabling us to worked dual space devices at various levels and to their maximum potential. Compares non-isolated bidirectional chopper topologies with various types of ultra capacitor-based regenerative braking system topologies that use chopper analysis for ultra capacitor interfaces. Numerous control strategies have been published and researched for DC-DC converters and others are a few well-known control algorithms. The main goal is to maintain control the load voltage within the predetermined range in circumstances like greater input voltage. There is an increase (deceleration period/regenerative time) and a decrease (acceleration period) for an ultra capacitor source. The effective non-linear controller known as sliding mode control (SMC) requires the system trajectory to stay on the sliding surface, which is a suitable surface chosen inside the same space. In comparison to alternative control methods, the SMC has a number of advantages, such as stability for even the most extreme line and load fluctuations, robustness, good dynamic response, and simplicity of use. Establishing an energy management plan that takes into account both the development of electric vehicles has a difficulty with regard to the real-time performance of the vehicle and its efficiency. QPIS [18], fuzzy logic-based neural algorithm [17], and rule-based algorithm [13], and the linear filtering algorithm [14] are just a few of the power and energy management solutions for electric vehicles that are presented in [13-16]. The rule-based techniques provide advantages for real-time software. An EV's energy and power management shows how different electrical power sources contribute to meeting load power requirements while taking into account all of the dynamic states of the vehicle system. The most popular electric car just uses batteries as a means of energy storage. The power management only ever makes use of one controllable variable (source power level) and a controlled state (source state-of-charge). Consequently, incorporating an ultra capacitor into the system indicates the presence of a new control variable with some state. Further state hinders the scheme and the energy and power executive. This study examines the efficacy and potential for rule-based power distribution amid the battery and ultra capacitor using a sample and real-time load outline for the e-vehicle. The hybrid source and its operating characteristics, together with the electrical vehicle model, are explained in the second half of this study, which is broken up into the following subsections. The final section covers the vehicle dynamic forces and the total power requirements of the vehicle. The fourth segment discusses the topologies of passive and active dual energy storage systems. The outcomes of fusing a source with an EV as a load are described in the final section. These topologies are simulated in MATLAB/SIMULINK under beat load conditions. The load profile for electric vehicles is produced by modeling the dynamic energy management system using MATLAB algorithms.

II. MODEL OF PROPOSED VEHICLE

Figure 1 shows the block diagram in its entirety. The SMC control algorithm individually controls both sources, and the rule-based EMS controls how much power is distributed among them. This task concluded with the setting up of an energy control system for a dual-source electric car utilizing lead-acid batteries and ultra capacitors. This hybrid source provides the pulse load requirements for the e-rickshaw. For high pulsed discharge current, a hybrid source made of batteries and ultra capacitors can lessen the rate capacity effect. The E-vehicle system limitation is shown in the Table. I each system in the system block diagram depicted in Fig. is represented by an equivalent circuit equation. In the MATLAB/SIMULINK upbringing, 1, including the battery, ultra capacitor, DC-DC converter, etc., are modeled.

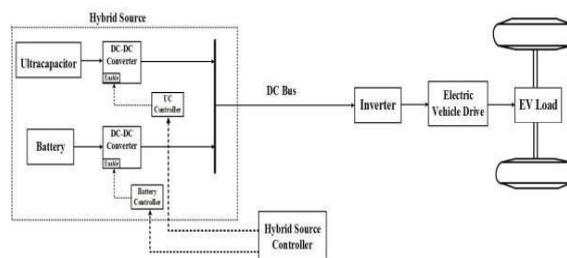


Fig.1 hybrid source's overall interface block diagram with the EV load

Vehicle Dynamics	
Transport Load	300Kg
Load Passengers	240Kg
max Vehicle loading	540Kg
Max rate	42kmph
Typical Tempo	24kmph
Forward region	2m ²
Coefficient Rolling	0.01
Coefficient of Drag	0.346
Wheel Base: Front	3.250-16.6
:back	4.52-12.2
Electric engine	BLDC motor(650W,48V)
Running	76Km/per charge
Earth coverage	20cm
Operating Voltage for a Drive	48V

TABLE I: System specifications for e-rickshaws

III. SYSTEM FOR VEHICLE DYNAMICS

The amount of electric power the hybrid power source will require during the drive cycle is calculated by the electric vehicle dynamical modeling's power management. A few of the power torque equations borrowed from [20] and [21] form the foundation of the dynamic modeling strategy used here. The system accepts inputs such as the required speed of the vehicle and the EV variables listed in Table I. The rolling resistance force, which the EV must overcome to continue moving because of rolling movement amid the surface and the tires, is an opposing force. The rolling friction coefficient, which varies based on the composition of the EV wheel and the surface unevenness, determines the rolling resistance force. From (1), the rolling resistance can be estimated. Where GVW stands for gross vehicle weight (kg), Cr for rolling resistance coefficient, and FR for rolling resistance force (N-m).

$$FR = GVW \times (1)$$

When an electric vehicle (EV) is climbing an inclined terrain, a gravitational force called the grade resistance force tends to pull the EV back. Using (2), it is possible to determine whole grade resistance force acting on the Electric Vehicle at a specific time when it is travelling along a tending surface. FGR stands for grade resistance, and is the angle of inclination. For the exact sizing of the Electric Vehicle as illustrated in Fig.2, the Real Time Indian City Drive Cycle is utilized to calculate the speeding up power as well as overall attractive power. Fig. 2 (e) and (c). The vehicle dynamic model's evaluation of the corresponding power requirement is scaled back to meet the load current.

$$FGR = GVW \times \sin \theta \quad (2)$$

With the dual source described in the following segment, this load will be tested using the EV profile. In a predetermined amount of time after the electric vehicle (EV) starts moving, a predetermined speed is reached thanks to the acceleration force. The acceleration force and motor drive torque have a direct relationship. Less time is needed for the Electric Vehicle to get at its target speed the higher the acceleration torque. The mass affects the acceleration force. (3) And (4) are used to determine acceleration force. Where FA is the acceleration force (N-m), m is the vehicle's weight, and g is the gravity's acceleration (9.81 m/sec²).

$$FAE = m \times a \quad (3)$$

$$m = GVWg \quad (4)$$

$$Fda = 1 \times p \times V^2 \times Cd \times A \quad (5)$$

$$F_T = F_R + F_{GR} + F_{AE} + F_{da} \quad (6)$$

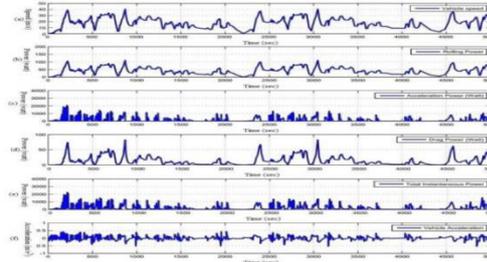


Fig. 2. Real-time Indian city drive cycle (a), rolling power curve (b), (a) Total instantaneous power, (b) Drag power, (c) Acceleration, and (d) Total instantaneous power.

IV. HYBRID SOURCE PERFORMANCE USING EV AS ALOAD

Testing of the performance of hybrid sources is done under various operating circumstances using various battery and ultra capacitor operating modes. Electric vehicles (EVs) require loads that are always pulse power, or a mix of peak power and average power. Therefore, the pulse load condition is used to test this vehicle model. The fundamental approach for connecting an ultra capacitor to a battery formation is to arrange these energy storage systems in parallel via pulsation load (machine drive load in the case of an electric vehicle load since the HESS's input voltage is the same as the Aerodynamic force is computed by calculating (5). The drag phenomenon is a function of vehicle speed, and while it is insignificant at inferior speeds, it becomes a significant effect at higher speeds. Where F_{da} = Force of drag (N-m), ρ = air density (Kg/m³), V = speed of the vehicle (m/s), C_d = drag coefficient, and A = frontal area of the vehicle (m²). The internal resistance of the hybrid sources determines the load power distribution between them [22].

V. PERFORMANCE OF PASSIVE HESS WITH RESISTIVE PULSATION LOAD

The dual system depicted in Figure 3 is suitable just for initial motors are an ineffective of thrust power for EVs. The representation can successfully block the during passing changes in the Electric Vehicle load profile; there is a heavy load current to the ultra capacitor. However, one particular flaw in analysis is done using the vehicle's dynamic equation the performance's effect on the drive cycle. The force needed to drive the vehicle is provided by these equations, and it is supplied by (6). When employing this method, higher voltage-rated components, such as batteries, are used. Two sources are operating at full voltage, which prevents us from using the ultra capacitor to its maximum capacity because the performance of an ultra capacitor depends on a decrease in terminal voltage.

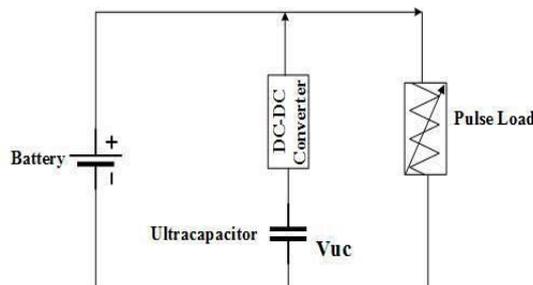


Fig. 3. Passive HESS system using a parallel combination of batteries and ultra capacitors

The results of simulating the routine of the passive HESS system for a uninterrupted stair variation in load are displayed in Fig.3. Table II lists the simulation parameters for the model, which includes an ultra capacitor model connected in parallel to the load typical lead-acid battery. The ultra capacitor source current immediately increases after the 1st step load increase in the current, absorbing the load current changes. As lead-acid battery current linearly begins supplying the load, the ultra capacitor source in progress subsequently begins to decline. As the load current stabilizes

and becomes constant, the ultra capacitor source begins to draw a tiny quantity of output current from the string to maintain its input voltage at the recommended level. The ultra capacitor’s ability to supply high power is dependent on the decrease in its voltage. Because the energy stored in an ultra capacitor is precisely relative to the square of its input voltage, this scheme's restriction is that the battery prevents the ultra capacitor from using its power. As battery voltage won't drop considerably, the ability of parallel-connected ultra capacitors to share power will be limited. To prevent local current circulation in the system, one must use ultra capacitors with high ratings in this design. Additionally, using two different voltage level sources will not be permitted.

Passive HESS system	
Module for Ultra capacitor	48V,166F
Power supply	48V,60Ah
Pulsation rate	48Aat20.5%duty

Table II: Parameters of the passive system

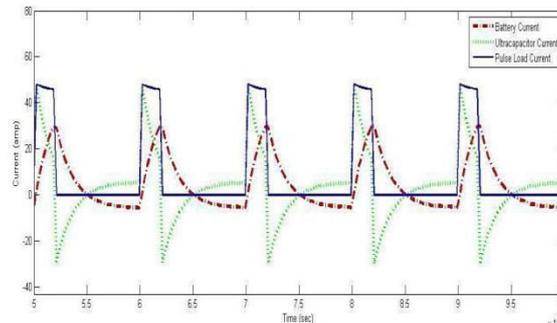


Fig. 4. Current distribution of the pulse loads from batteries and ultra capacitors in passive HESS

VI. PERFORMANCE OF ACTIVE HESS WITH RESISTIVE PULSE LOAD

It is preferable to use an active dual energy storage device while operating a various ultra capacitor voltage level hybrid source. The system includes a chopper unidirectional converter to link with each component, a battery and an ultra capacitor, individually. It is an analogous pairing of an ultra capacitor and a battery with a load. Fig. 5 shows the active HESS structure that includes a chopper converter controlling both the battery and ultra capacitor sides. If the battery functions solely as an EV source and if it is connected to a pulse load, then the battery must source all rapid load changes that arise in the system but only briefly. The characteristics and life of the battery terminals will be severely hampered by this. With a hybrid energy storage system, the challenging issue mentioned above can be remedied. The sole negatives of this active HESS technology, which provides improved control over electrical power flow, are the system's complexity and higher cost because it uses more choppers. In the MATLAB/SIMULINK environment, the ultra capacitor and battery with a coupled DC-DC converter and pulsation load are simulated together with the necessary pulse width programmable switch. The charge controller of the active HESS architecture is controlled by a closed loop control SMC algorithm [12], which generates the control signal for ultra capacitor and battery converter exploit in response to load fluctuation. The MATLAB/SIMULINK active HESS model depicts a method for integrating battery and ultra capacitor systems in parallel with converters using an EV's pulse load model. The DC bus and the ultra capacitor source are connected by SMC control technique is used in a bidirectional DC-DC converter [23]. This chopper with SMC control system indicates that the battery can provide or absorb the average load need while the ultra capacitor source can supply or absorb unexpected continuous load variation requirements [24]. The rules-based energy management algorithm of this Live HESS design dynamically controls the power supply allocation between battery and ultra capacitor energy sources. [14]. The major goal of this design is to accurately have the ultra capacitor source give

high pulsation power for a brief amount of time. When the battery source is used, low constant electrical power is delivered for an extended length of time, as during acceleration and deceleration.

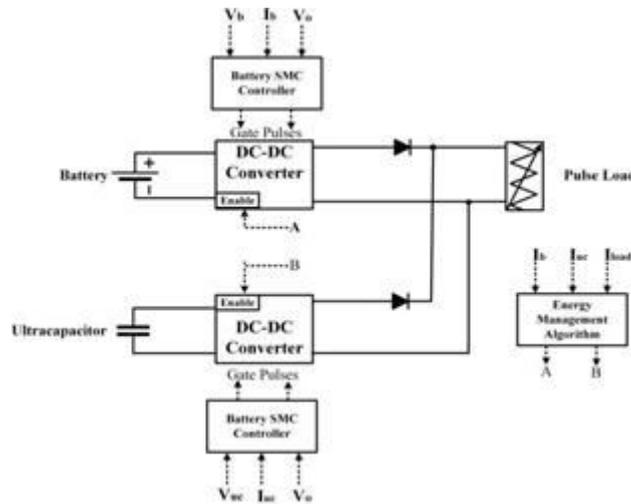


Fig. 5. Controlled operation of a hybrid active HESS system using batteries and ultra capacitors

A brief time of the EV driving cycle, not the entire cycle, is when the abrupt load fluctuation or acceleration period is used. In order to meet the pulse load demand, the ultra capacitor source must therefore exert effort only Fig. 6 shows the ultra capacitor voltage, battery current, ultra capacitor current, pulse load current, and SOC are measured variation during the test drive cycle where a pulse load is intermittently delivered with a variable duty cycle. The effective load voltage guideline for the chopper under SMC control is shown in Fig. 7. Table III displays the parameters for the active HESS simulation.

HESS Passive system	
Module for Ultra capacitor	16V,500F
Power supply	48V,60Ah
Pulsation rate	48Aatvariable duty
Inductor	0.2H
Capacitor	10F

Table III Parameters of the Active HESS system

The results in Fig. 6 show that although the battery and ultra capacitor’s terminal voltage, SOC level, and drive cycle time increment are all decreasing, the changes in ultra capacitor limitations are significantly greater than those in the battery. Therefore, it is determined by looking at the data of Fig. 6that employing an ultra capacitor as a dual power source with a battery for an Electric Vehicle is a viable and reasonable alternative.

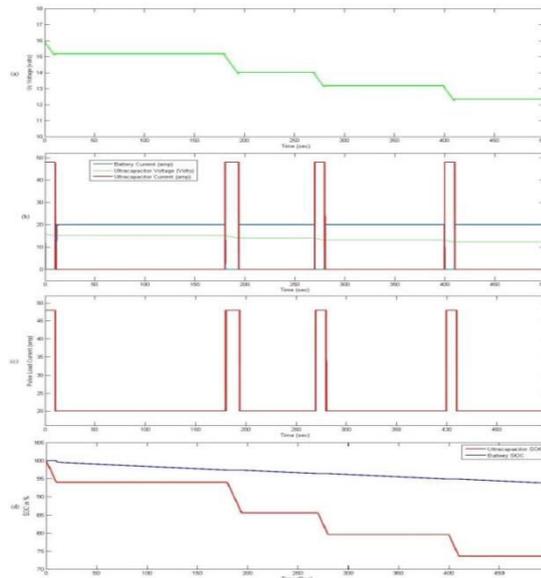


Fig. 6. A pulse load profile with changing duty cycle, B battery and ultra capacitor current circulation and voltage level, C pulsation load profile

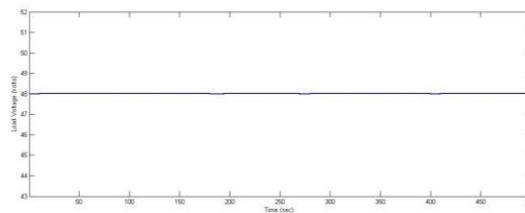


Fig. 7 shows a DC-DC converter with load voltage regulation under SMC control

VII. DUAL SOURCE PERFORMANCE FOR EV AS A LOAD

The working stages of an electrical vehicle include accelerating, decelerating, and average. When in acceleration mode, the ultra capacitor must give the majority of the acceleration power, when in average mode, the battery must meet the EV's minimum power needs, and when in deceleration mode, power can be returned to the hybrid source through regenerative action. As a result, the power requirements vary depending on the mode, and a dual source will help us control these requirements. An energy management method is required for controlling the fluctuating point and power distribution between dual sources and EV drives .The active HESS system is currently using the EV as a load. In this instance, a Battery (48.6 V) and an ultra capacitor (16 V, 550F) are employed as a hybrid source. The power and energy managing of Electric Vehicle [6] produced the real-time urban load profile displayed in Figure 10 and the real-time Indian city drive cycle is depicted in Figure 2(a). Because of this urban burden. The hybrid source is employed with the matching current profile MATLAB EV drive load model. The active HESS topology with source SOC control technique is used in simulation work. The block diagram for this technique is shown in Fig. 8, which compares the instantaneous values of the battery's base current and the ultra capacitor's lowest SOC with the reference values, respectively [25]. As a result, a control signal is generated based on the aforementioned circumstance, and it is then applied to the chopper to change their switching in line with the demands for high and low loads, as shown in the hybrid source controller sub-system of Fig. 1.

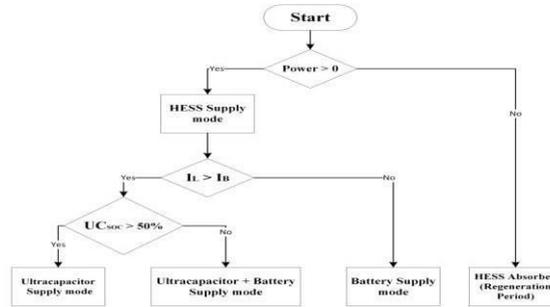


Fig. 8: Representation of the SOC control algorithm block diagram

Figs. 9 and 10 demonstrate, respectively, the load current profile and load distribution between the battery- and ultra capacitor-based hybrid sources. According to the findings of Fig. 10, the ultra capacitor is responsible for supplying the bigger pulse load, and the battery is also responsible for supplying load up to the value of its base rating, which in the case of the active HESS control system model in MATLAB is 16A. When the battery side converter causes the battery source to operate in the constant current mode above this base current value, the ultra capacitor source converter's operations provide the remaining high pulse load.

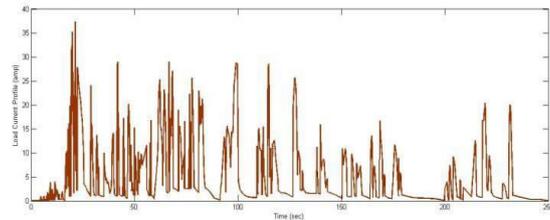


Fig. 9. The e-rickshaw needs to have a real-time, instantaneous load current drive.

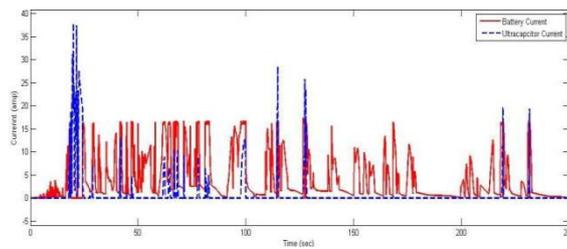


Fig. 10. Distribution of ultra capacitor and battery load in the e-rickshaw load profile

In Figures 4 and 6, respectively, two sets of simulation results for Passive and Active HESS are displayed. The control of these two topologies differs from one another. The bi-directional chopper ability to maintain voltage and power ratings within acceptable ranges as well as the power between the dual source and the converter. The maximum load rating of the ultra capacitor bank can be raised when the power edge of the battery side chopper is lowered, as can be shown from the simulation results of Fig. 10. Due to the fact that active HESS has more controlling parameters than passive HESS, it is able to maintain system parameters during conditions of high pulse load.

VIII. CONCLUSIONS

This paper described the strategy used to regulate the power of hybrid sources. Finding the ideal EV load profile is a frequent step in the hybrid source implementation procedure. The effectiveness of hybrid source response and voltage control under pulse load patterns is tested in the MATLAB/SIMULINK environment utilizing simulated passive and

active HESS systems. The active HESS topology is also discussed in this work, which connects hybrid sources and electric vehicles (EVs) as a load and offers better control over the pulse load distribution between the battery and ultra capacitor. In MATLAB/SIMULINK, the accurate rule-based power control of the EV system and the bidirectional DC-DC converter connected to the hybrid source has been implemented and verified. The results of the simulation indicate that the active HESS generates better outcomes, where the ultra capacitor serves the power requirements of the EV's continual transient shifting load profile and the lead-acid battery satisfies the slow-changing and steady-state power needs.

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