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Simulation of Grid-Tied Photovoltaic Battery Storage system using SimPower

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Abstract: The recent innovations and growing demand for renewable energy sources more especially Photovoltaic energy system has made Energy storage systems become an area of utmost interest. This paper focuses on Simulation of grid-tied Photovoltaic Battery Storage system using SimPower Systems. Battery Storage system is employed to conserve the excess power produced by solar panel during high irradiances so as to provide uninterrupted power to realize the load demand during low irradiances or grid collapse. A simulation of Energy Storage Systems is carried out using SimPower System software to analyze the performance and determine appropriate sizing of the Battery device. The results of the proposed model met the load demand and showed satisfactory performance.
Keywords: Gassing, Irradiance, Battery Autonomy, Hydrogen storage, SimPower Systems

1.0 Introduction

Energy is the major driver of socio-economic growth of any nation and as such, the paucity of this precious commodity can seriously impede its successful development. Energy storage is a vast term that describes various technologies designed to store energy for future usage. This recent innovations and growing demand for renewable energy sources more especially Photovoltaic energy system has made Energy storage systems become an area of utmost interest. Conventional energy storage systems consisted of banks of batteries capable of storing and delivering continuous power to the load. The duration of battery storage depends on its autonomy. Battery autonomy is the period of time battery last for a specified load level in the event of power outage. However, the high energy density characterizing the batteries making them a perfect choice for steady power supply, supplying a large burst of current from the battery degrades its lifetime. An alternative solution is to combine batteries with high power density source capable of supplying the burst transient current such as super capacitor. In such a hybrid system, the battery fulfills the supply of continuous energy while the super capacitor provides the supply of instant power to the load. The system proposed in this model is grid connected Photovoltaic Battery Storage System.

Energy can be stored by converting the ac electricity and storing it electromagnetically, electrochemically, kinetically, or as potential energy. This technology is adopted to store the excess power produced throughout the duration of high irradiances, enhance the performance of PV systems by bridging their power fluctuations, shifting the time of their peak generation, supplying critical loads during power outages, and providing reactive power support. The electrical grid is a complex system that requires power supply and demand to be equal at any given moment, that is why viable energy storage solutions are emerging to help mitigate that power usage. Constant adjustment to the grid is required to maintain stability, and efficient storage will play a significant role in that critical balancing act, providing more flexibility and reliability to the system.

This paper provides a detailed review of Grid-tied Battery storage architectures used in Photovoltaic power systems in Owerri City to improve electric power supply. Grid-tied photovoltaic systems are power-generating systems that are connected with grids. Solar PV energy that is generated must be processed with the help of a grid-connected inverter before putting it to use. This inverter is installed between the solar PV arrangement and the utility grid' it could be a single unit or a collection of small inverters attached to the individual PV units.

2.0 Types of Energy Storage Systems

Pumped Hydroelectric Storage

Pumped hydroelectric energy storage facilitates store energy in the form of water through the use of two reservoirs at different elevations. When the supply of energy exceeds the demand of the energy, water is pumped into the upper reservoir, however when the demand of energy exceeds the supply at the facility, water is released into the lower reservoir and run downhill through turbines that provide electricity in a manner that is similar to conventional hydropower stations

Battery

A battery is an electrochemical device that stores chemical energy in internal components and releases energy as electricity, which is generated through electrochemical reactions. Batteries are reversible, i.e., can be charged and discharged, and the parameters of these processes are regulated to avoid damage by overcharging or over-discharging. Battery life is expressed in number of charge-discharge cycles.

Compressed Air Energy Storage

Compressed air energy storage (CAES) systems utilize compressed air that is stored during off-peak times in underground caverns that, when necessary, is eventually fired with natural gas in a combustion turbine to generate electricity. By utilizing only 30% of the natural gas that is required in traditional energy methods, CAES plants operate at an efficiency of approximately 70%.

Thermal Energy Storage

The storage of thermal energy is typically used to generate electricity by transforming solar power, even when the sun is not shining. Thermal energy plants capture the heat from the sun and store this thermal energy in water, molten salts or other fluids for the future generation of electricity. Currently, thermal energy storage plants have been successfully implemented in California, Arizona and Nevada, in which a California molten salt storage plant has successfully provided power to approximately 68,000 homes. Thermal storage technologies have also been used in the reverse by freezing water at night through the use of off-peak electricity, and then releasing the stored cold energy from the ice to assist with air conditioning during the day.

Flywheel storage system

France-based start-up Energiestro has developed a storage technology for residential PV based on a flywheel system based on concrete. A flywheel system is able to store electricity by converting it into kinetic energy using a motor to spin a rotor. The flywheel rotates at such a high speed that the electrical power is transformed into mechanical power. The proposed solution consists of a hollow or solid cylinder that is rotated around an axis and connected to an electric motor and generator the engine drives the flywheel, which accelerates and stores energy. The flywheel is guaranteed for 30 years and a change of its inverter is expected after 15 years. Currently, Energiestro offers a standard storage solution with a nominal power of around 10 kW, which corresponds to a charge and discharge cycle in one hour. The flywheel has a diameter of one meter and weighs three tons, and can be placed in the garden of a private house[1].

3.0 Software Simulation

In this step, a simulation of the Battery Energy Storage system model was carried out using a Simulink software to determine the behavior and performance of the system.

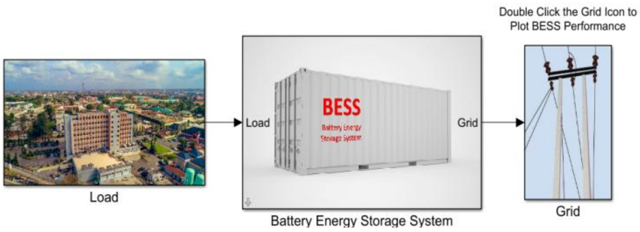

Figure 1: Simulink Model for Battery Storage system [4]

A Simulink model of Battery storage system is shown in Fig. 1 above. The model will be located within the distribution substation very close town connected at the point of common couple in between the grid transmission supply and load. It serves as energy buffer to temporary store and delivers energy under specific conditions such as time or load level to achieve the intended objective.

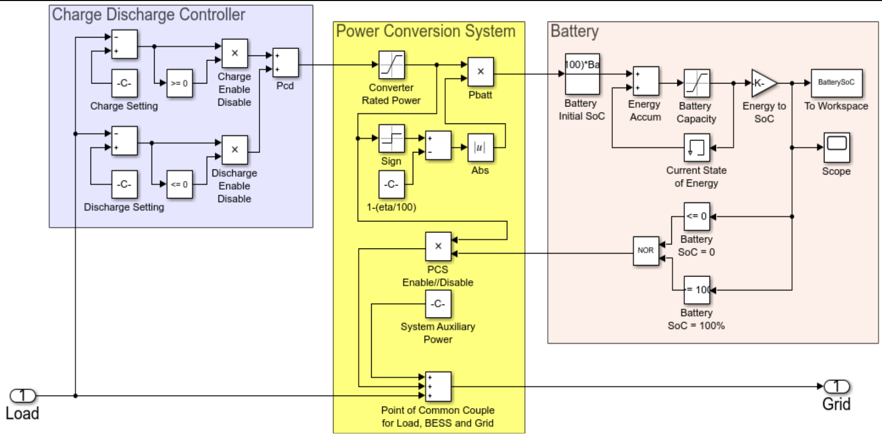

Fig 2: Simulink model for implementation of the battery storage system

Fig 2 shows the details of Simulink model for implementation of the battery storage system. The three subgroups of the battery model mask inside block, makes the understanding of the implementation and flow of the storage system. The subgroups are composed of a Battery, Power Converter System and Charge Discharge Controller. Gassing might occurwhen the battery is fully charged at this point, essentially all of the active materials have been converted to their fully charged composition and the cell voltage rises sharply. In battery, the overcharge or gassing reaction is irreversible and it results in water loss. All gassing reactions consume a portion of the charge current which cannot be delivered on the subsequent discharge, thereby reducing the battery charging efficiency[4-5].

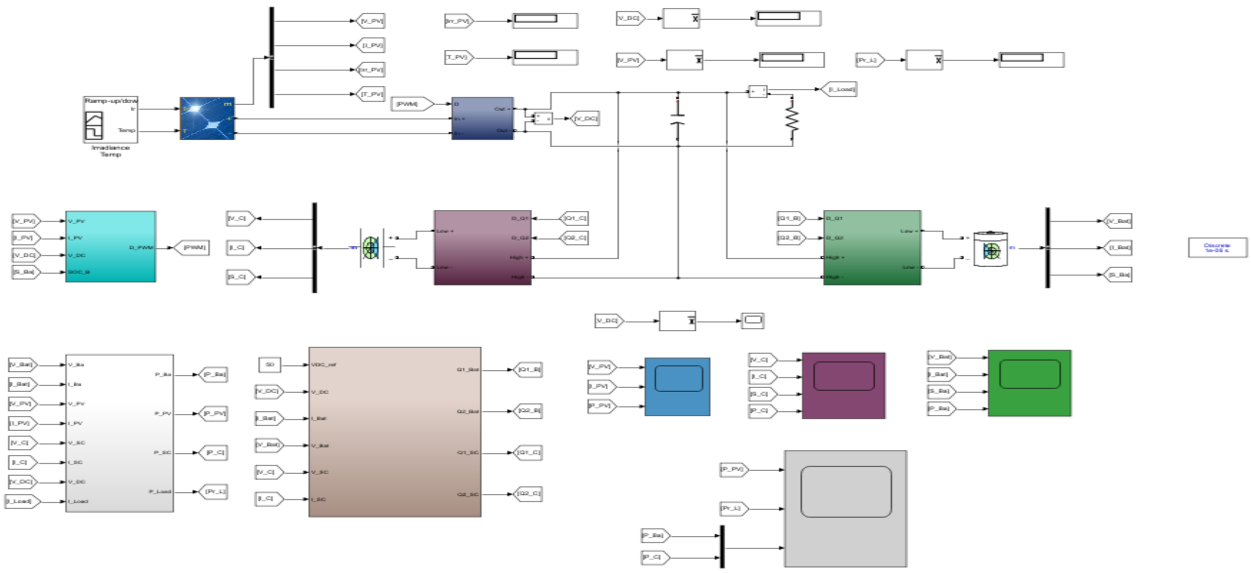
Figure 3: Model Super Capacitor Battery storage system

Fig 3 This model of supercapacitor battery storage system to store the excess power produced throughout the duration of high irradiances, or as to maintain a stable supply of power to fulfill the load demand during low irradiances, an Energy Storage System (ESS) is employed.

4.0 Result and Discussion

The Simulink results provide an accurate, reliable and easy-to-tune model of photovoltaic array. A lot of models were developed in MATLAB/SIMULINK to examine different aspects of Battery Storage system. The Simpower simulation results are shown in the following tables and figures as discussed hereafter.[4]

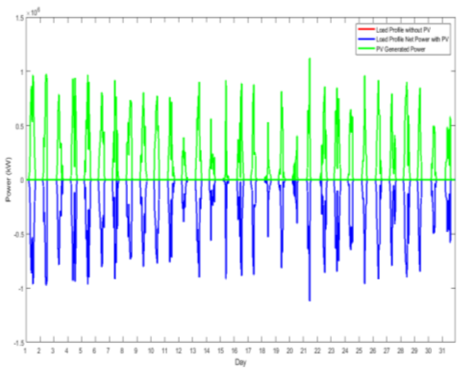

Fig 4 Load profile with & without PV power

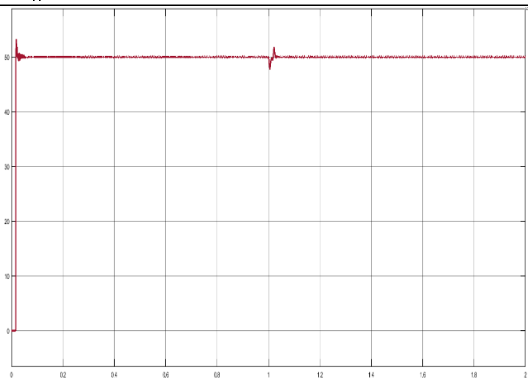

Fig 5 V_{DC}curve of super capacitor battery storage

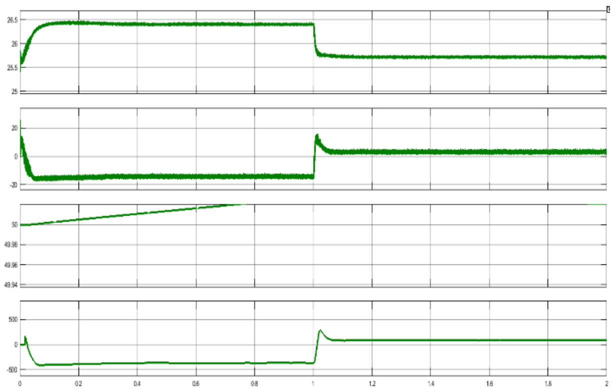

Fig 6: Battery curve of Super cap storage system

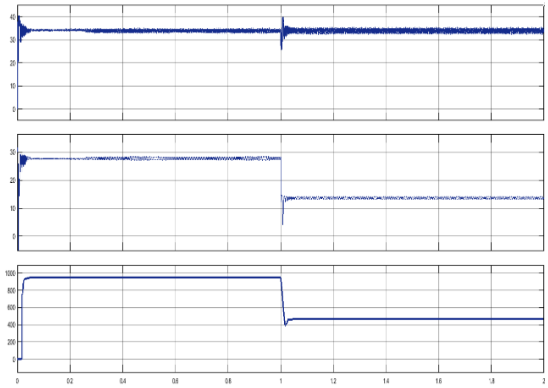

Fig 7: PV curve of Super Cap storage system

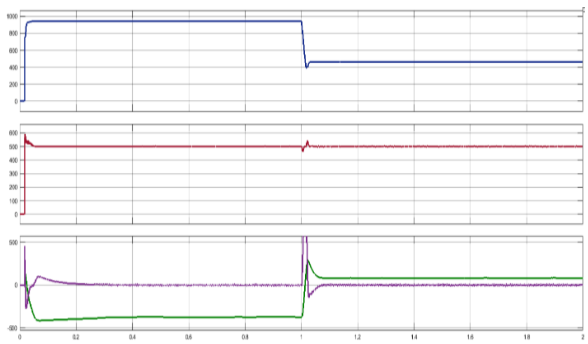

Fig 8: Power curve of Super Cap storage system

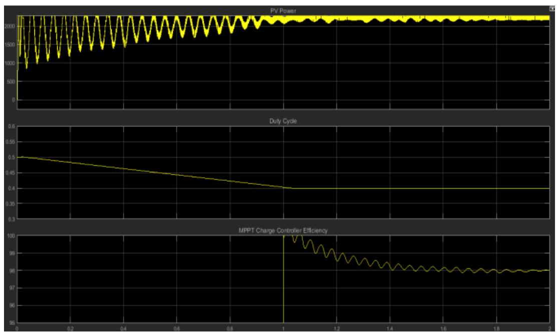

Fig 9: PV waveform of Power Duty cycle efficiency

Fig 4 to 9 show the graph of the behavior of various parameters of Super Capacitor storage system.

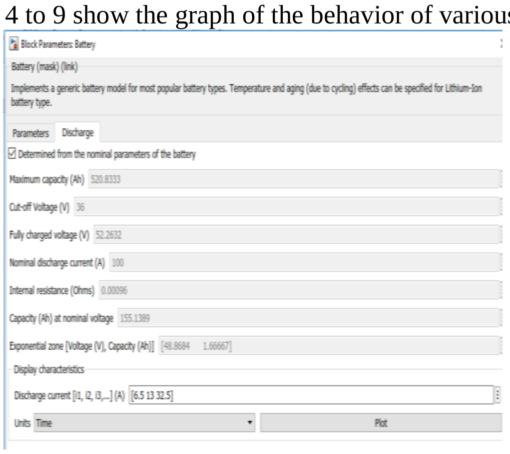

Fig 10: Block Parameters of Battery

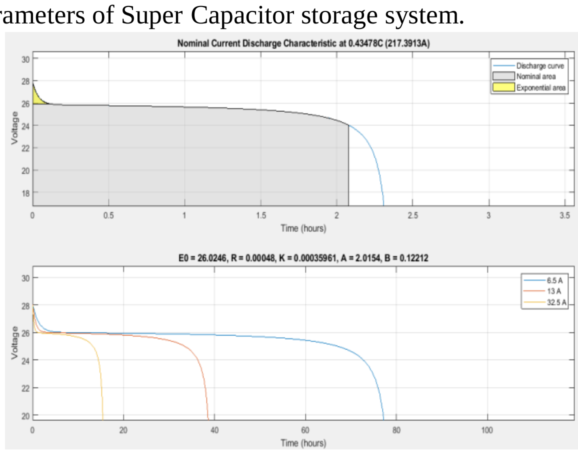

Fig 11: SOC Waveform of Battery discharge properties

Figure 11 shows the discharge characteristics of the battery at rated discharge current and all parameters can be calculated. The first graph represents the battery terminal voltage under charge and discharge conditions of the battery. The second graph represents the state of charge of the battery [4-8].

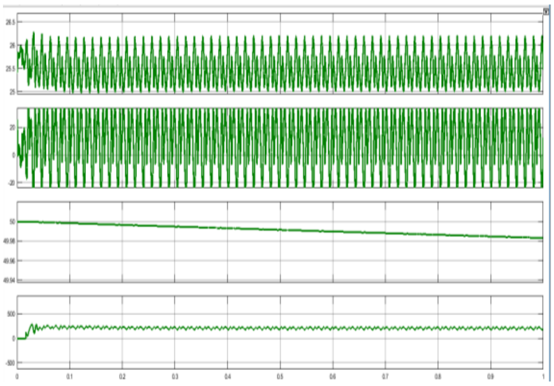

Fig 12: Waveform of the Battery scope

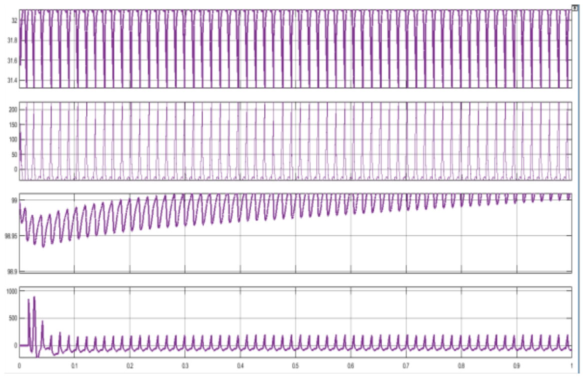

Fig 13: Waveform of the Super Cap Battery scope

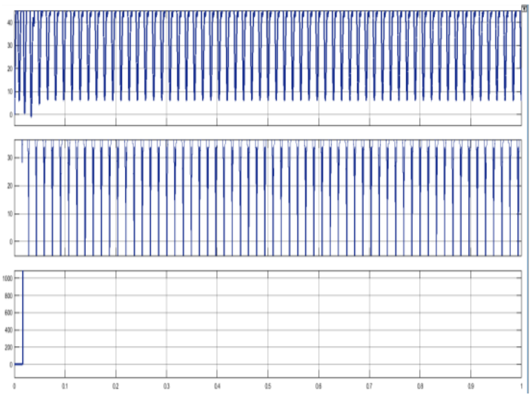

Fig 14: Waveform of the PV scope

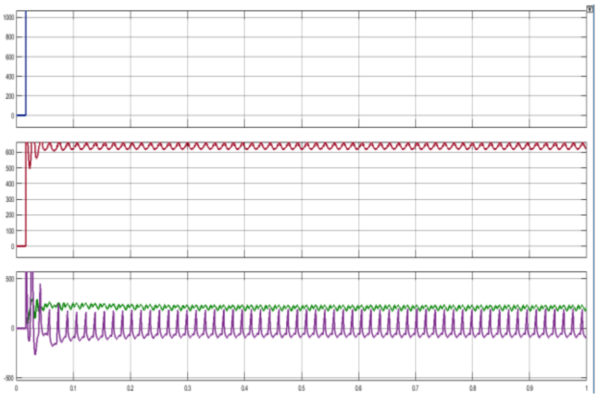

Fig 15: Waveform of the P_ scope

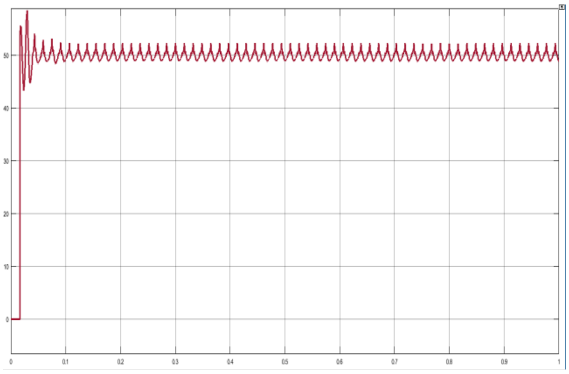

Fig 16: Waveform of the PV scope

5.0 Conclusion

Battery Energy storage system plays an important role in the evolution of renewable energy technology, more especially photovoltaic energy system. This Battery Storage technology is employed to store the excess power produced by solar panel during high irradiances so as to provide uninterrupted power to realize the load demand during low irradiances or grid collapse. Several other energy storage methods were highlighted in this paper but not detailed. Simulation of grid-tied Photovoltaic Battery Storage system using SimPower.were carried out. The model determined the appropriate battery sizing (power & capacity) of an Energy Storage System equipment connected to Owerri Urban electrical distribution network. The results showed the proposed model met the load demand and showed satisfactory performance.

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