DESIGN AND IMPLEMENTATION OF HYBRID ENERGY STORAGE SYSTEM (HESS) FOR ELECTRIC VEHICLE BY USING FUZZY LOGIC CONTROLLER

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Abstract

In this research, a battery and an ultra-capacitor were integrated into an electric vehicle to evaluate its performance. Utilizing internal combustion engines (ICE)-based vehicles frequently has had a significant negative impact on the environment and has accelerated the depletion of fossil fuel supplies, which has caused gas prices to significantly increase over the past two decades. The shortcomings of the traditional approach to determining precise values for factors relating to current and motors the fuzzy logic controllerbased system was created to overcome the drawbacks of the traditional controller-implemented fuzzy logic controller-based system. Multiple iterations were performed by the logic controller, which produced precise values. The DC link voltage is controlled by the fuzzy logic controller. Using the MATLAB/SIMULINK software, the performance of the proposed controller and the electric vehicle at variable input speed with an interleaved bidirectional buck-boost converter was evaluated.

Introduction

The electrification of the vehicular systems with energy storage systems will leads to high performance and efficient working. Due to this electrification of vehicular systems there is a possibility to implement Electric Vehicles(EVs) and Hybrid Electric Vehicles. Currently it is not possible to meet all requirements imposed by vehicles by using single type of energy storage.Now a days Li-Ion batteries are offering most efficient performance for vehicular applications.when compared with lead-acid and NiMH batteries due to its high specific energy and relatively higher specific power will gives more efficient performance [1]. But there is a limitation for these batteries that If the Li-Ion batteries are exposed to fast charging(or discharging) currents the life span of Li-ion batteries is greatly reduced. In other hand, Ultra capacitor has a very high specific power but with very low specific energy. To combine the capabilities of both the systems In this paper it is worth trying to combine these energy storage devices to achieve high performance of ESS[2],[3].

The most efficient technology for power electronic converter topology is identified for HESS application.

In the following sections the development of power management systems is presented and it is integrated with a closed loop controller which can drives the power requirements driven a vehicle on a certain drive cycle.

Hybridenergy Storage System Configuration

Unit and Controller Unit.This implementation leads the lower weight and smaller size.Either ultra capacitor unit or battery unit is directly connected with DC bus.

When Battery unit connected directly with the DC bus, Ultra capacitor can offers wide range of terminal voltages due topartial presence of dc-dc converter interfacing ultra capacitor with the DC bus.In this case, Bus unit is exposed to fast charging and Discharging currents, which results in fast changes in the torque and power of the traction motors. The partially Decoupled Hybrid EnergyStorage Systems topology with ultra capacitor is directly connected to the DC bus, and battery unit placed behind a dc to dc converter in order to overcome the short_comings.

A small in size converter is going to be used in this case compared to the where battery unit is directly connected to the DC bus and ultra capacitor is placed behind a dc to dc converter.The DC bus voltage is free from fluctuations when both the battery unit and ultra capacitor unit is being interfaced to the DC bus via dedicated dc to dc converters in fully_decoupled configuration.

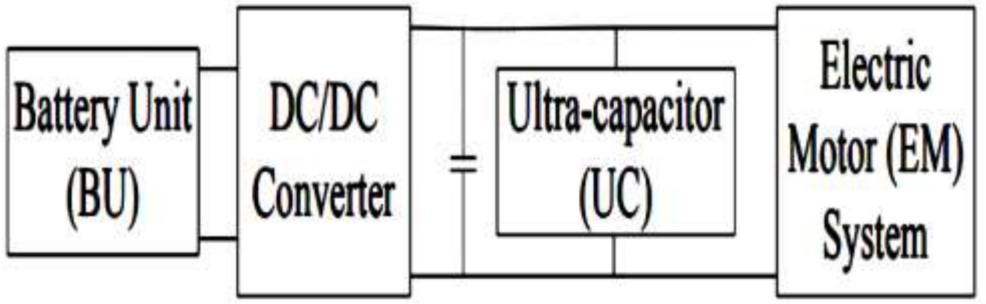

Fig:1 Proposed partiallyde-coupled H-Energy Storage System with directly coupled UC with DC bus

It has to be bi-directional when dc to dc converter interfacing the battery unit and ultra capacitor unit can be able to provide propulsion power and can be able to absorb regenerative breaking.

The very important considerations for HESS are the simplest design of bidirectional boost-buck converter besides operational performance, less cost, volume and weight. At low voltage side of the converter the battery unit is connected and ultra capacitor unit is connected to high voltage side. The battery unit is connected on low voltage side will reduce the complexity of the system and cost of the cell_balancing [2],[8]. A 2 module inter-leavedstructure is adopted to make the DC-DC converter to handle high currents which is shown in Fig 2, this technique can reduce the total conduction losses by 50% [9].This technique can also be helpful in current ripple cancellation. This can results from the phase delay between individual PWM signals.to obtain the low current ripples low pass LC filter is used ,at battery unit terminals the switching frequency being twice the actual frequency.

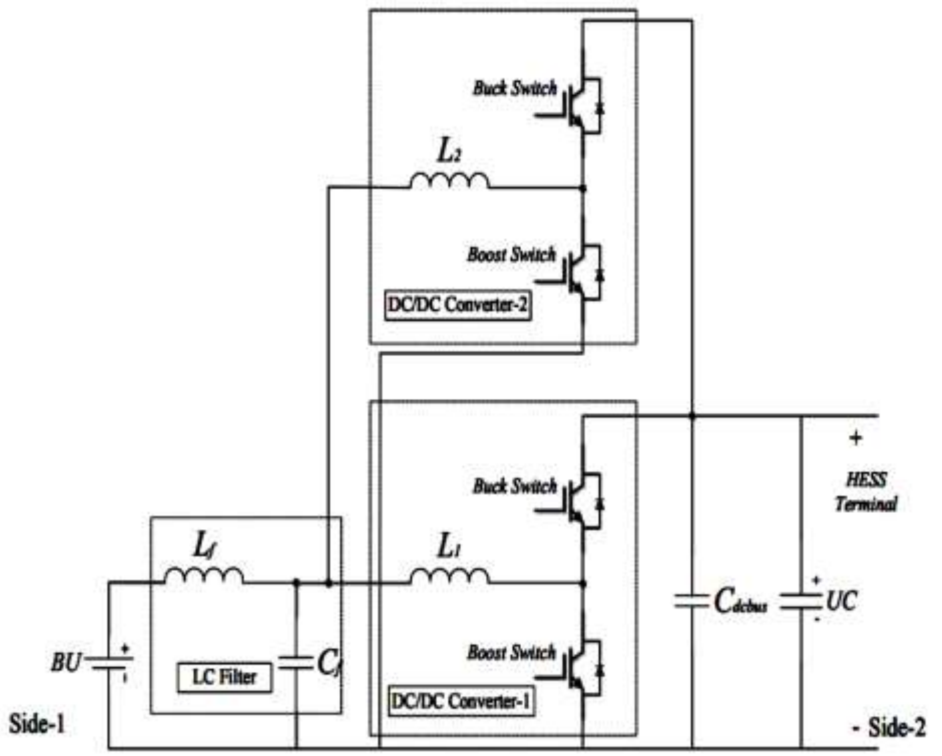

Fig:2 two module interleaved bi-directional buck boost dc to dc converter

Controller For Dc To Dc Converter

The operation of battery unit and ultracapacitor is co-ordinated by Hybrid Energy storage power management algorithm.The Hybrid Energy Storage management algorithm should satisfy the 4 considerations (1)maximum discharging current of battery (2) Maximum rate of rise of charging or discharging power of battery. Limiting the change of dp/dt can protects the battery unit against fast discharging and charging current. (3) charging and charging voltages: there are 2 possible operations are associated with the system , the first operation is the battery unit in the vehicle is charged by grid according to the CC-CV scheme.The second way is battery unit is charged through regenerative braking power. (4) DCbus voltage regulation; every electric motor having the allowable input voltage range,DC bus voltage should remain in the allowable volage range. The over voltage and under voltage can cause the malfunction of electric motor system.Battery unit is controlled to charge ultra capacitor or it may receives energy from ultra capacitor to keep DC bus voltage with in the specified range.

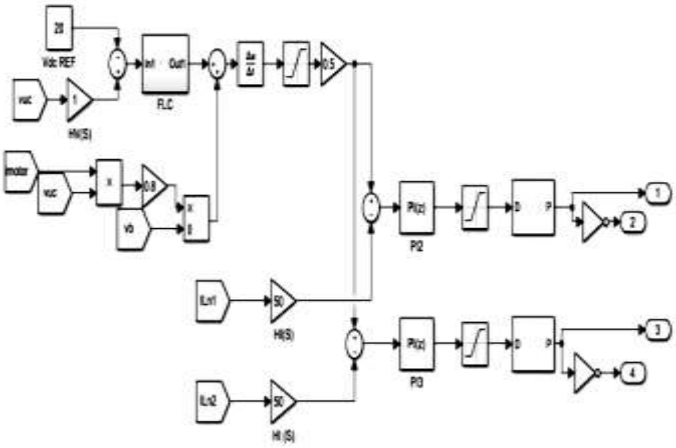

Fig 3:FLC based controller for HESS

In the Proposed model of buck converter, output voltage Vout(t) is expressed as a function of input voltage Vin(t), output currentiout(t) and duty cycle d(t). In case of boost converter with controlled current, input current iin(t) is expressed as a function of input voltage Vin(t),output voltage Vout(t) and duty cycle d(t). Fig. 4 shows the closed-loop control system for current regulation of the individual inductors [12]

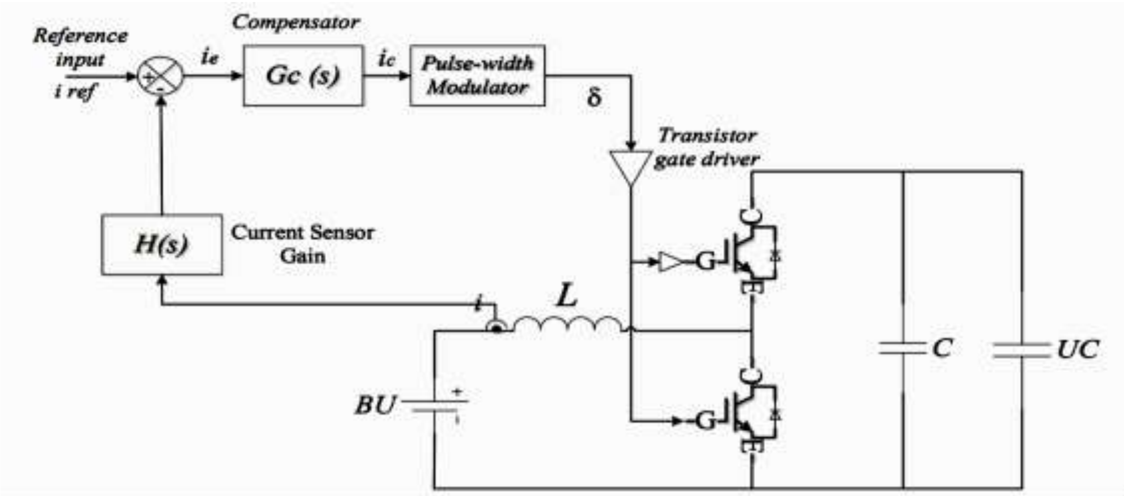

Fig 4:Schematic diagram of Individual Inductor's Current Regulation

Power Calculation Of The Vehicle

For a vehicle at any time-step Deceleration or Acceleration can be found from the difference between the speed of vehicles at 2 successive time-steps. The power demand of a vehicle can be calculated from speed,acceleration,deceleration and additional parameters of a test vehicle such as aero dynamic drag,mass,gearratio, rolling resistance and transmission efficiency.The power profile for the vehicle for each drive-cycle should consider road grades aswell The required power for a vehicle can be derived as follows:

$$Power = Torque * \omega \quad (1)$$

$$Torque = Force_{eq} * r \quad (2)$$

$$Force_{eq} = F_{ad} + F_{ac} + F_{rr} + F_g \quad (3)$$

$$F_{ad} = \frac{1}{2} * \rho v^2 C_{ad} A \quad (4)$$

$$F_{ac} = ma \quad (5)$$

$$F_{rr} = C_r mg cos\theta \quad (6)$$

$$F_g = mg * sin\theta \quad (7)$$

$$\omega = \frac{v}{r} = \frac{n}{C_{gr}60} * 2\pi \quad (8)$$

Equation (1) is the power demand(W) tothe wheel's torque (Nm) and angular speed ω(rad/s). Equation (2) relates the wheel's torque and equivalentForceeq and wheel's radius(m). Equation (3) is the equivalent force,Forceeqas the summation of forces due to acceleration, rolling resistance, aerodynamic drag and gravity, described byequations (4)to(7), respectively. In (4), Cad is the co-efficient of drag determined by body shape of the vehicle A(m2) the frontal area,ρ the density of air and , Vvehicle velocity. In equations (5)to(7)m(kg) is the vehicle mass and the angle between the the horizontal plane and road surface.Equatin (8) determines angular speedof the wheel from vehicle velocity,Vand tire radius r,as well as from motor speed n(rpm) and gear ratio Cgr .

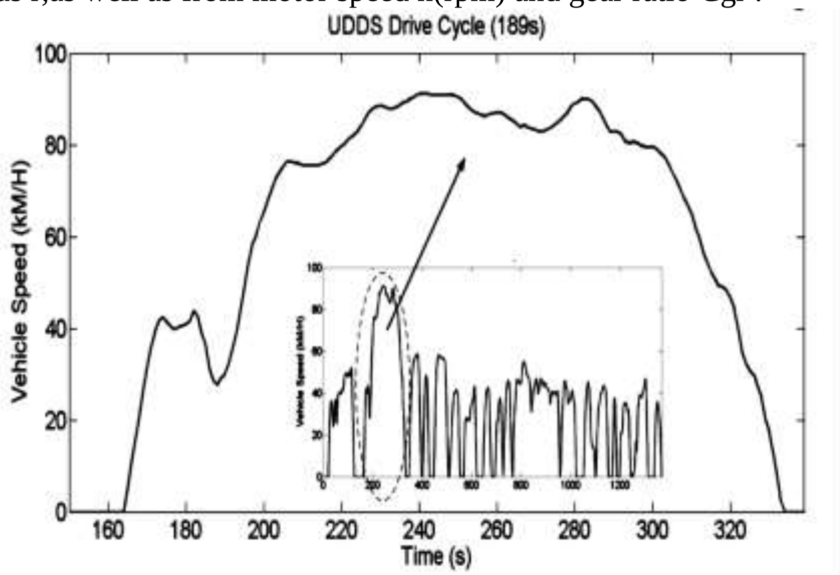

Fig:5 UDDS drive cycle and zoomed-in view of the 189 seconds of UDDS drive cycle used in the study

1.1 Table of Specifications

Mass	2108kg
OverallLength	4976mm
Width	1963mm-2187mm
Height	1435mm
WheelDiameter(EagleRS-A2245/45R19)	703.58mm
AerodynamicDragCoefficient	0.24
EstimatedRang@88km/h	480km
EnergyStorage	85kWh
PeakMotorPower	310kW@ 5000-8600rpm
MaxTorque	600Nm@0-5100rpm
0-100km/hAcceleration	4.4s
TopSpeed	210km/h
Gear Ratio	9.73:1

NO. ofBatteryCells	~8,000
BatteryCell	PanasonicNCR18650B
NominalVoltage	3.6V
Capacity	3350mAh (typical)
ChargingCurrent	Std.1625mA(0.5C)
MaxDischarging Current	6700mAh(2C)
GravimetricEnergyDensity	243Wh/kg
VolumetricEnergyDensity	676Wh/L

The assumption is that TeslaSedan is running on the UDDS drive cycle, The Vehicle's parameters will be substituted in the corresponding power curve of the vehicle.Fig 6 shows the corresponding results

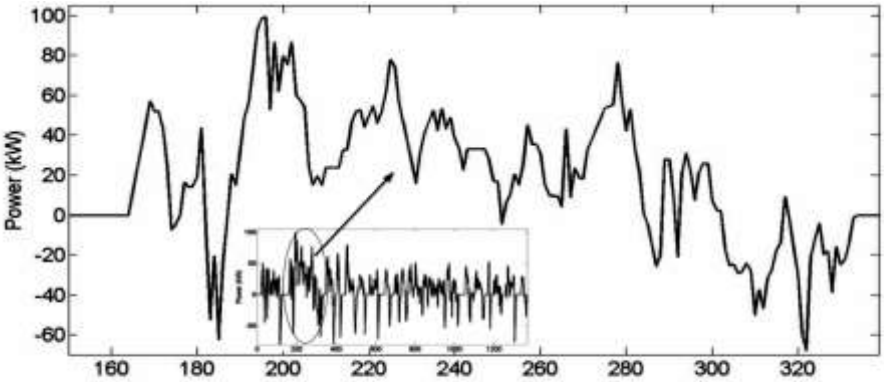

Fig6: Powerprofile of Teslamodel S on the UDDS drivecycle and the zoomed-inview of the power during the 189seconds

Fig. 7 shows the control signals to drive the switches, with 180 degrees phase-shift between the switch controlsignals of the 2 inter-leaved modules. Fig. 8 describes the cancelation of the current ripple in interleaved dc to dc converter. The bluecoloured waveformrepresents discharging currentof the battery, and the pinkcoloured waveform is the inductorcurrentof one of the two modules. The one inductor current is calculated by taking half of the local average battery current (average per switching period)implying that power from Battery Unit isequally shared by the two bi-directional buck-boost converters. Battery is protected from high-frequency current ripple because of the interleaved structure, asshown by the blue waveform.

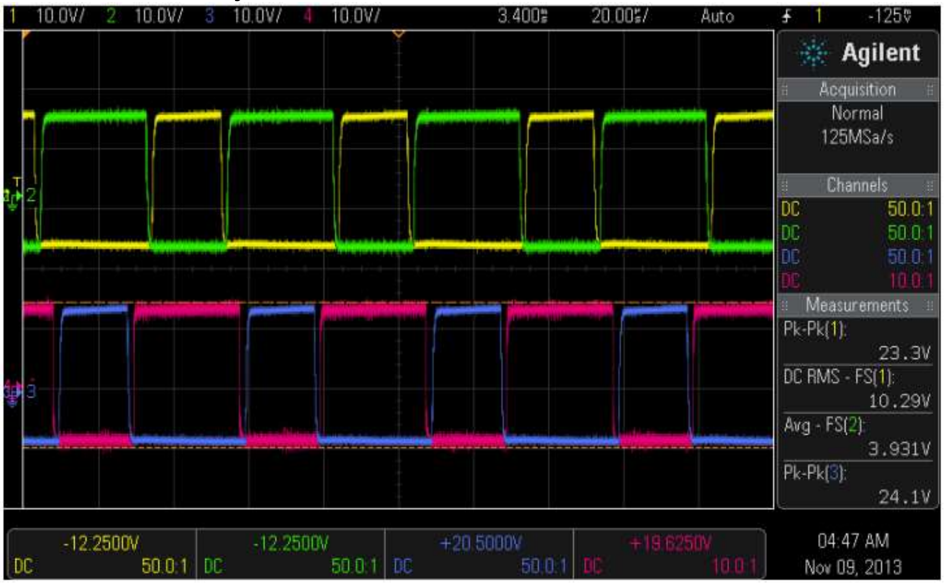

Fig:7 Boost switch PWM signal in module-1 (Yellow), Buck switch PWM Signal in module-1 (Green), Boost switch PWM signal in module-2 (Blue), Buck switch PWM signal in module-2 (Pink).

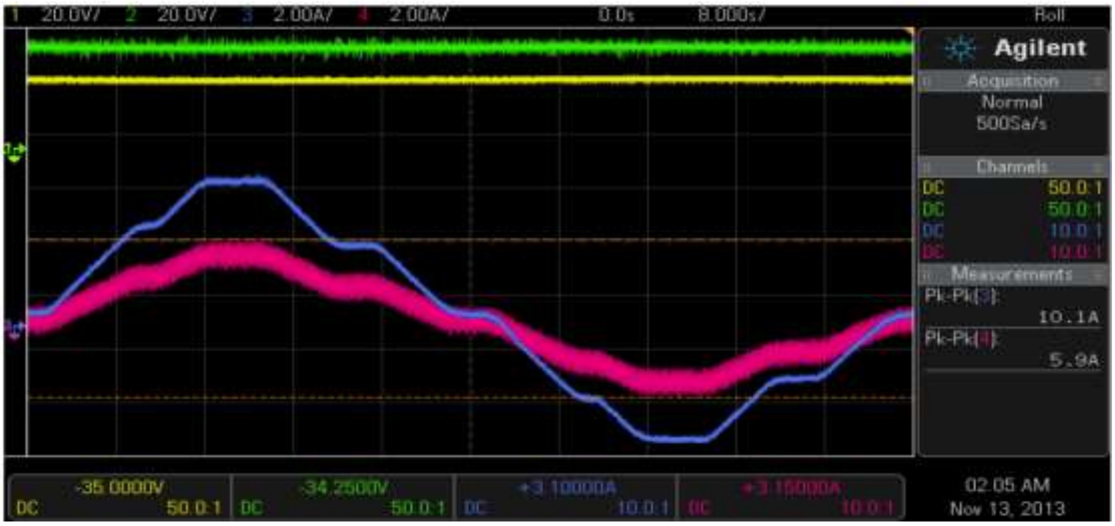

Fig:8 Results of Battery discharging current from proposed model (blue), inductor current from proposed model(pink), battery terminal voltage from proposed model (yellow), ultra-capcitor terminal votlage (green)

Simulation Results Of Proposed Method

189 seconds of UDDS drivecycle is shown in Fig.5. Fig. 6 showed The corresponding powerprofile for the TeslaModel S.

.The power using a scalingfactor of 1/100 By down scaling, Anew sequence of data corresponding to power is generated. Fig9 and fig 10 showed the experimental and simulation results which represents battery unit discharge current(in blue), Ultra Capacitor discharge current(in pink),Battery unit voltage(in yellow),DC bus voltage(in green)

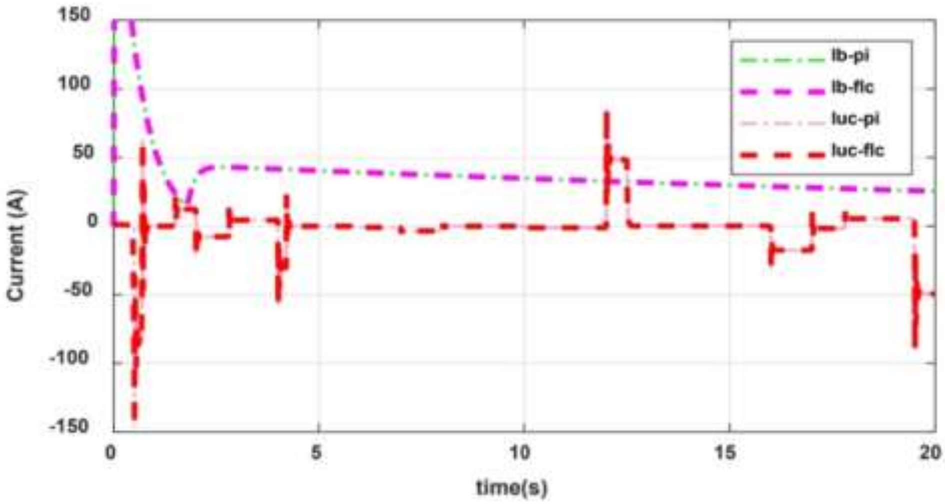

Fig:9 Battery unit Discharging Current(PINK), Ultra capacitor discharging Current(RED)

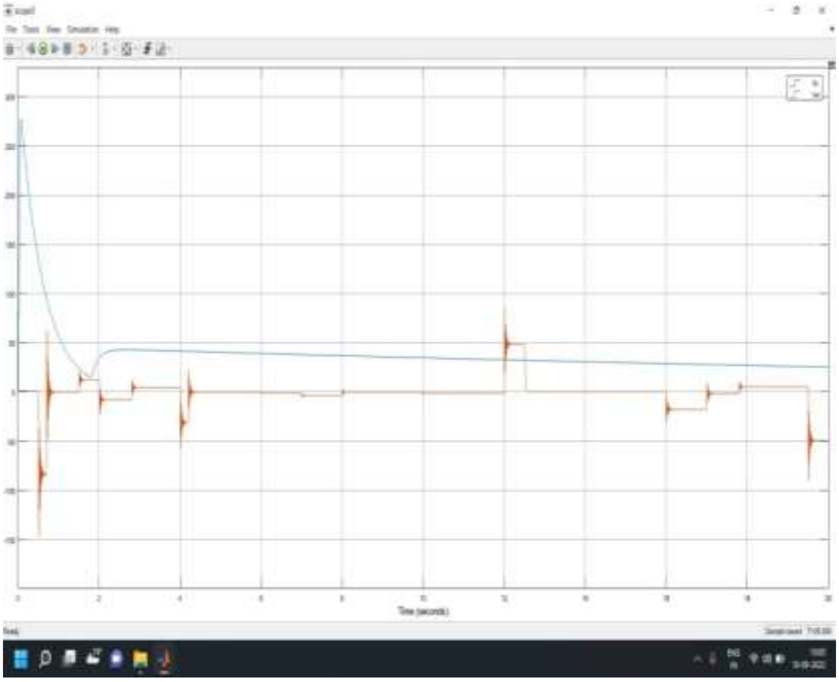

Fig:10 Results for the selected drive cycle:Battery unit discharging current(Blue),Ultra capacitor discharging current(Red).

The flat segments markedas 1,in Fig.10 which shows that the higher limit of discharging current of battery. The battery current shouldn't exceed it's higher limit irrespective of load required power.The remaining requirement of power can be supplied by the ultra capacitor unit.The rate of rise of discharge current of battery is also limited as shown in the figure which is marked as 2,Inorder to prevent batteryfrom supply fast charging power, similar to the change of power in power demand.When rateof changeof power demand exceeds battery dp/dt limit, then ultracapacitor responds to satisfy the fastcharging power requirement.

Conclusion

The performance of a two-module, interleaved bidirectional buck-boost converter positioned behind a battery unit and an ultra-capacitor unit connected directly across the DC bus in a hybrid energy storage system (HESS) for EV and HEV applications was built and tested using simulation.Due to its comparatively low cost, small size, and good performance, the chosen HESS topology stood out among all other conceivable HESS topologies. The power demand was divided between the battery and ultra-capacitor units by implementing a power management algorithm that took the operational restrictions of the battery unit into account. Using the MATLAB/SIMULINK software, the effectiveness of the fuzzy logic controller-based technique was examined.

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