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Impact of Supercapacitors in Battery on Hybrid Energy Storage System for an Integrated Microgrid

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Abstract- The perception of micro-grid structures within the ac distribution system is main to various demanding situations to have a secure and dependable operation in the power system. Also micro-grid is receiving attention because of increasing need to integrated distributed generation and to provide electricity surety to essential loads. For the power system it is obligatory to keep up voltage and frequency inside the given variety at neighborhood bus below numerous situations of renewable energy source (RES), grids. With those conditions, the requirement for power storage systems (ESS) will become extraordinarily eventful for efficient operation of critical and frequency sensitive loads. This paper provides about HESS and discusses potential difference topologies which might enhance the life of LA battery in photo-voltaic structures. The hybrid energy storage system topology capabilities in allying pressure of battery are analyzed and compared. A robustness of battery and its cost is discussed here to calibrate the brunt of negative elements on the cell, consequently the cogency of various hybrid energy storage structures in allaying stress of battery and the related cost evaluation may be multiplicity in comparison.

Keywords— Micro-grid, voltage source converter, electricity control, renewable energy resources (RES), energy storage systems (ESS),state of charges(Soc),Maximum power point tracking (MPPT).

I. INTRODUCTION

The fast increase inside the penetration of distributed energy resources (DERs) with a purpose to maximize power safety, energy first-rate, electricity efficiency, challenges the secure and reliable operation in power system and additionally reliability for critical loads [1]. There are several technical ideas in the back of the micro-grids, consisting of (i) transmission constraints requiring in delivering the direction of loads (ii) call for stepped forward reliability, efficiency, and satisfactory (iii) call for electricity safety (iv) conglomeration of renewable energy and DER. The minimum expenses of Photo-voltaic installations, electricity depot, and natural gasoline devices have been supporting distributed generations and grids. The unpredictable nature of renewable resources along with the aberrant behavior of loads due to the effect of voltage and frequency caricature at the nearby bus. As they mutate in RES power at the neighborhood bus are unavoidable, this places demand for a brief electricity source or sink. This need is redeemed through the veracious acceptance of energy storage devices [1][2]. The primary case for dependable operation is inflexible in dc-link voltage, in dc side of the micro-grid. Also, dependability relies upon, regulating in local bus frequency and voltage, at the ac side. Therefore, the work of storage of power is redoubled through not only simplest inlay of the distance among renewable resources and loadside demand, but also acting within the direction of stabilizing the grid [3].

The dc–dc converter with many-input can excerpt power from the PV array with MPPT characteristic for each string of PV module. An alternative approach to comprehend the dc–dc converters with numerous inputs is to utilize unattached dc–dc converters. The input output power flow fluctuations in power flow will be buffered by the dc-link filter. The dc–ac inverter which is related to grid will intercalate an ac sinusoidal contemporary towards the ac mains even as a controlled dc- link voltage. However, battery voltage and current is overpowered to unexpected transients in the course of RES or load adjustments, which affect the battery performance and decrease its existence span within the long term. In [4], battery based energy storage system (BESS) is implemented in frequency control utility which cohere of a conventional droop manage [5] consisting of an inertia emulation function to sway the BESS active energy transfer. When the micro-grid power system deteriorates, the BESS detaches and keeps operating in islanded mode. In addition

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to a dynamic and high strength density based totally the energy storage device (ESD) such as supercapacitors into the prevailing of system enhances the performance of the battery units. Hence, a aggregate of ESD's along with battery and supercapacitors, nicely called hybrid energy storage system (HESS) which is recently used in a micro-grid surroundings. Therefore, the long term overall rendition of battery units can be more desirable by means of the software of supercapacitors.The capacitors stores power in the form of static electricity which has high charge density, with fast charging and discharging, immeasurable lifecycle [6]. The total current trade is addled into or extra frequency constituents in battery-supercapacitors hybrid energy storage system. In [7], an energy management system (EMS) is based on weather situations. The State of charge limits are decided on the climatic conditions such as sunny, cloudy and also predicated on lower, medium and higher load needs. The source of energy to the ESD is obtained as much as the indemnification of output electricity inconstancy from the PV panels and primarily predicated on the EMS mode. The energy storage is completed in stationary gadgets, different types of batteries (e.g. Lead-acid, vanadium redox), flywheels, and so on. Also the speedy improvement of electric vehicle to micro-grid idea, a electricity storage aid affable additionally come close to destiny from the electric vehicle. Firstly the battery bank is attached to the through dc/dc converter to the dc bus, therefore by making feasible to attain a optimized charging and discharging operation mode. A 2nd benefit is an extraordinary bank of capacitor which is delivered and is likewise linked to the dc bus along a dc/dc converter. Batteries are used for an extended-term deliver of electricity. Supercapacitors cause faster dynamic low of powers. Charge controllers save you with an battery from excess charging without interrupting the modern-day flow from the PV array to the battery until the battery is absolutely charged.

II. SYSTEM CONFIGURATION

Interaction of micro-grid with HESS taken into consideration on this work is proven in Fig. 1. The PV panel is linked to the DC link through a high gain boost converter (HGBC) and only a one section inverter interfaces the unusual DC link with the application grid as proven in Fig. 1. The PV panels are attached to the load in order to improve DC converter if you want to achieve a regular voltage across the terminals where is load is connected. The battery is hooked up into the load along dc/dc converter which is bidirectional. The PV panel is linked to the load along buck boost converter with the intention to attain a steady voltage.

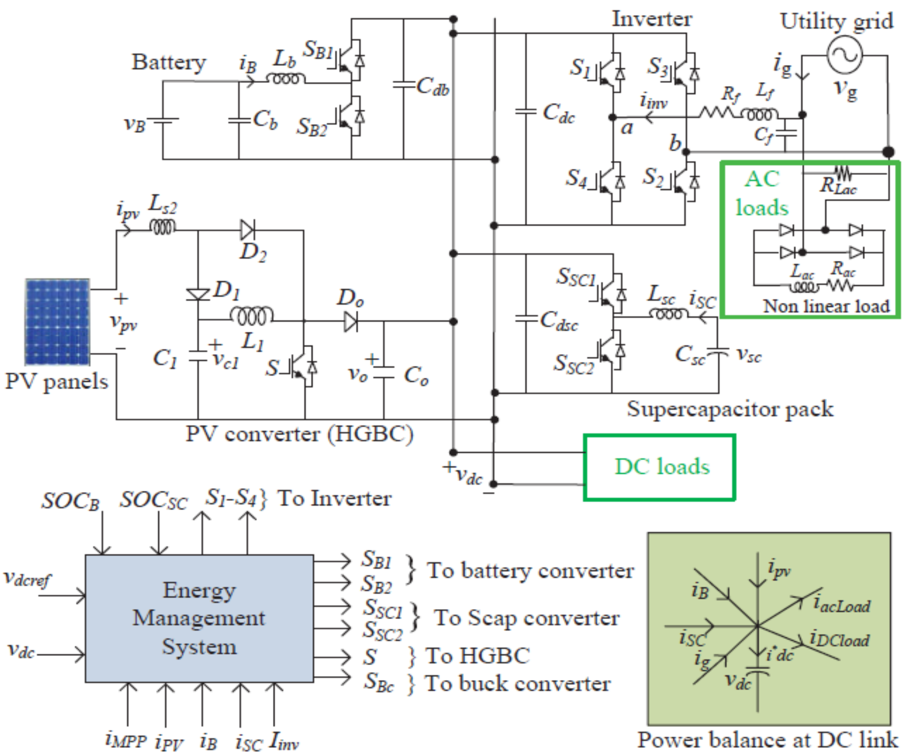

Figure 1: Grid interactive hybrid micro-grid

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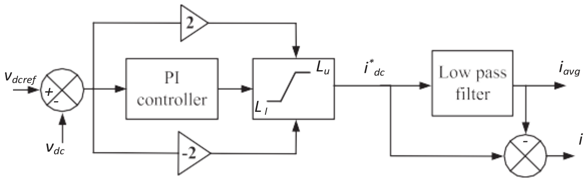
A. DC hyperlink voltage controller:

The stability of power inside the system is carried out to indicate regular DC link voltage. The actual dc voltage (v_{dc}) is as compared with the reference voltage (v_{dcref}) and PI controller process the mistake signal to generate a reference current (i∗ dc).



DC link is modeled by means of relation:

A. $v_e(t) = v_{dcref}(t) - v_{dc}(t)$

B. $i^*_{dc}(t) = k_{p1}v_e(t) + k_{i1}v_e(t)$

C. $i_{avg}(t) = \frac{1}{1+ST_c} * (i^*_{dc}(t))$

Where $f_c = \frac{1}{T_c}$ is the cut-off frequency of low-pass filter.

B. *Structure of Grid integrated micro-grid*:

A hybrid micro-grid system which is grid-interactive is taken into consideration which includes the subsequent components:

Sources: Renewable source, utility grid, storage structures are numerous resources discussed in this paper.RES source taken into consideration corresponding to the standard wind or solar energy. Two Energy storage devices are taken into consideration together with battery and supercapacitors devices.

Converters: There is an interface between battery, supercapacitors units and dc-bus using a dc-dc converter which is bidirectional. The dc-bus linked to the RES increases the usage of converter. AC and DC buses interfaces with the µG-VSC systems, to pump actual energy amongst ESS, RES and utility grid based totally by the provisions of loads and numerous resources. AC and DC bus also has additional feature to improve energy quality of the grid.

C. Power Management Strategies:

In general, Power management (PM) making plans is completed with the aid of strategic deployment of DGs in micro-grid that includes the determination of excellent DGs in conjunction with its size, position, and the manner wherein it's miles interconnected to the device.

Its most important assignment consists of:

I. Initial expenditure, energy demand and manufacturing and so on, are facts of micro-grid collected
II. Determination of the amount of KW and KVAR exchange between grid and micro-grid.
III. Micro-grid is stifling at some stage in the change over from grid- tide to autonomous mode.

D. Battery-SC HESS topologies:

Combining both the battery with SC in HESS either in series or in parallel, configuring with active, passive or combination of both can be done. In a passive connection, DC bus is linked to the terminal of the ESS with study of electrical characteristics of Energy storage device. DC/ DC power converter which is bidirectional in nature is the active elements which is combined with ESS elements from DC bus and to earnestly manage flow of electricity implemented in active HESS topology. Fig. 2(a) suggests the battery- supercapacitors HESS combinations are connected passively to the DC bus. Hardly there may be lively thing delivered to device and sharing of power between battery and supercapacitors are depended on the system time constant in this configuration. In passive HESS the ability of the supercapacitors depends on the system time constant and SC, along with low efficiency in HESS layout. The ESS modules which are controlled actively are shown in (Fig. 2(b)). (Fig. 2(c)) shows cascaded controlled ESS modules. The fully active topology can reap a good manage impact, but usually on the price of machine efficiency,

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intricacy, and cost value. The flow of power in SC and batteries are managed by DC-DC converter which is bidirectional at the same time in parallel with active HESS topology to regulate DC bus-voltage. The ESS factor is not depended on the voltage and the DC bus.

The different configuration of different active HESS is developed by various management algorithms [8–10]. Also Cascaded active-HESS with supercapacitors and battery are organized as shown in Fig. 2(c). The controller complexity increases with the cascaded active HESS different voltage rating. Fig. 2(d) and (e) illustrates Semi Active HESS topology, It is proposed to overcome the drawbacks of active and passive HESS topology [11]. In this, the terminal voltage of the supercapacitors is varied to obtain the volumetric- efficiency. The supercapacitors have the ability of absorbing frequency fluctuation in DC bus in many of the instances. The bank of battery supplies the energy required for the power system with decrease in terminal voltage. Also the passive battery supercapacitors configuration increases the durability of the power device. Similar to [12], due to frequent electricity surges in Li-ion battery it uses semi- supercapacitors battery configuration. Contrarily, the battery semi-active HESS in (Fig. 2(e)) bidirectional DC-DC converter is interfaced with the battery module and also it is passively coupled between the DC bus and Supercapacitors module. But instability of DC bus voltages troubles the topologies. The troubles in the DC bus voltages can be eliminated by the usage of the supercapacitors.The hybridization of two ESS modules may be designed in distinct combinations of active, passive, parallel, and /or cascaded with specific energy management machine by considering a primary module which includes both or each Supercapacitors and batteries with or without DC-DC converters, which is as illustrated in Fig. 2(f) [12–13].

The battery and supercapacitors can be modeled for distinct voltages, power ranges and system requirements. Ye et al. offered an ideal Supercapacitors cell circuit to rectify the voltage imbalance between the cell voltages. In Fig. 2(f) [14] depicts the one of the example of supercapacitors-battery HESS.

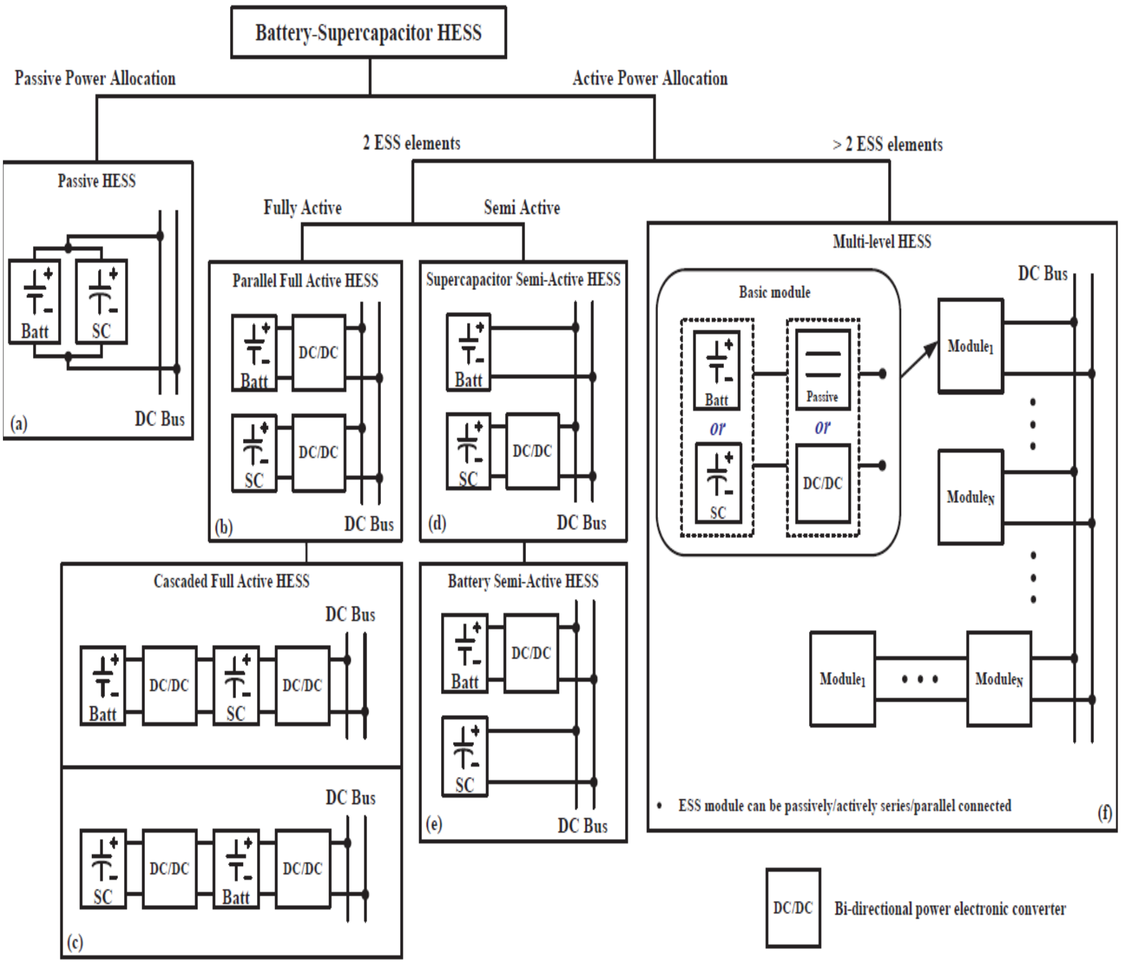

Fig. 2.w.jing et.al Battery-SC HESS topologies

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III. HESS MODELS AND EXPERIMENTAL RESULTS

To compare and calculate the charge-discharge nature of the chosen designs of HESS and they are investigated with the pulse load current and its outputs are of distinct ESS factors. Mat-lab models with Simulink of the topologies of HESS are shown. Passive HESS and SC energetic HESS are evaluated.

A. Passive HESS:

The passive HESS version in Mat-lab Simulink is proven in Fig 3(a). A battery of 12 Ampere-hour and SC of 10 F are across the load. A current load which is triggered with input current is connected to period of cycle of 10s with 50% duty cycle and 5 A. Fig. 3(b) gives the simulation consequences of sharing of power among SC and LA battery. During the increasing phase, the responses of SC are faster because time constant is relatively small. The outcomes display decreases the effect on the energy-sharing within the quietly connected supercapacitors HESS-battery for which energy-sharing is simplest happened in less time. Moreover, the sharing of power functionality of HESS is set primarily depending on the inner values of the two factors of ESS. Lead-Acid battery is one of the ESS's of sharing HESS functionality is set depending totally on inner values of the 2 factors of ESS. Desired type of ESS is usually LA battery. Unidirectional Dc to DC converter uses the charge controller with maximum power-point tracking (M.P.P.T) set of rules and load and HESS are interfaced using control-switches. Whenever system fails, for a back-up dispatchable power supply, a diesel or petrol generator is included normally.

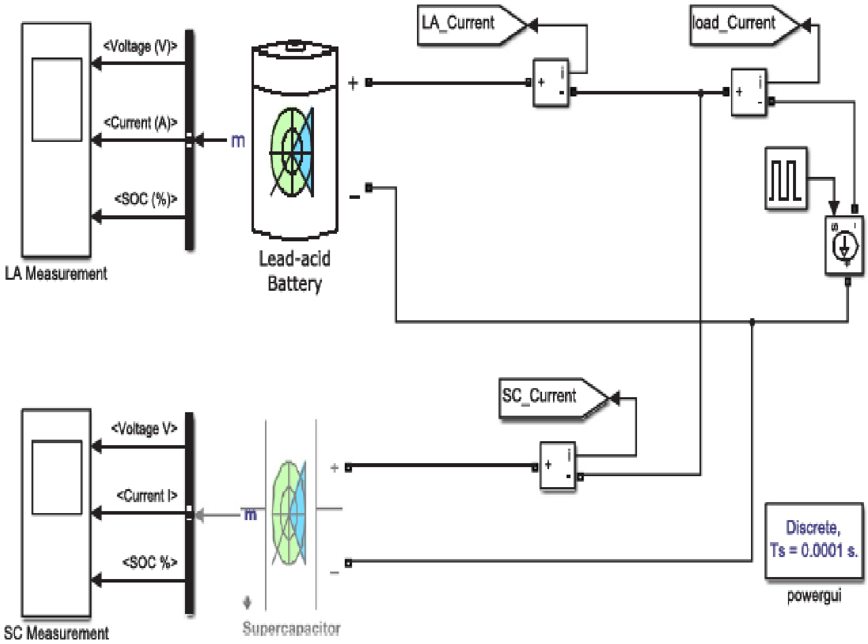

Fig 3(a): Passive HESS model using Mat-lab Simulink

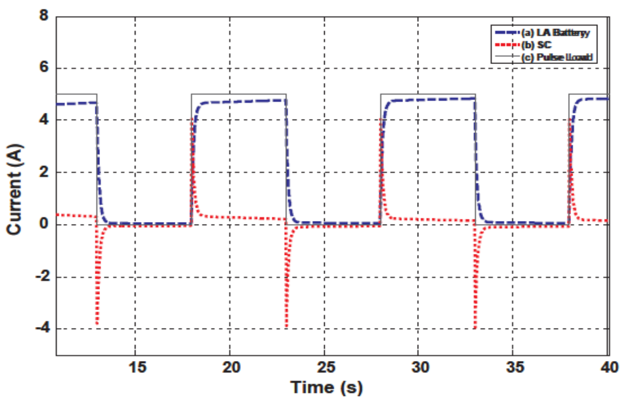

Fig 3(b): Pulse load reaction of passive HESS.

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B. SC Semi-active HESS:

The supercapacitors semi-active HESS is shown in Fig (2(d)), where its equivalent time and frequency domain circuit is shown. By ignoring the dynamic-traits, the DC-DC converter is interpreted and expressed as η_{sc} performance parameters and K_{sc}, voltage- switch charge [15]. The supercapacitors semi-active HESS model in Mat-lab Simulink progressed supercapacitors and LA battery's he parameters. Figure suggests the consequences of simulation for energy-sharing among supercapacitors and LA battery in Semi-active setting. Initially, the low-pass filter is used to filter the total alternate in demand (τ=1.5s). A PI controller is realized to tune the signal of reference, at the same time as ultimate of the present day demand could be acknowledged by using the bank of LA battery which is managed passively. Gain of SC module which is actively controlled is the time constant of the response which adjusted to higher to make use of the supercapacitor module. Moreover the difference between SC-module and DC-bus permits larger variant in charge state that reforms the efficiency. Because of the inevitable delay in time of the controller and the active component, there is high in rush of current.

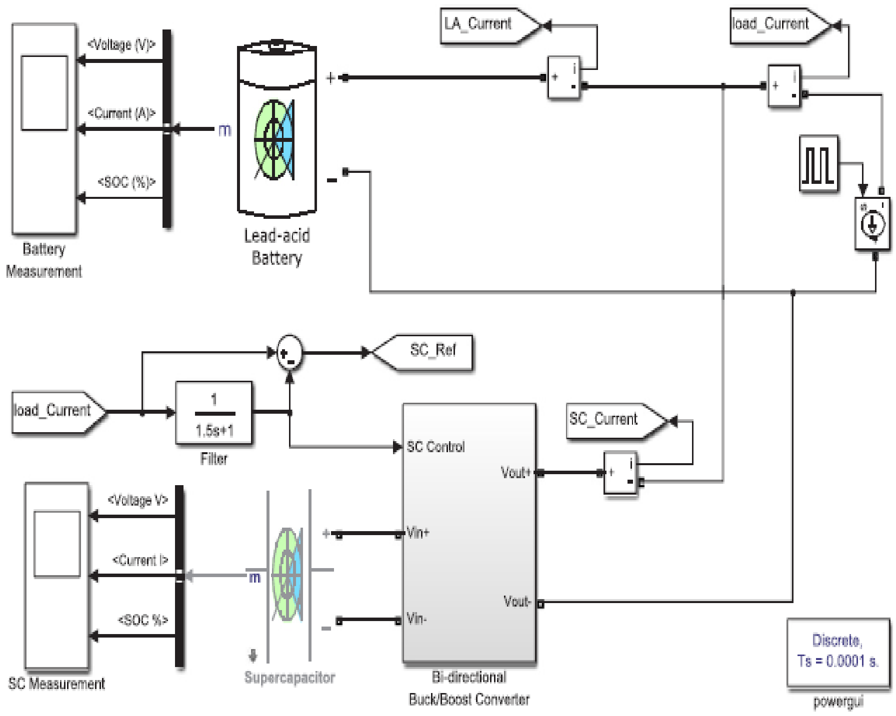

Fig. 3(c) The supercapacitor semi-active HESS model using Mat-lab Simulink

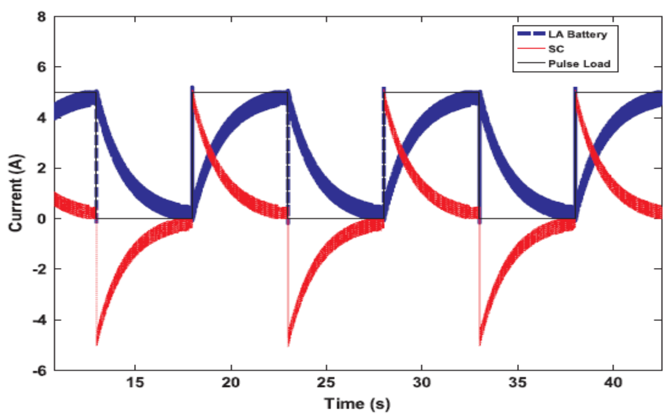

Figure 3(d) Supercapacitor semi-active HESS: Pulse load reaction

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The low by-pass filter is used to filter demanded energy PHESS and the high frequency energy change is used as $P_{SC(ref)}$ for SC as the reference signal. A current tracker which is tuned carefully is utilized to govern, flow of energy from supercapacitor. The bypass filter bandwidth is decided with relation between smoothness of battery current I_{Batt} and the capacity of supercapacitor.

IV CONCLUSION

The solar power reasons, extra impact on the battery which reduces the performance and life cycle of battery. The most commonly used ESS technologies are Lead-acid (LA) battery and Lithium-ion (Li-ion). Li-ion batteries have a higher power density, extended life cycle than LA batteries, but are exceptionally of high cost. Hybridization of various power garage devices has compared with BESS and aims to expand the efficiency of the battery in many packages with high energy during last many years. This paper presents Hybrid energy storage system topologies observed by means of simulation and experimental verification. The overall performance of super-capacitor devices is they bypass the high frequency factor from battery and also from the grid system. Hence the results of simulation prove the capabilities under certain storage, grid conditions and loads and renewable power. Models of some chosen HESS are developed and simulated using Mat-lab Simulink. The profile of load which is estimated, assess the battery strain mitigating effectiveness. Outcomes of Simulation, health of battery charge and economic analyses, and empirical results validate that the active energy storage with passive energy storage combination which gives better result.

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