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Review of Energy Storage System with Battery and Supercapacitor for Electric Vehicle Applications

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Abstract : Now a day's the demand for Electric vehicle is growing day by day. There are some limitations of conventional vehicles like fuel cost and availability, environmental pollution, high maintenances etc. A renewable energy source is an alternative source of the energy. This source can also provide huge amount of energy. After the generation of the energy, it is also necessary to store this energy. There are some storage systems like battery, supercapacitor etc to store and manage the energy. This paper reviews the energy storage system with battery and supercapacitor for electric vehicle applications.

***IndexTerms* – Energy Management, Converter, Electric Vehicle, Supercapacitor, Battery, Hybrid. Solar.**

I. INTRODUCTION

One of the main technological stumbling blocks in the field of environmentally friendly vehicles is related to the energy storage system. It is in this regard that car manufacturers are mobilizing to improve battery technologies and to accurately predict their behaviour. A bi-directional power exchange between the plug-in electric vehicle (PEV) and the AC electrical grid is necessary to perform the Vehicle to Grid (V2G) and Grid to Vehicle (G2V) operations. While performing these operations, different power converters and controllers play an important role as mediators between the PEV and electric grid. Various works have demonstrated the utilization of controllers for PEV's battery power management. However, the existing conventional controllers have technical shortcomings in vulnerability to controller gain, accurate mathematical modelling, poor adaptability, sluggish response to a sudden outburst and lengthy interval execution processing [2].

Energy storage is essential for balancing the generation and load in power systems. Building a battery energy storage system (BESS) with retired battery packs from electric vehicles (EVs) or plug-in hybrid electric vehicles (PHEVs) is one possible way to subsidize the price of EV/PHEV batteries, and at the same time mitigate forecast error introduced by load and renewable energy sources in power systems [3]. Lithium-ion (Li-ion) batteries are still the best technology to power the Electric Vehicle (EV), due to their high power and energy density. However, the use of these batteries can be limited in cars with a high demand for peak power and very high energy density. One way to improve the performance of the Li-ion battery and reduce its weight is to associate this battery with another technology of higher specific energy as a second energy source, e.g. Lithium-sulfur (Li-S). The development of Hybrid Energy Storage Systems (HESSs) is a promising solution for optimizing the energy management of Evs [5].

This research designed an energy management system involving a battery-supercapacitor Hybrid Energy Storage System (HESS) for electric vehicles (EV). The objective is to improve the performance of the HESS by combining battery and supercapacitor features, accounting for topographical information to guarantee continuous hybridization during the drive cycle. Contour Positioning System (CPS) was used to determine the slope of the road travelled by the vehicle. Two adaptive algorithms were designed for a rule-based controller to control the energy shared between the battery and the supercapacitor; an optimal adaptive controller and a fuzzy adaptive controller [6].

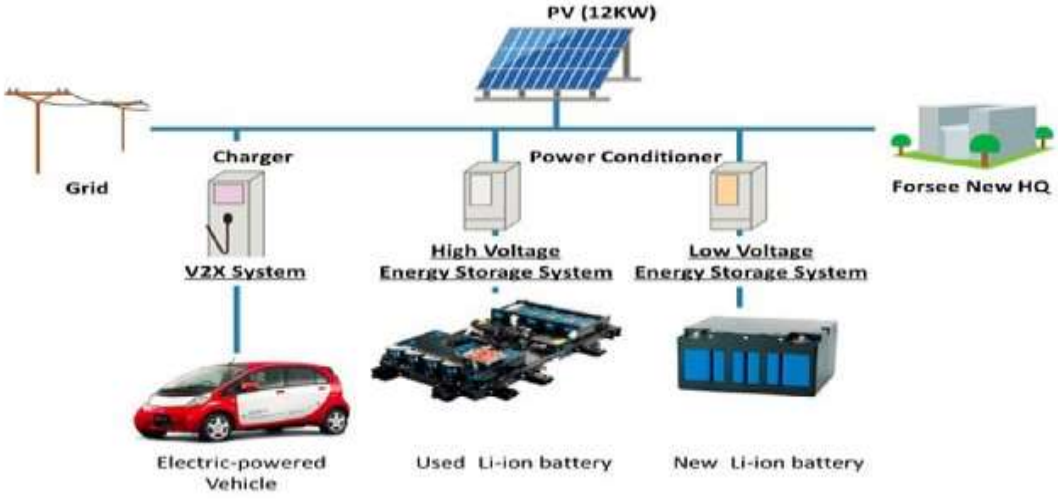

Figure 1: HESS of Electric Vehicle

When the silicon carbide (SiC) power module is applied to the energy storage converter of a hybrid locomotive, under the action of di/dt and loop stray inductance, it is easy to produce excessively high voltage overshoot, which affects the battery life and stimulates high-frequency oscillations, causing power devices to withstand greater electrical stress. In order to optimize the system layout and improve system performance, it is extremely necessary to accurately extract and evaluate the loop inductance [7]. With the popularity of electric vehicles (EVs), a large number of EVs will become a burden to the future grid with arbitrary charging management. It is of vital significance to the control of the EVs charging and discharging state appropriately to enable the EVs to become friendly to the grid. Therefore, considering the potential for EVs seen as energy storage devices, this paper proposes a multiport DC-DC solid state transformer topology for bidirectional photovoltaic/battery-assisted EV parking lot with vehicle-to-grid service (V2G-PVBP). Relying on the energy storage function of EVs, V2G-PVBP cannot only satisfy the normal requirements of EVs' owner but also provide the function of load shifting and load regulation to the microgrid. In this paper, EVs are categorized into limited EV and freedom EV. Limited EVs are always kept in a charging state and freedom EVs can take part in the load regulation of the microgrid [8]. Electric vehicles (EVs) are considered to relieve energy crisis, and environmental problems due to their high efficiency, and low emissions, and energy management strategies (EMSs) have been extensively studied to improve the performance of hybrid energy storage systems (HESSs) for Evs [9].

II. LITERATURE SURVEY

T. Mesbahi et al.,[1] presents the advanced electro thermal modeling of a hybrid energy storage system integrating lithium-ion batteries and supercapacitors. The objective is to allow the ageing aspects of the components of this system to be taken into account. The development of a model including the electro thermal behaviors makes it possible to evaluate the progressive degradation of the performance of the hybrid energy storage system. The characterization of both components constituting the hybrid system is carried out via a hybrid particle swarm-Nelder-Mead (PSO-NM) optimization algorithm using the experimental data of an urban electric vehicle. The obtained results show the good performance of the developed model and confirm the feasibility of our approach.

M. A. Islam et al.,[2] develops an 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 paper aims to reduce the stress on the grid power side and utilize the unused power properly. The performance of the ANFIS model is varied using two PEVs based on real-life power consumption by different loads at home based on five operational modes. Besides, a comparative analysis between the ANFIS controller and the PI controller is carried out to demonstrate the effectiveness of the proposed control by the PEV battery.

S. Chai et al.,[3] 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 vehicles 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. This is how second-life BESS's performance translates into cost savings on power generation. An optimization problem is formulated to maximize total cost savings in power generation over the battery's second life. This is done by striking a balance between short-term benefit (daily cost savings) and long-term benefit (cost savings through service years). Numerical results validate the effectiveness of the proposed framework/models. They show that battery usage and retirement criterion in its first life directly affect the performance in its second life application.

X. Zan et al.,[4] To improve the endurance and charging flexibility of electric vehicle battery packs, this paper proposes a multi-battery block module (MBM) topology for four-phase switched reluctance motors (SRMs), which not only allows flexible electric vehicle operation but also achieves fast demagnetization and excitation. By integrating the multi-battery block module and photovoltaic (PV) panel into an asymmetrical half-bridge (AHB) converter, the MBM topology is designed to supply a multilevel bus voltage for the SRM drive. To 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. The simulation results based on

the MATLAB/Simulink platform and the experimental results on a four-phase 8 / 6 switched reluctance motor verify the effectiveness of the proposed design.

A. Avila et al.,[5] present experimental results obtained with 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. The developed GaN-based power converter achieves high efficiency (96.5%) operating at 300 kHz with reduced size (0.4 L). Besides, the behavior of the developed HESS prototype is experimentally evaluated under standard automotive profiles, for different driving scenarios.

T. Sadeq et al.,[6] The HESS model, electric vehicle and controllers were tested using MATLAB/Simulink with three real drive cycles, namely, uphill, downhill and city tour, at three different speeds 50Km/h, 60Km/h and 70 Km/h. The results proved the controllers managed to extend the battery life cycle by reducing the stress on the battery for the drive cycles. The results were compared in terms of energy consumption for the optimal adaptive rule-based controller and fuzzy adaptive rule-based controller. The optimal adaptive rule-based controller guaranteed the HESS was able to operate continuously and extend the number of drive cycles in a wide range of speeds and road slopes.

Y. Fan et al.,[7] presents the typical high-frequency converter structure as the object, establishe 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. Finally, the calculation results of the model are compared through a double-pulse experiment. The results show that the error between the model and the experimental results is about 1%, and the effect of evaluating the stray parameters of the converter circuit is good, and it can provide theoretical support for the selection and design of the absorption capacitor.

D. Qin et al.,[8] The proposed adaptive bidirectional droop control is designed for freedom EVs to make them autonomously charge or discharge with certain power 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.

C. Zhai et al.,[9] proposes a predictive EMS (PEMS) for the battery/supercapacitor HESSs. 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 a 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 life at the same time.

M. Ban et al.,[10] Nanogrids are expected to play a significant role in managing the ever-increasing distributed renewable energy sources. If an off-grid nanogrid can supply fully-charged batteries to a battery swapping station (BSS) serving regional electric vehicles (EVs), it will help establish a structure for implementing renewable-energy-to-vehicle systems. A capacity planning problem is formulated to determine the optimal sizing of photovoltaic (PV) generation and battery-based energy storage system (BESS) in such a nanogrid. The problem is formulated based on mixed-integer linear programming (MILP) and then solved by a robust optimization approach. Flexible uncertainty sets are employed to adjust the conservativeness of the robust optimization, and Monte Carlo simulations are carried out to compare the performance of the solutions. Case studies demonstrate the merits of the proposed applications and verify our approach.

X. Hou et al.,[11] 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 better flexibility and economic advantages as well as to prolong the life of the batteries. Based on the mixed integer linear programming (MILP) and the proposed model, the energy schedule of the smart home can be derived to guarantee both the lowest cost and the comfort for the users. An illustrative case study is employed to demonstrate the effectiveness of the proposed method.

B. Wang et al.,[12] 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) converter. Moreover, photovoltaic (PV) panels are also considered in the system, because the proposed method is designed for solar-assisted EV applications to achieve a longer driving range. The proposed BTLC converter can integrate the battery and the supercapacitor as a HESS to effectively mitigate the power mismatch between the PV power 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.

III. CHALLENGES

- EV cost- The cost is the most concerning point for an individual when it comes to buying an electric vehicle. However, there are many incentives given off by central and state governments. But the common condition in all policies is that the incentives are only applicable for up to a certain number of vehicles only and after removing the discount and incentives the same EV which was looking lucrative to buy suddenly becomes unaffordable. This tells that buying EV’s no more be cheaper after a certain saturation point.

- Battery Cost- It's no more hidden from anyone that the Li-ion battery in electric vehicles is built to last till 6-7 years or hardly 8 years and after the battery decay period of an electric vehicle battery its user remains with no other choice than to buy a newer battery which costs nearly 3/4 th of the whole vehicle cost. Battery cost is going to be a pressing issue for the EV buyers because electric vehicles are new to both market and customers the battery issue requires at least 5 years to surface this will going to be impacted in a long run.

- Beta version of vehicles- Right now, both the technology and companies are new to the market and the products they are manufacturing are possibly facing real customers for the first time. And it's nearly impossible to make such a complex product as an automobile perfect for the customers in the first go, and as expected the buyers faced many issues. Vehicles like RV400, EPluto 7G and Nexon all them has to update their vehicle up to a very high extent after customer feedback and reviews. Recently Pure EV has made a lot of changes in their policies, software, hardware, and not even Tata motors has to upgrade their BMS and regen software after a lot of complaints from the customers regarding extremely low range. So, buying the vehicle from the first batch of the company's production would be a bad idea and can even give you an extremely bad experience.

- Poor Infrastructure and range anxiety- Poor infrastructure is among the most pressing issue among people thinking to opt for electric vehicles. Poor infra doesn't only include a lack of charging stations but also the lack of proper charging set up in their home. Charging a heavier electric car could be a major problem for any electric car owner if he/she lacks proper setup (Powerful MCB, wire, and earthing) near their place.

- No Universal charger and Ecosystem (Lack of standardization)- Every second electric vehicle-making company has its own different charging port which is becoming a hurdle to setting up a proper charging ecosystem. Also, many EV users complained about facing moral trouble for charging their vehicles in different EV-making Companies' charging stations which can impact the growth of the EV industry. Lack of standardization is a curse to the Indian electric vehicle industry; it's damaging the present and future of the EV market. Every second electric scooter has its own different charging port, which affects the charging station infrastructure because no specific charging station can be built that can charge all types of electric vehicles. Also, the lack of standardization reduces the EV adoption rate in society-based communities.

- Temperature Issues- Temperature can affect the performance of an EV battery to a large extent which makes EV's inappropriate for too cold (Uttarakhand, Meghalaya) or too hot regions like (Rajasthan, Kerala). The battery can give its ideal performance when it's in use under the temperature range of 15-40 degrees.

- Very few academic and local skill awareness- EV push is necessary along with the academic awareness and importance to the students of coming generations. Because the EV spare part and servicing industry is another essential part of the growth of EV's. When one is stuck with their broke ICE vehicle, he/she can easily find a help or customer support near them but when it's about electric vehicles it's surely a tedious task to find someone who can fix their issue or help them.

- Less performance for ideal economy- IC engine-driven vehicles are still way ahead of electric vehicles when it comes to performance. In order to make sure that an EV is giving the promised range it becomes highly important to drive the vehicle at lower performance and be aware of maximum usage of 'regen'. It's just a matter of assuming the increment in electricity demand when everyone in the city is using solely electricity to charge their vehicle. It'll be a horrific increment in the demand for electricity and as of now, we are majorly dependent on burning fossils for generating electricity. Until we use renewable sources of energy for generating electricity the EV revolution will be of no use.

- Environmental concerns- The EV revolution is necessary for the most populated and polluted parts of India like Delhi, Mumbai, etc. but in such cities the major chunk of electricity is generated through burning fossil fuels which are equivalent to spreading the pollution through the ICE vehicle smoke, even most of the charging stations are reportedly operating upon diesel-driven electricity generator.

IV. CONCLUSION

Electric vehicles made their proper debut in the commercial vehicle market in the year 2019. Still, there are so many challenges in the electric vehicle. The major issues occurred in the electric vehicle battery operation. Recently many of the EV is blasted due to the thermal effect. This paper presents the review of an energy storage system with battery and supercapacitor for electric vehicle applications. In future, design a model for hybrid energy storage system for EV applications.

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