e-ISSN:2582-7219

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

Volume 6, Issue 12, December 2023

INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.54

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.54| Monthly Peer Reviewed & Referred Journal |

| Volume 6, Issue 12, December 2023 |

| DOI:10.15680/IJMRSET.2023.0612031 |

Design and Analysis of Hybrid Energy Storage System for Electric Vehicle Applications

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ABSTRACT: Global warming and lack of fossil fuels are the main drawbacks of vehicles powered by oil or diesel. Electric vehicles (EVs) have also been studied. EVs rely on energy stored in energy storage system (ESS). Limited driving range and long battery charging time are their main drawbacks. This research presents the design and performance analysis of Hybrid energy storage system for electric vehicle applications. The simulation is performed using MATLAB Simulink 9.4 software. Simulated results show that the proposed model gives significant better results.

KEYWORDS: EV, Ultracapacitors/Supercapacitors, Battery Charger, Power, Capacity, ESS, Current, Voltage.

I. INTRODUCTION

Energy Storage Systems are the set of methods and technologies used to store energy. The stored energy can be drawn upon at a later time to perform useful operation. For instance, many renewable energy sources (such as wind, solar energy or solar energy, tides) are intermittent. Sometimes the use of renewable energy is not direct when the energy is available, but at other times. Then we need energy storage so that energy can be used when needed. Energy is available in various forms including radiation, chemical, gravitational potential, electrical potential, electricity, elevated temperature, latent heat and kinetic. The main advantages of hybridizing are enhancing fuel economy, providing a more flexible operating strategy, overcoming fuel cell cold-start and transient problems and reducing the cost per unit power. In the literature, few numbers of researches have been reported on EVs' and HEVs' electronic interfaces. The converter for electric vehicle has high efficiency due to achieving turn-on zero voltage switching (ZVS) of all switches. However, it lacks a bidirectional port. Hence, in applications in need of ESS, it can't be used. A compact two input converter for electric vehicle is present for standalone PV systems. Moreover, high voltage gain of the converter for electric vehicle makes the converter for electric vehicle suitable for low input voltage applications. However, the high number of semiconductors and passive elements reduce the efficiency. Control method preset in the vehicle's controller should control the power flow between renewable resources, battery unit and electrical motor.

Figure 1: PV based charger

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Figure 1 is presenting the PV based energy storage system for the charging the electric vehicle. Optimal utilization of power resources, providing demand power permanently, operating fuel cell and PV panel in their optimum region are the main duties of control scheme. Some converter for electric vehicles has been proposed recently for PVs systems. But, the required converter for electric vehicle for HEV applications should extract power from PV and FC. Besides, in order to supply Back-up power from the battery, a bidirectional port is needed to charge and discharge the battery according to discrepancy between generated power and demanded energy. A multi input converter for electric vehicle (MIC) can provide power to the load from different energy sources simultaneously or individually. Due to the fact that initial cost of PVs is high and in order to increase the extracted power from the PV panels, MPPT algorithm has to be utilized.

II. LITERATURE REVIEW

T. Mesbahi et al., presents PSO-NM optimization algorithm facilitated the identification of the parameters of the developed model with high efficiency, as the error observed is less than 3%. The advanced model associated with an adapted sizing method can be used in many cases to compare energy management strategies in electric vehicle applications [1]. M. A. Islam et al., provides adaptive neuro-fuzzy inference system (ANFIS) control strategy based bidirectional power management scheme to ensure the optimal electrical power flow exchange between the AC electrical grid and battery storage system in PEVs. This aims to reduce the stress on the grid power side and utilize the unused power properly [2].

S. Chai et al., proposes a detailed framework to evaluate end-of-life (EOL) EV/PHEV batteries in BESS application. The framework consists of three parts. A generalized model for battery degradation is first introduced. It is followed by modeling the battery retirement process in its first life. Two vehicle types—EV and PHEV—as well as two retirement modes—nominal and realistic modes—are considered. Finally, the application of the second-life BESS in power systems is modeled in a detailed economic dispatch (ED) problem [3]. X. Zan et al., improve the endurance of battery packs, a PV panel is also added to the topology to charge battery packs when the system is stationary. According to the different operation requirements, multiple power supply modes and charging modes can be realized by controlling the power devices in the proposed MBM topology [4].

A. Avila et al., present experimental results obtained with a high specific energy and power capability HESS prototype, composed of i) a Lithium-Titanate-Oxide battery to ensure high power capabilities, ii) a Li-S battery to improve specific energy, and iii) a power converter based on Gallium Nitride (GaN) devices to link both battery modules, minimizing at the same time system weight, volume and power losses [5]. T. Sadeq et al., presents optimal adaptive controller and fuzzy adaptive controller. The HESS model, electric vehicle and controllers were tested using MATLAB/Simulink with three real drive cycles, namely, uphill, downhill and city tour, in three different speeds 50Km/h, 60Km/h and 70 Km/h. The results proved the controllers managed to extend battery life-cycle by reducing the stress on the battery for the drive cycles [6].

Y. Fan et al., the typical high-frequency converter structure as the object, establish an equivalent model of the circuit, and quantitatively analyze the loop inductance from a mathematical point of view. For the circuit after the parallel of absorption capacitor, the small signal model is used to analyze and reveal the role and influence of the absorption capacitor [7]. D. Qin et al., proposed adaptive bidirectional droop control is designed for freedom EVs to make them autonomously charge or discharge with certain power which according to each EV's state of charge, battery capacity, leaving time, and other factors to maintain the stability of the future microgrid. Eventually, the simulation and experiment of the adaptive bidirectional droop control based V2G-PVBP is provided to prove the availability of V2G-PVBP [8].

C. Zhai et al., presents battery/supercapacitor HESSs model. First, the pattern sequence-based velocity predictor is presented to accurately predict the future short-term velocity profile. Second, the PEMS is proposed by formulating an HESS power split optimization problem, where the HESS energy loss, and the battery capacity loss are considered. Third, an improved chaotic particle swarm optimization algorithm is presented to solve the formulated optimization problem. Simulation results demonstrate that, compared with the benchmark, the proposed PEMS can effectively reduce the HESS energy loss, and extend the battery lifetime at the same time [9]. M. Ban et al., provides optimal sizing of photovoltaic (PV) generation and battery-based energy storage system (BESS) in such a nanogrid. The problem is formulated based on the mixed-integer linear programming (MILP) and then solved by a robust optimization approach [10].

X. Hou et al., provides a holistic model to center the preference of users when scheduling the involved physical equipment of different natures. Further, a dedicatedly designed charging and discharging strategy for both the ESS and EV considering their capital cost is proposed to integrate them into the HEMS for providing a better flexibility and economic advantages as well as to prolong the life of the batteries [11]. B. Wang et al., presents a deadbeat-based method for the hybrid energy storage system (HESS) in solar-assisted electric vehicles (EVs), using a new bidirectional three-level cascaded (BTLC)

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converter. Moreover, photovoltaic (PV) panels are also considered in the system, generation and the load power consumption for the solar-assisted EVs. The BTLC converter is superior to the conventional parallel-connected bidirectional battery/supercapacitor converters from the perspectives of related component size reduction and control flexibility [12].
H. Moradisizkoohi et al., presents converter can supply the load in the absence of FC or battery. The converter takes advantage of active clamp configuration in terms of reducing the voltage stress across switches and providing soft-switching performance. Consequently, the converter's overall performance in terms of switching losses and cost can be considerably improved. The switching scheme doubles the effective switching frequency, which, in turn, reduces the size of the boost inductors to enhance power density [13]. Q. Xu et al., proposed in which the rule-based control strategy is used for braking mode switching and neural network algorithm is used for the optimal efficiency control for the system. The simulation of the control strategy is carried out under New European Driving Cycle (NEDC) based on the joint platform of CRUISE and MATLAB software [14].

III. PROPOSED MODEL AND METHODOLOGY

The proposed model and methodology description is as following-

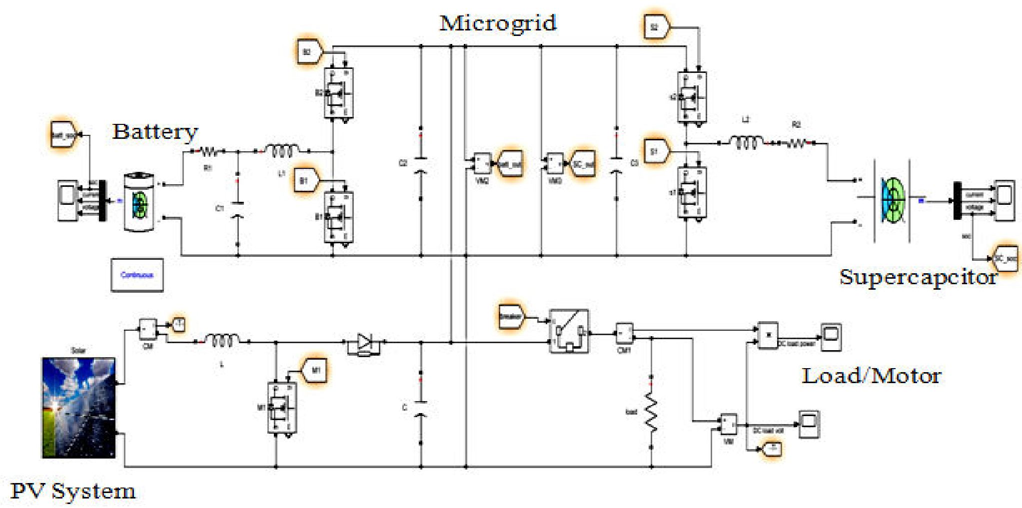

Figure 2: Proposed Model

Figure 2 is showing present HESS EV model. This model consist various sub models which is described in details.

Sub-Modules

- Solar power
- MPPT Algorithm
- Boost converter
- Battery
- Super capacitor

Solar Power: Photovoltaic solar panels absorb sunlight as a source of energy to generate electricity. A photovoltaic (PV) module is a packaged; connect assembly have 96 solar cell. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Photovoltaic (PV) array which is composed of modules is considered as the fundamental power conversion unit of a PV generator system.

MPPT Algorithm: The Maximum power point tracking is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. Maximum power point tracking

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(MPPT) is an algorithm implemented in photovoltaic (PV) inverters to continuously adjust the impedance seen by the solar array to keep the PV system operating at, or close to, the peak power point of the PV panel under varying conditions, like changing solar irradiance, temperature, and load. MPPT algorithms are typically used in the controller designs for PV systems.

DC-DC Bidirectional Capacitor: Bidirectional dc to dc converter is used as a key device for interfacing the storage devices between source and load in renewable energy system for continuous flow of power. In electric vehicles also, bidirectional converter is used between energy source and motor for power supply from battery to motor. Bidirectional dc to dc converters work in both buck and boost mode and can manage the flow of power in both the direction between two dc sources and load by using specific switching scheme and phase shifted control strategy and hence generated excess energy can be stored in batteries/super capacitors.

Battery: A battery is a gadget consisting of at least one electrochemical cells with outer connections gave to power electrical gadgets, for example, spotlights, cell phones, and electric vehicles. At the point when a battery is providing electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal checked negative is the wellspring of electrons that will course through an outside electric circuit to the positive terminal. At the point when a battery is connected to an outside electric load, reaction converts high-energy reactants to bring down energy items, and the free-energy distinction is conveyed to the outer circuit as electrical energy. Verifiably the expression "battery" explicitly alluded to a gadget made out of different cells, anyway the utilization has advanced to incorporate gadgets made out of a solitary cell.

Super Capacitor: A supercapacitor (or ultracapacitor) contrasts from a common capacitor in two significant manners: its plates successfully have an a lot greater territory and the separation between them is a lot littler, in light of the fact that the separator between them works in an alternate manner to a conventional dielectric. In spite of the fact that the words "supercapacitor" and "ultracapacitor" are frequently utilized conversely, there is a distinction: they are normally worked from various materials and organized in somewhat various manners, so they store various measures of energy.

IV. SIMULATION RESULTS

The design and analysis of the proposed model is performed using MATLAB software with version 9.4.

Battery Discharging Mode- When the battery is fully charge then it supplies the power to the load or motor, so battery is in the discharging mode.

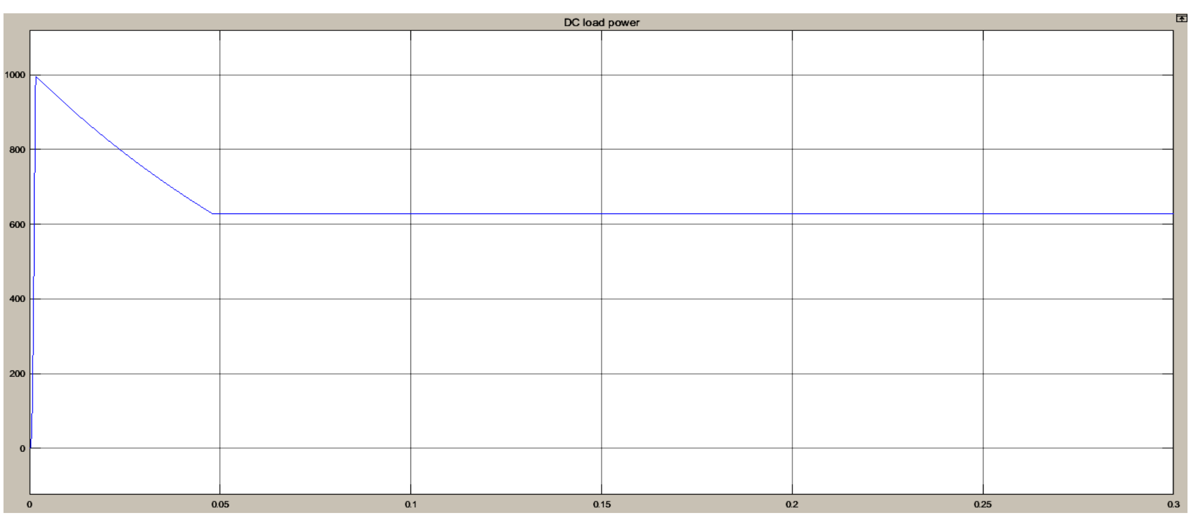

Figure 3: DC Load Power

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Figure 3 is presenting the DC load power graph. The value of the DC load power is 630W.

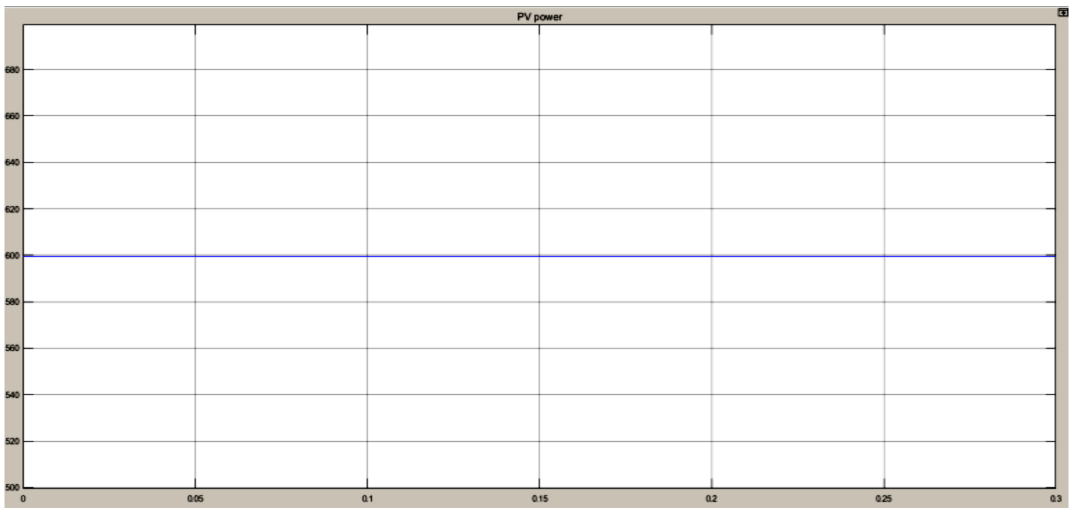

Figure 4: Solar Power

Figure 4 is presenting the solar power graph. The collected solar power value is 600W.

Load Shedding Mode (LSM)- When the battery is fully discharge then the load is disconnected and battery is stop giving the power to the load.

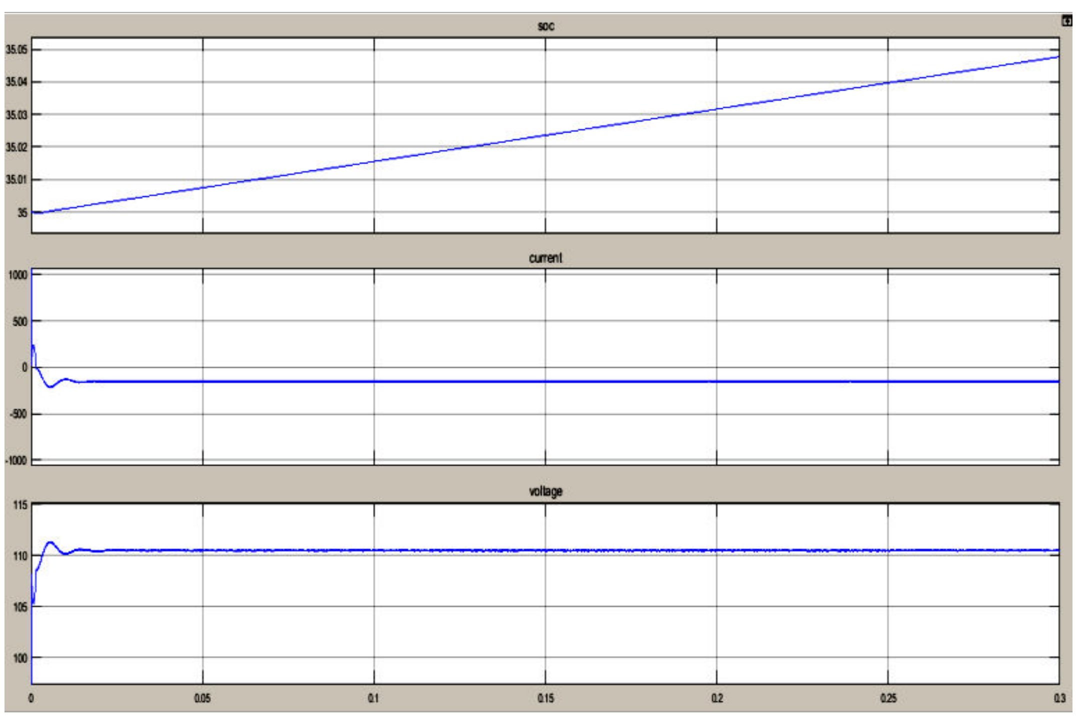

Figure 5: Battery Performance

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Figure 5 is presenting the performance of the battery in terms of the state of charge, voltage and current. At the load shedding mode the state of charge of the battery is approx 30%.

Battery Charging Mode- As the battery is fully discharged, and then the solar power is start to charge the battery. Now battery charges up to the more than 80%

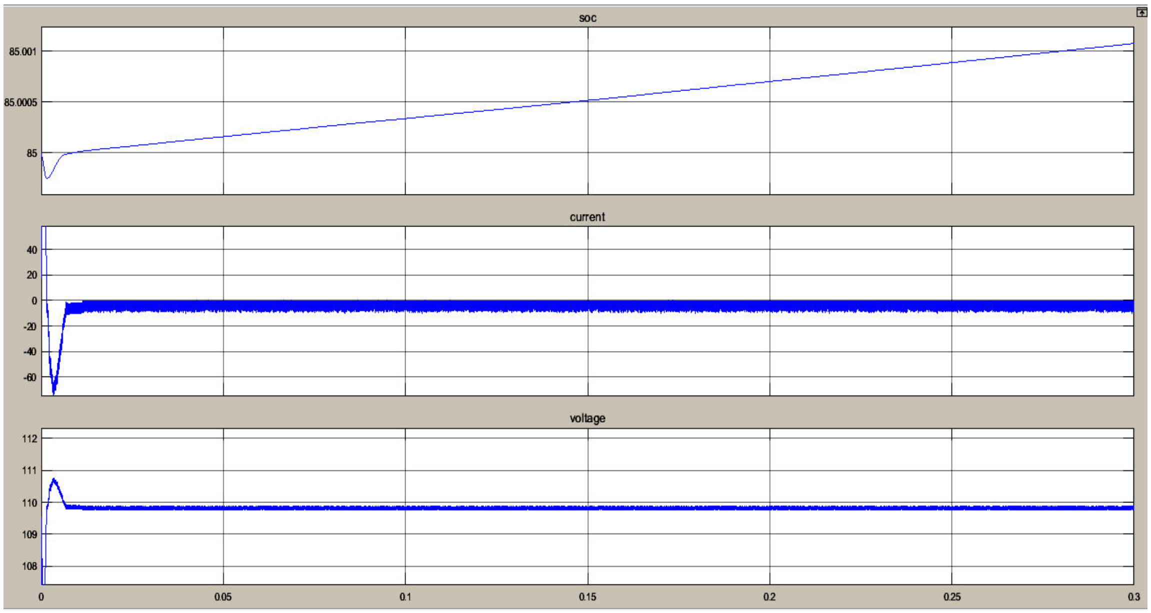

Figure 6: Battery performance

Figure 6 is presenting the battery performance during the charging state. The battery is charging and as completed charge, its start to give power to the load or motor.

Off-MPPT Mode- When the battery is fully charges then the MPPT is off. MPPT is used to track maximum power in the less time. After completion it off and when battery is discharge then it again present in the ON state.

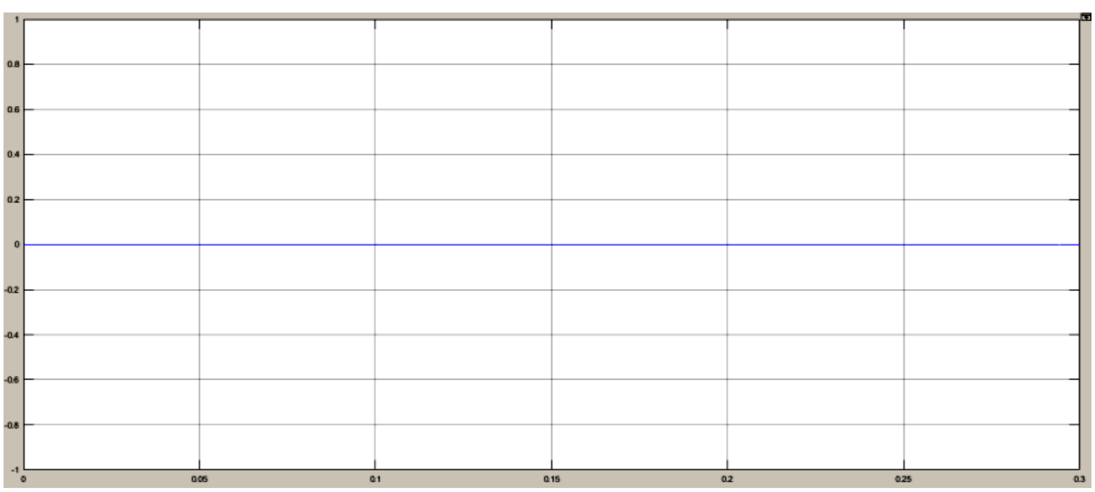

Figure 7: MPPT output

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Figure 7 is presenting the MPPT output, at the mode of off MPPT; it shows at the 0 state.

Table 1: Result Comparison

Sr No.	Parameters	Previous Work	Proposed Work
1	State of Charge (SOC)	80%	95%
2	Lithium-ion battery voltage	4V	12 V
3	Temperature (^{0}C)	43	35
4	Battery Current	60A	100A
5	Renewable Source	NA	Solar
6	Control technique	Particle Swarm–Nelder–Mead	MPPT

Table 1 is presenting the result comparison of the previous and the proposed model simulation results. The overall state of the charge of the battery and the super capacitor is approx 95%, while previous it is 80%. The battery current achieved is 100A while previous it is 60A. Proposed model using the solar system to collect the power while in the previous work, it's not mention. The proposed model used MPPT control technique; which is less complex than the previous model control technique. Therefore proposed model is better than the previous model based on the simulation results.

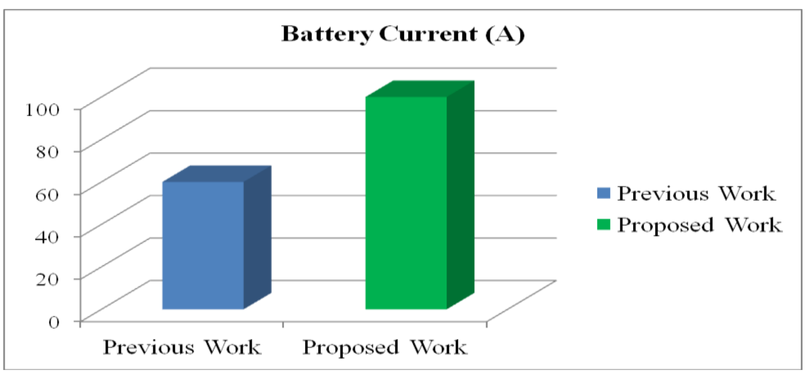

Figure 8: Result comparison

V. CONCLUSION

This research presents a design and analysis of hybrid energy storage system for electric vehicle applications. This EV storage system is made up of two complementing sources: chemical batteries and ultracapacitors/supercapacitors. The benefit of using ultracapacitors in a hybrid energy storage system (HESS) is to extend the extra storage. Simulation is done using MATLAB/SIMULINK software. Simulated results show significant improvement in present model performance than existing model performance.

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