iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VIII **Month of publication:** August 2017

DOI: http://doi.org/10.22214/ijraset.2017.8236

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

Smart Power Gen using Renewable Sources with Intelligent Energy Storage System in Grid

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Abstract*: In marine industry shipping is considered as the backbone of international trade as most of the exported goods are transported by ship. Therefore the sea exports are doubled by 2025. To continue with the sea transport without any discontinuity a new and more eco-friendly power has to be generated with the available sources. The power can be generated by using fossil fuels or by using renewable energy sources. Energy crisis increases due to the demand of fossil fuels. The generation of power using conventional source increase the cost of generation and utilizing the same in shipping industry is difficult. Therefore in this manuscript the power is generated using Renewable Energy Sources (Solar, Wind & Ocean). The generated power is configured as grid. But the Static power load (SPL) in ship causes instability issues. To increase the Stabilization and optimization of the electrification, Z Source virtual impedance Compensation technique is used on load side. The generated power using solar, wind and ocean are stored using intelligent hybrid energy storage system.This manuscript deals with CrossBreed Energy Storage System (CBESS) implemented in ship as storage compensation technique. CrossBreed Energy Storage System (CBESS) has an amalgamation of battery unit and Electric Double Layer Capacitor (EDLC) unit, thereby reducing the use of battery and Electric Double Layer Capacitor (EDLC) storage system as individual. The combined feature of battery and Electric Double Layer Capacitor (EDLC) gives higher energy and higher power density. Here, the storage will provide high power density with quick charging/discharging time and the Electric Double Layer Capacitor (EDLC) will compensate the transient demand for a short period of time; therefore compensating the required power by the combined features of its constituents. Besides CBESS is operated by a simple algorithm, to improve its overall efficiency, cost effectiveness, life span and reduce the energy storage size and stress on the battery. The Performance of the entire configurations is analyses, simulated and verified using MATLAB/SIMULINK.

***Keywords*: Renewable Energy, Static Power Load, Z Source Load**

I. INTRODUCTION

Though the Pros of Microgrid is more when compared to conventional grid system, maintaining the stability of the system has become a major concern in different loading conditions. The designed microgrid deals with Constant power loads and exhibits negative incremental characteristics. The property of negative incremental characteristics hampers the microgrid system stability considerably. At present, as the continual increase of the modern inverter-based loads, the problem is being intensified. To increase the stabilization of the system, engineers, professionals, and researchers undergone many research works in and around the world [1-5]. In [7], Kwasinski and Onwuchekwa outlined the different strategies to sort out the problems of steady load in DC microgrids. In view of this, the effect of adding filters and capacitors was studied and it is analyzed that it is not the cost effective system and also the addition of capacitor causes capacitor failure which increases with rated voltage. Load shedding of SPLs can restore stability, but this is of little practical value since it only temporarily restores the system without increasing long-term capacity. Linear and non-linear controllers for time variant and invariant can also be used but the former cannot assure the global stability of the desired equilibrium point and the latter is very challenging in its design and changes with each system's parameters. The generated power can be stabilized and can be sent to the load as reference parameter with slight modification which modifies the SPL behavior of the load. Using such a constrained optimization technique, a method to design the stabilizing system is proposed in [8]. Coupling two systems together can allow the oscillating characteristics of the two systems to dampen each other out [9]. The systems may have slightly different characteristics, usually because of different inductances, or they may be identical but coupled with a small delay factor. Mathematical analysis for two systems has been done to find the region of stability. It is cumbersome to identify the system's stability characteristics for the large complicated system. For that particular case in DC microgrids, instead of over- linearizing, sliding mode control technique- with nonlinear modeling of the system- has been adopted by the researchers. By using a sliding mode controller, a sliding surface has been established to stabilize the voltage of the entire system [10]. In order to attain optimal operation, Bo Wen et al implemented four-wire-lattice network in Non Conventional Energy Source energy resources

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for a three phase AC system in islanded mode operation [11] and small signal stability of the system is analyzed using Clark's transformation.

Zeng Liu et al, at [12], analyzed the distributed power system using state variable analysis by infinite norms in input/output matrix, to identify the stability criterion for distributed power system. It is axiomatic that, due to the abrogating incremental load characteristics, the alternation botheration is agitated with the accretion and measurement of the Steady Power Load. Nadeem Jelani et al, at [13], have formed to acquisition out the attributes of this accord and has advised the antecedent works on this issue. To break the instability problem, STATCOM Compensation technique is introduced. At [14], Dena Karimipour et al worked on Popov's Stability criterion, one of the advanced nonlinear techniques, to handle SPL instability issues. Using this technique for AC systems, they have accomplished stability analysis of the microgrid system. Yanjun Dong et al worked with pulse width modulation rectifier to mitigate the Steady Power Load instability. In their research, they introduced a simulation model for AC μ-grid Configurations loaded with SPL at [15]. By adopting a boost rectifier as a SPL load, Zeng Liu et al investigated the stability issues of the system. In that occasion, they used infinite norm impedance matrix for their analysis. Researchers have noticed that all available techniques for SPLs compensation can be classified into several groups of common criteria based on the location of providing compensation. The classifications are mentioned below.

Feeder side compensation to make the system robust against SPL instability.

Compensation by adding intermediate circuitry or elements between the feeder side and load to enhance system stability.

Load side compensation so that the system doesn't experience the effect of Steady Power Loads.

In this manuscript, because of having a number of advantages over the other compensation generalized techniques, virtual impedance based load-side compensation technique have been adopted to improve microgrid stability [16-17].

Energy storage has been promoted as a very significant tool in the integration of Non Conventional Energy Source energy-based μ-grid Configurations. It is adopted by the system engineers and operators due to several important features such as energy time frame shifting, ancillary features, capacity firming, intermittency handling, transmission congestion relief, and power quality improvements. Besides that, from recent researches regarding microgrid stability, the energy storage system can be considered as an important tool to retain microgrid stability. In practice, an energy storage unit assures the required power when it is needed to compensate. In this course, battery storage is the most basic of its kind among the distributed network energy storage systems. It provides easy implementation as well as geographical independence; hence it is comparatively popular to other storage technologies. But, batteries, though easy to implement, are not preferable for compensation technique due to their low power density. Hence, the storage system only comprised of the battery units doesn't experience a sound functionality in microgrid arrangement in case of highly variable distributed energy systems like Non Conventional Energy Source energy sources [18-22]. From figure 1, it can be interpreted that the Electric Double Layer Capacitor (EDLC)s range in between the conventional batteries and the conventional capacitors in terms of energy density and power density. Hence, they are usually installed for the applications where batteries have a shortfall when they require a transient high power. Moreover, to handle the situation of transient high power requirement, conventional capacitors cannot be used because they lack expected energy. On the other hand, Electric Double Layer Capacitor (EDLC)s offer a high power density along with adequate energy density for the most transient high power applications [23]. Matsuo et al, at [24], developed multiport converters with hybrid fuel cell, battery systems and hybrid ultra-capacitor systems. Comparison of various electrochemical storage devices in Energy Density, Power Density and charging time shown in Fig.1.

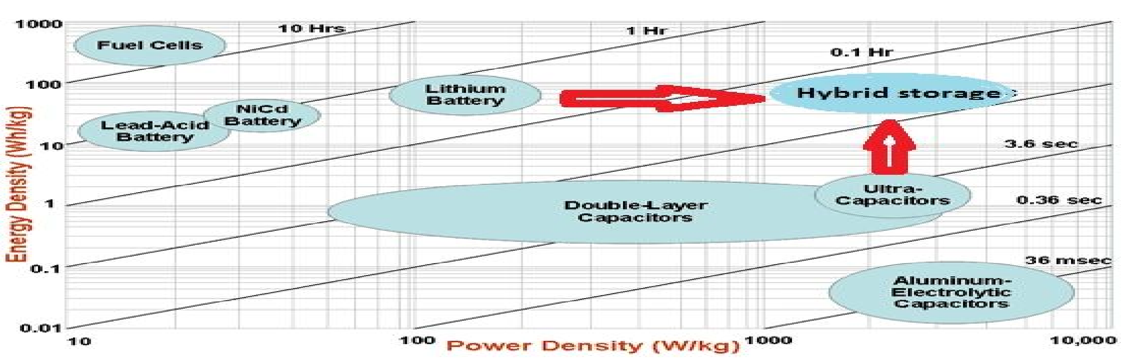


Figure.1 Comparison of various electrochemical storage devices in Energy Density, Power Density and charging time.

T. Yuvaraja et al, at [25], developed fuzzy controlled based distributed generation unit in grid operated in islanded mode with storage system. The Simulation results validate the model and robustness of the proposed control scheme to changes in system loading and power factor. T. Yuvaraja et al, at [26], incorporated Decoupling algorithm and notch filter with three level hysteresis controllers under stiff symmetrical and asymmetrical grid conditions. Also the entire concept is analyzed in dq reference frame. Yuvaraja Teekaraman et al, at [27], concluded that distributed generation units in islanded mode Controlled by Fuzzy model in a reference frame promptly and establish legitimacy of the model and robustness of the control scheme to change system loading and power factor. Yuvaraja Teekaraman et al, at [28], implemented the Solar Energy with new controlling parameter in microgrid under partial shading condition for better stabilization and optimization. The dynamic control scheme is aso presented to analyze the performance of a three-phase grid-connected PV system and to enhance the dynamic stability limit with the change in atmospheric conditions by utilizing the new control factor. T. Yuvaraja et al, at [29], implemented multicarrier level shifted current control, at higher feed forward gain and hence better control characteristics. Also it can be controlled to feed the load real power with the balance real power being supplied from the grid. In addition to real power injection, the objective of load compensation is also achieved leading to a balanced, distortion free, and unity power factor source current.
This manuscript deals with CrossBreed Energy Storage system consisting of both Electric Double Layer Capacitor (EDLC) and battery. As microgrid is a distributed power system, load side compensation technique can be used by implementing this portable SPL compensator. Here, an Electric Double Layer Capacitor (EDLC) contributes also in transient power demand where a battery handles the nominal power requirements. Comparative analysis is done for various storage systems with the designed hybrid storage system and relevant graphical analogies have been represented in this manuscript [30].

A. Conventional Energy Storage Systems for Microgrid Applications

As constant power load exhibits negative incremental characteristics when connected to the grid it experiences a transient spikes in DC bus voltage response. Practically the power handling capacity of CVL is KW or MW and SPL power is of 533 W, the transient spike created by SPL load are significantly higher. Fig.2. shows the microgrid parameter without compensation and is observed with certain disadvantages. To handle this issue, energy storage systems are used in microgrid application. Here, In this manuscript, two kinds of conventional energy storage systems are analyzed. At first, the battery-only compensator is presented here with the regarding simulation platform and performance graphs in several cases. Similarly, the Electric Double Layer Capacitor (EDLC)-only compensator is described here with necessary detail for microgrid application. Furthermore, the advantages and limitations of each storage system will be described.

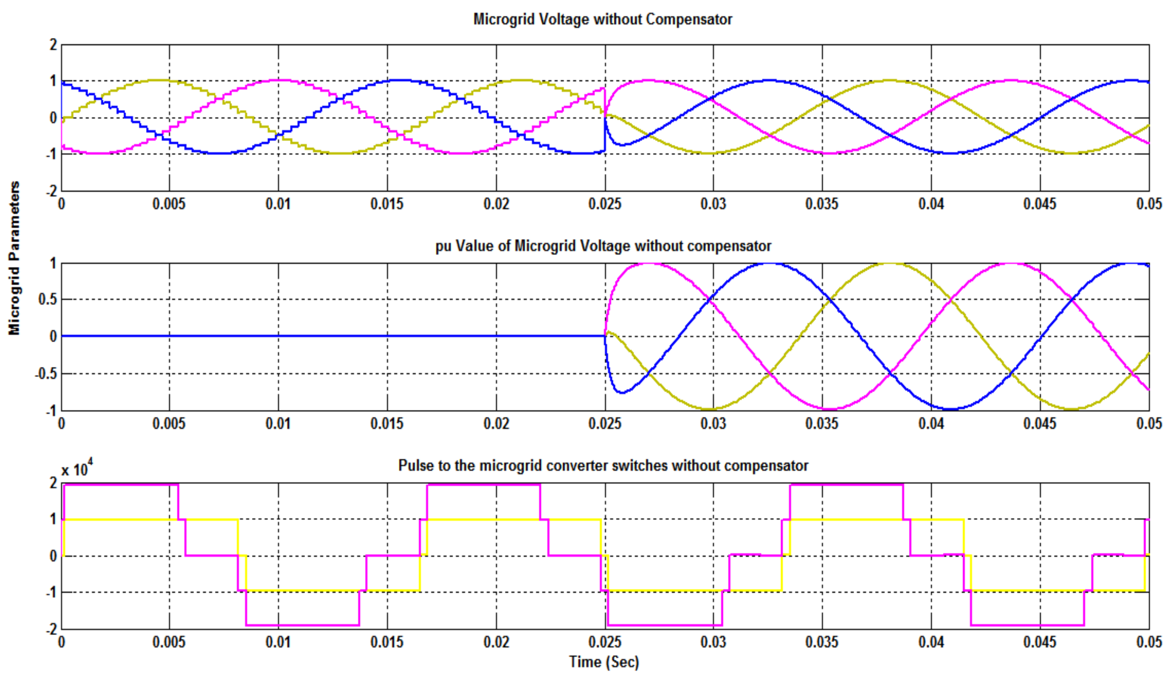


Figure.2. Microgrid Parameter without compensation

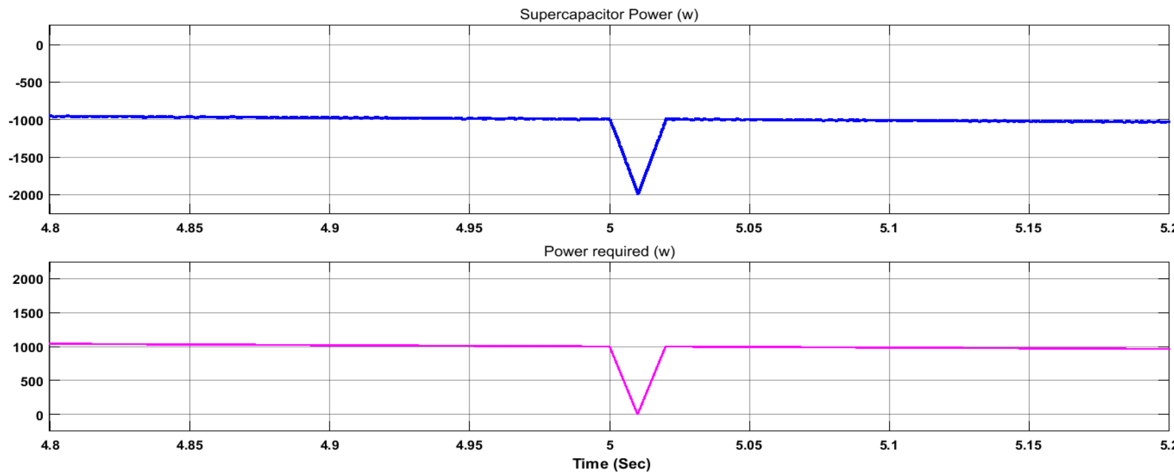
II. MICROGRID SYSTEM WITH COMPENSATOR

The simulation diagram of Microgrid with Compensator is shown in fig.3. When Microgrid tens to fluctuate from the stable voltage range, the battery connected in the system tends to deliver the required Compensated voltage to stabilize the grid. In the simulation the connected battery acts as a compensator.

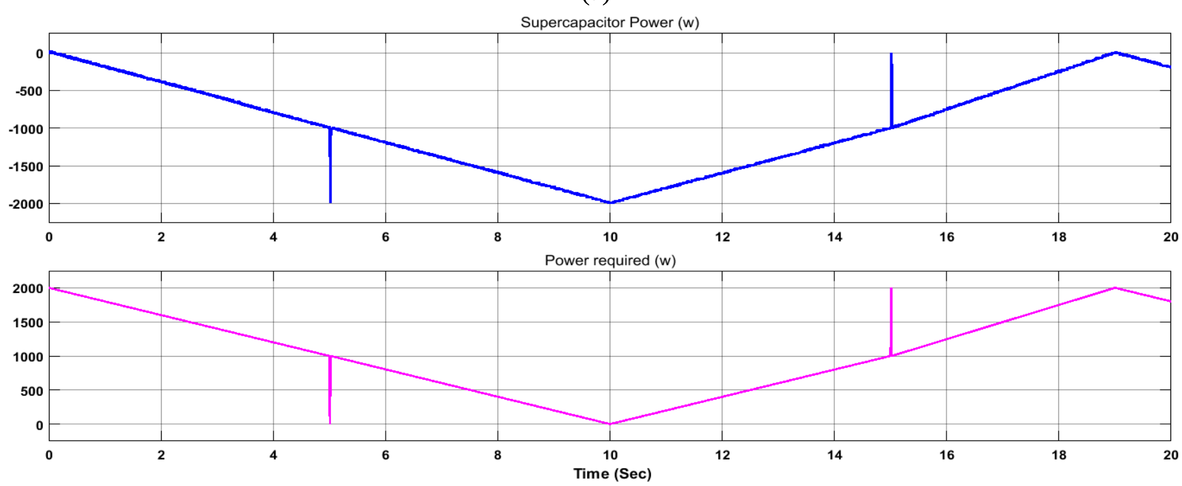
As is obvious from the above graphical demonstrations, the battery-alone compensator supply nominal power efficiently for a longer period without charging-discharging backward and forward, but, in alternative juncture, it’s unproductive while it comes to fading transitory demand. Due to the hefty response time and low power density, the battery necessities longer time to maintain constancy. As can be seen from the figure 6, to retain microgrid stability, the transient spikes must be handled effectively. Hence, Electric Double Layer Capacitor (EDLC)-only compensator is used as compensator unit to mitigate microgrid instability. The load profile of the microgrid system is presented at figure 7 in presence of SPL loads.

A. Electric Double Layer Capacitor (EDLC)-Only Compensator

When microgrid voltage tends to fluctuate from the stable voltage range, an Electric Double Layer Capacitor (EDLC) delivers the required compensation to stabilize the microgrid voltage. In figure 3, simulation platform is presented for the entire microgrid system using compensator unit (here, Electric Double Layer Capacitor (EDLC) as compensator unit) in Matlab/Simulink.



(a)



(b)

Figure. 3. (a) Representation of the Electric Double Layer Capacitor (EDLC) power support and power demand,

(b) Representation of the transient power demand and respective Electric Double Layer Capacitor (EDLC) support.In the representation of the Electric Double Layer Capacitor (EDLC) power support and the power demand for a certain period of time are illustrated to comprehend the practical scenario. In the power demand and the respective power support by the Electric Double Layer Capacitor (EDLC)-only compensator in transient cases are illustrated. To illustrate the characteristic of Electric Double Layer Capacitor (EDLC)-only compensator, the instance of Electric Double Layer Capacitor (EDLC) terminal voltage, current, and power are presented (in the presence of SPL).

III. CROSS BREED SYSTEM IN MICROGRID

Battery alone and capacitor alone configuration have lower energy density and lower power density. To utilize the advantage of highest energy density for an electrochemical battery and highest power density for an Electric Double Layer Capacitor (EDLC) CrossBreed Energy Storage System is proposed in this manuscript. A comprehensive energy management control system is furnished in fig.4 (a) & (b). To microgrid stabilization and to handle SPL transients effectively. The main advantages of a CrossBreed Energy Storage System are

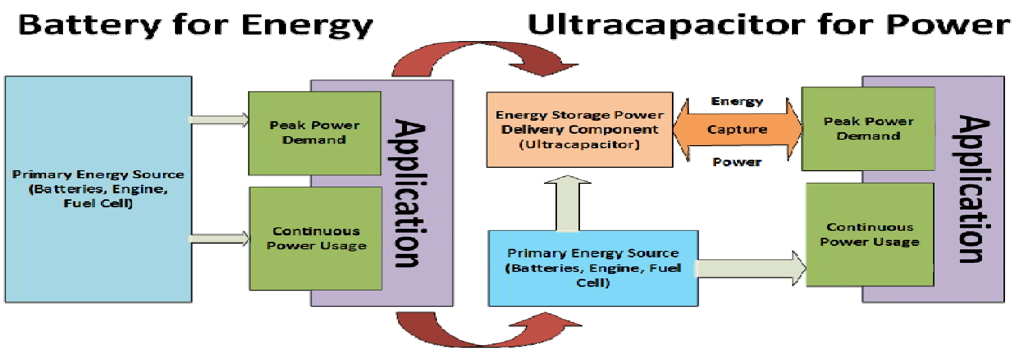


Figure .4. a. CrossBreed System with Energy Storage System for an Microgrid

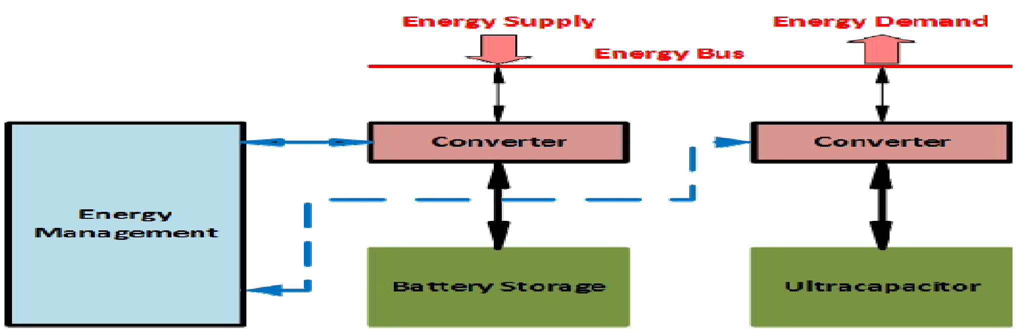


Figure.4. b. Basic Structure of CrossBreed System with Energy Storage System

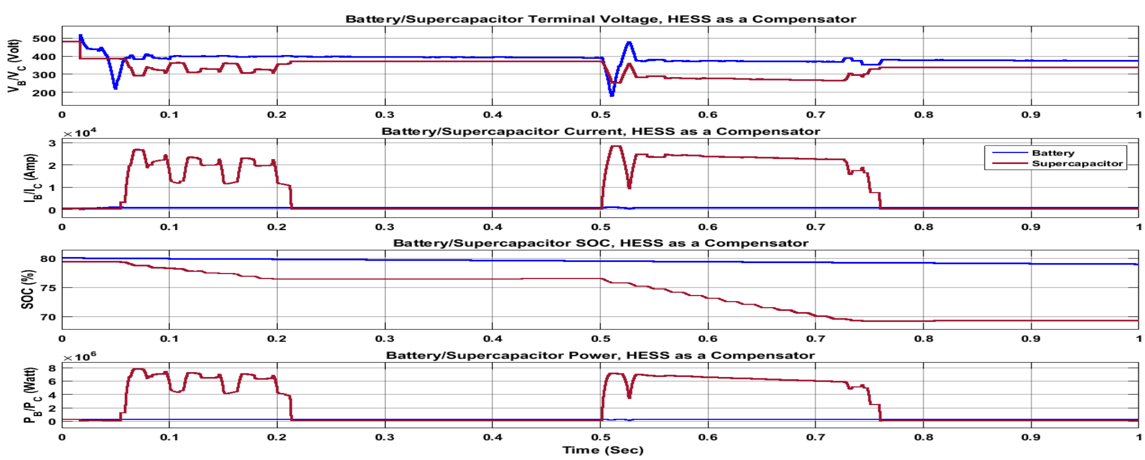


Figure. 5. Characteristics of the CBESS in the presence of SPL

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As shown in fig.5. The crossbreed energy system is simulated for a microgrid and the following results are obtained. The results are shown for the current in the battery and ultra capacitor with and without compensator. The battery will initiate compensation according to the logic when terminal voltage remains within 0.99 and 1.01 pu. If the voltage tends to fluctuate from this zone the Electric Double Layer Capacitor (EDLC) will enter the compensation technique the converter and CBESS characteristics with and without the compensator is shown for, the instance of converter voltage, DC bus voltage, CBESS terminal voltage, current, SOC, and power is presented in fig. 8 (in the presence of SPL).

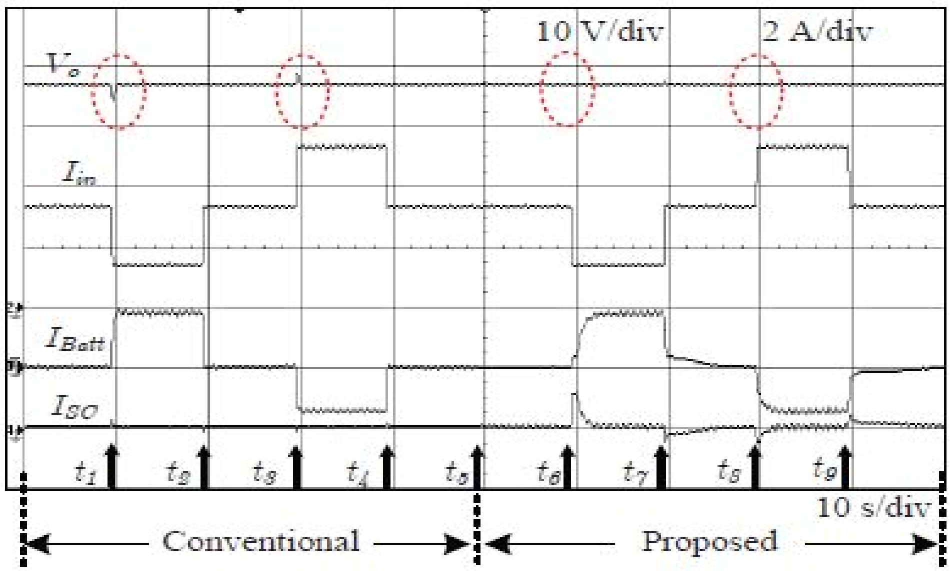

Figure. 6. a. Output voltage, input current, battery current, and SC current;

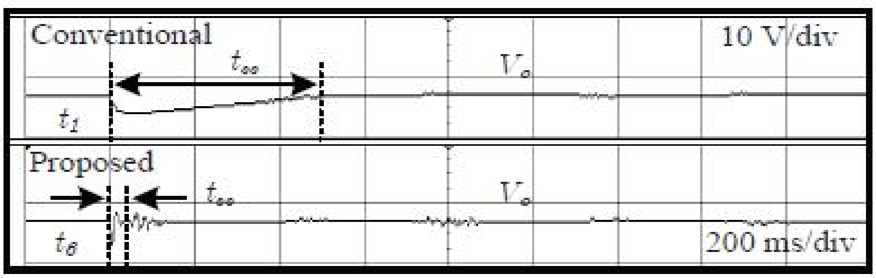

Figure. 6. b. Output Voltage

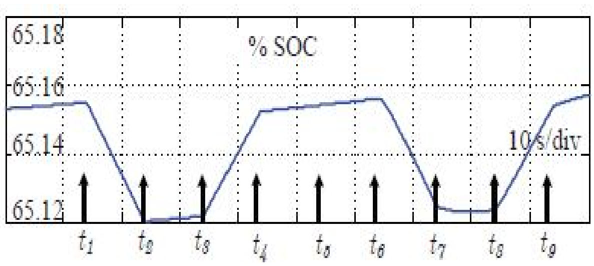

Figure. 6. c. % SOC

It can be observed from the high energy density from the battery unit and the power density from the Electric Double Layer Capacitor (EDLC) unit support both long term slow SOC demanding applications and transient fast load switching overshoot. In fig. 6 (a), (b), (c) the comparative analysis is presented on the performance of handling/compensating the transient spikes among the battery-only compensator, Electric Double Layer Capacitor (EDLC)-only compensator, and CrossBreed Energy Storage System as compensator. From this, it can be seen that the transient peak occurred in the microgrid system has been compensated up to 1.023 pu in case of battery only compensator, compensated up to 1.02 pu in case of Electric Double Layer Capacitor (EDLC) only compensator, and compensated up to 1.017 pu in case of CrossBreed Energy Storage System. So, it is evident that CBESS can handle the transient spikes most efficiently among these three.

IV. DISCUSSION

Battery size is scaled down significantly because the transient load/peak load demand is eventually compensated by the Electric Double Layer Capacitor (EDLC). The high energy density battery unit cannot sustain at the time of load switching when transient overshoot arises. In consequence, its life cycle reduces dramatically. To solve this dilemma, an Electric Double Layer Capacitor (EDLC) with high power density can be installed to ensure longer power sustainability.

V. CONCLUSION

Z Source Load compensation technique is implemented in shipping industry along with crossbreed Energy Storage System (CBESS) to retain microgrid stabilization and optimized output under stabilized Load condition. In this manuscript battery and Electric Double Layer Capacitor is compared and furnished that battery-only compensator can supply the long-term demand and the Electric Double Layer Capacitor (EDLC)-only compensator can handle the transient demand effectively. To take the advantage long term nominal load and transient demand and effective energy management technique along with CBESS is implemented. From the obtained results and the performance evaluations, it is evident that the CBESS can improve the overall efficiency, cost effectiveness, and life span of the storage system. Besides that, it reduces the storage size and the overall stress on the battery.

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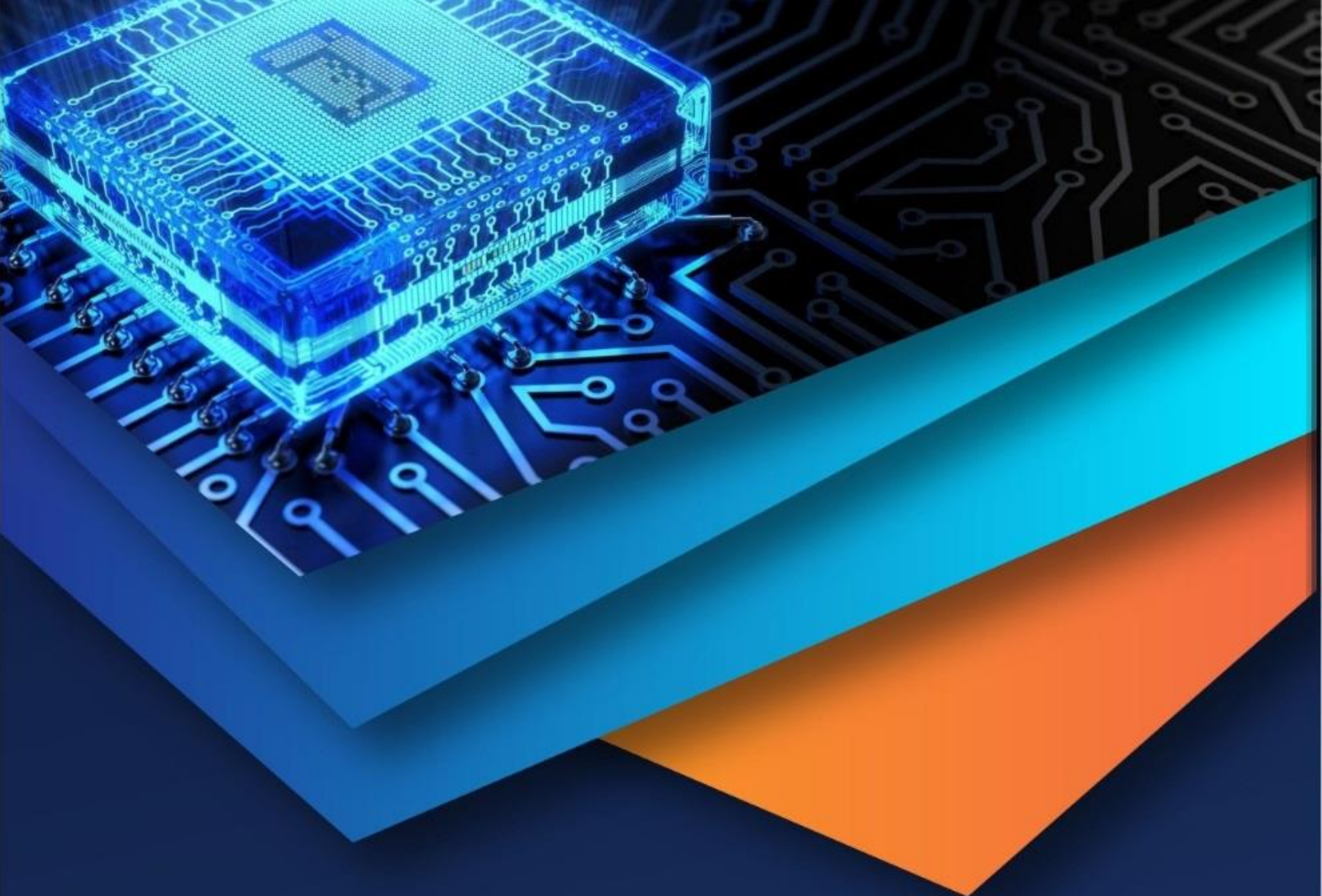

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