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Investigation of behavior of BESS with PV using MATLAB/Simulink

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Abstract: As renewable energy penetration rises, integrating it will become a major issue that will necessitate new generating support infrastructure; an energy storage system is one answer to this problem. Battery technologies, in particular, have a wide range of energy and power output capabilities, making them perfect for integration. In many regions where renewable energy generation systems will be implemented, distributed energy storage on distribution grids may be required. When the sun is not shining or the weather is cloudy, an energy storage system is required for solar photovoltaic systems. For PV applications, a battery is used as an energy storage system.
Keywords: Energy storage system, Battery, Simulink and modelling.

I. INTRODUCTION

Many power systems already have energy storage. Pumped hydro storage facilities account for nearly all of the current energy storage capacity. These necessitate big territories, unique geographical factors, and significant capital commitment. As a result, they're strategically positioned and have direct access to high-capacity, high-voltage transmission lines. These huge, central storage facilities do not directly help small distribution grids and weak transmission lines, especially when the intermittent generators are positioned towards the end of the line on such distribution grids. Smaller distributed storage solutions are necessary to address these concerns [4, 5].

Several battery chemistries, flywheels, compressed air, hydrogen, and capacitors are among the energy storage technologies accessible. This study focuses on batteries because they offer a wide range of power and energy storage capacities, are geographically unrestricted, have minimal parasitic losses, are relatively efficient, can be deployed across the grid, and are modular and scalable. Other technologies lack one or more of these essential features for distributed deployment. [3] shows the mathematical modelling of a PV system. In [7, 8] describes how to design a filter for an inverter system with a PLL for grid synchronization.

II. ENERGY STORAGE'S SIGNIFICANCE

Energy storage systems will be crucial in the integration of renewable energy sources with a high penetration rate. Before delving into the specific tasks, it's important to consider the typical duties that energy storage devices have served in the traditional electric grid. Energy storage systems are already widely employed for traditional grid support in a range of applications in various countries, with around 2.5 percent, 10%, and 15% of total power being cycled through energy storage in the United States, Europe, and Japan, respectively [6].

The duration of the charge/discharge cycle divides energy storage used for electricity grid services into three categories: short, medium, and long. The power and energy parameters required of the storage are the main distinction between the duration groups. The short duration category is concerned mostly with power quality and lasts up to one minute. The power characteristics of the storage are specified in this category.

To compensate for the temporal imbalance between production and demand, the medium duration category covers minutes to hours. Because it must respond to variations in generation/demand for several minutes or longer, the medium category specifies both power and energy characteristics of storage.

The extended duration category determines the energy characteristic of the storage by providing energy wheeling services across hours and days and control discussed in [9, 10,11,12,13].

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III. BATTERY ENERGY STORAGE SYSTEM MODELLING

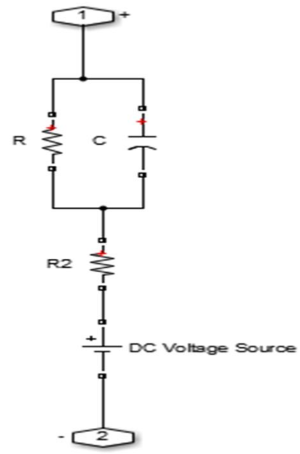


Figure 1 Mathematical modeling of BESS

One of the technologies for storing electrical energy is the battery energy storage system. The voltage of the battery should be higher than the voltage of the DC link. Because the DC voltage in our situation is around 1150 V, the battery voltage is set to 1200 V.

In the proposed system, the battery can store 950 KW of power at rated conditions and deliver it to the system when the irradiation changes suddenly. Under these conditions, the battery bank's storage capacity is estimated to be 1 MW h. Commercially accessible battery cells have a capacity of 12 V and 150Ah. We have a series of battery cells, each of 12 V, and the battery bank should have connected (1150/12) = 96 number of cells in series to get a dc bus voltage of 1150V. And (1MW/1150V) =869.56 Ah is the total Ah required. The total number of sets required for parallel linking would be (869.56Ah/150Ah) = 5.79 or 6.

Thevenin's model is used to represent battery energy storage, which uses a parallel combination of resistance Rb and capacitance Cb in series with internal resistance R and an ideal voltage source of voltage 1200 V to model the battery." [6] calculates the equivalent capacitance "Cb= (KWh*3600*1000)/ 0.5(V_{ocmax}^2-V_{ocmin}^2)

Taking the value of Voc max=960 V, Vocmin=940V, and KWh= 1000, the value of C_b obtained is 219512.2 F.

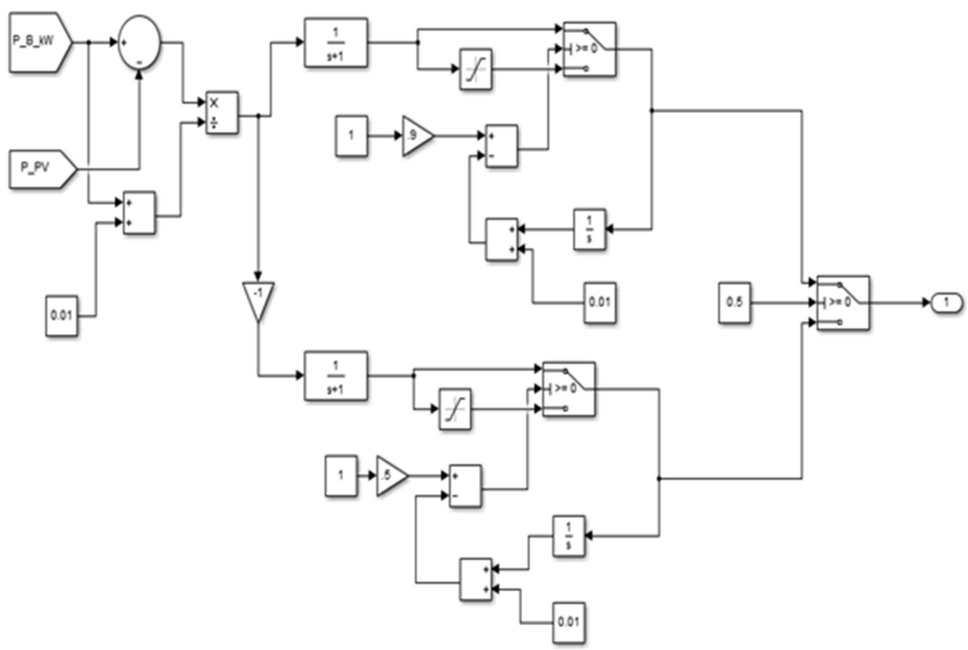
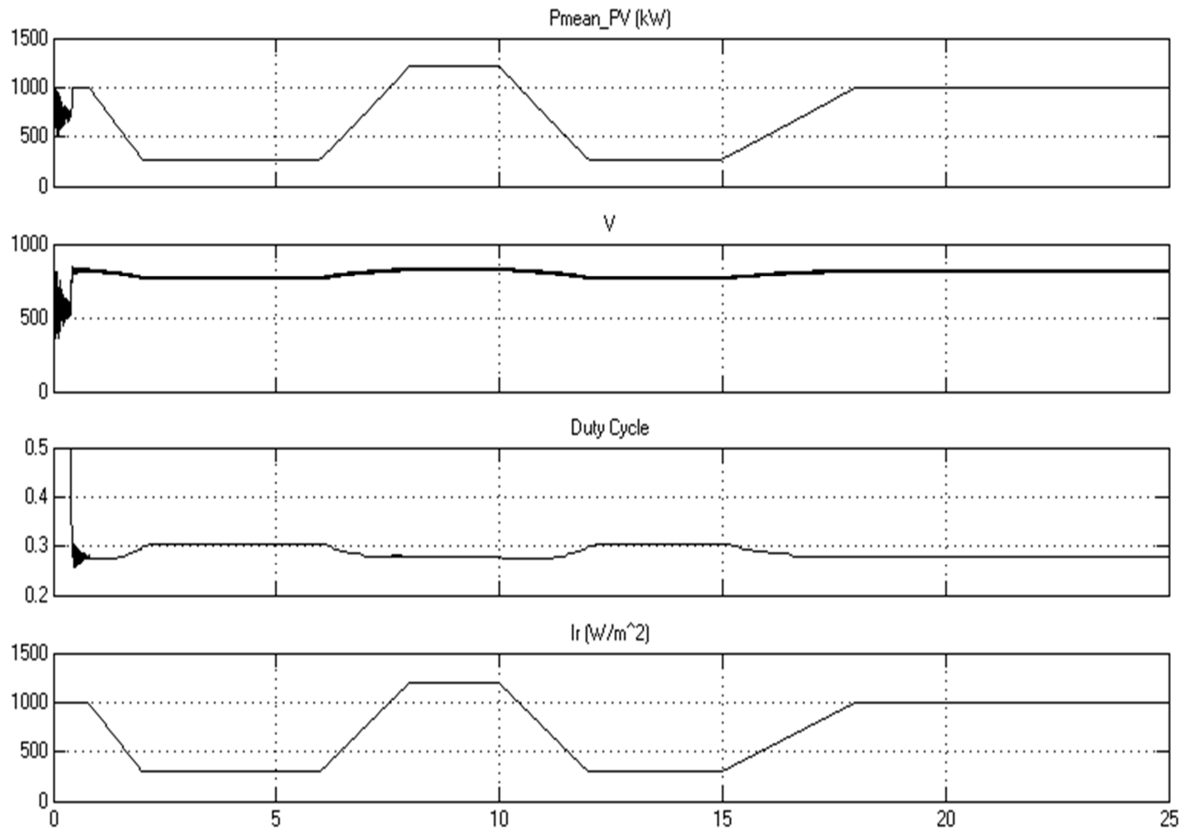


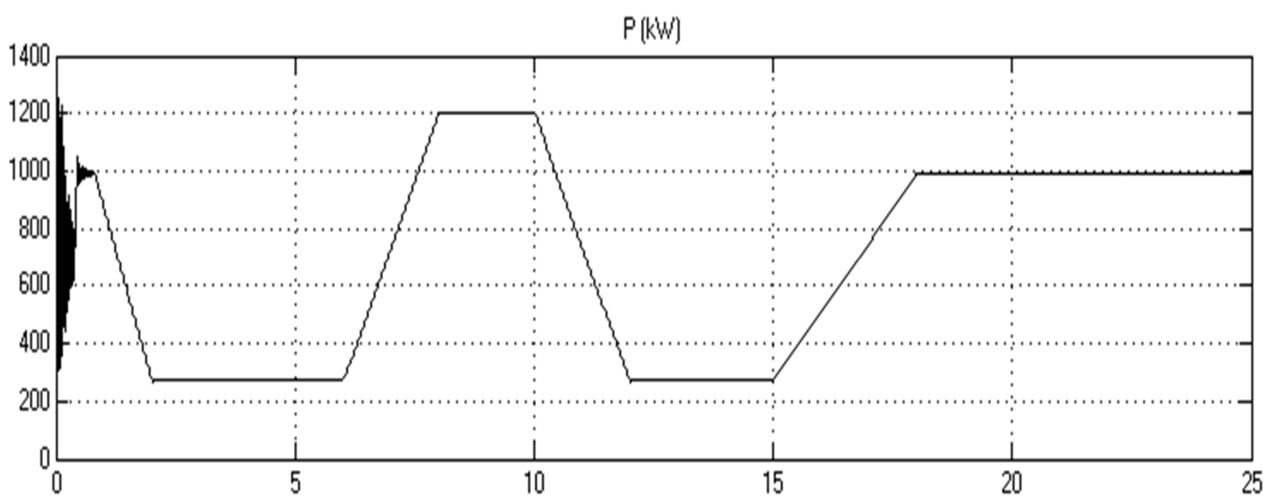
Figure 2 BESS control block

IV. SIMULATION STUDY OF THE SOLAR SYSTEM WITHOUT BESS

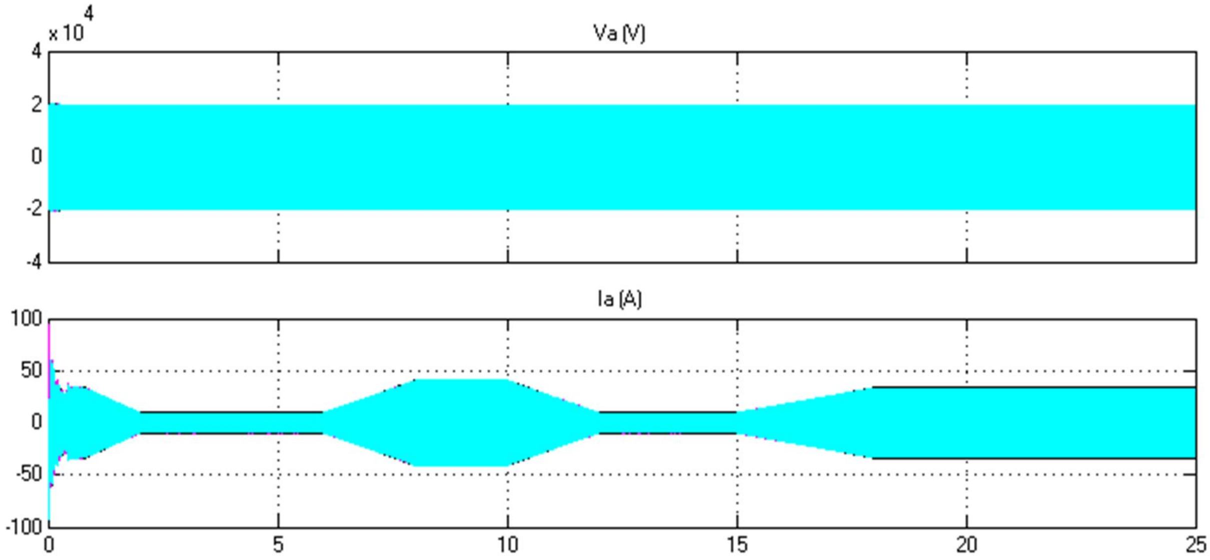
The simulation's objective is to look at how the system reacts to varying levels of irradiation. This is a scenario that occurs when clouds move over the PV array, blocking direct sunlight from the sun. While monitoring the DC current and voltage of the PV array and the associated power electronics interface, in fig 3 (a) the array was subjected to a sudden change in solar irradiation from 1000 to 300 W/m2 at t=4 sec, further change from 300 to 1200 W/m2 at t=9sec, and again irradiation change from 1200 to 300 W/m2 at t=14sec and 300 to 1000 W/m2 at t=19sec.



(a) Array power, voltage, duty cycle and irradiance



(b) Power at set point B



(c) Grid voltage and current

Figure 3 Behavior of system under irradiance change

As showed in fig 3, the effect of abrupt irradiation level fluctuates at different times and has an immediate effect on the DC output voltage and current. The converter moved the operating voltage to a new value that corresponded to the new maximum power point as a result of the predicted voltage change due to irradiation change. The array current, which is highly dependent on solar irradiation, decreased to 310 A from 1000W/m2 at the start.

The inverter controller worked on setting a new reference current for an inverter to match the output power to a new control set point as the input power to the DC link capacitor decreased.

The duty cycle and switching frequency of the boost converter's switching signal were investigated. During the initial transient phase of the simulation, the duty cycle of the switching signal is around 0.5 in fig 3 (a). The frequency of switching is set to 5 KHz. After the MPP has been found, the variable irradiation operation phase is completed. The duty cycle of the converter was changed as shown in fig. 3 (a), as indicated in fig. 3.

Figure 3(b) shows the system's power output at set point B. Following an initial transient, the power flow to the grid is adjusted in response to changes in irradiation. Figure 3(c) depicts the grid voltage and current.

V. SIMULATION STUDY OF THE SOLAR SYSTEM BESS

We discussed the simulated outcome of a solar PV system in various irradiation conditions in the preceding section; the power feed to the grid was altered in response to the change in irradiation. When the irradiance varies, the system should provide power. In a previous chapter, we discussed how to model a battery energy storage system.

Figure 2 depicts the control block sub-system. The BESS control system has two loops: one for charging and the other for draining the battery within a certain range.

The battery's SOC ranges from 0.5 to 0.9. When the battery is discharged and unable to feed the required power, the SOC is 0.5, and when it reaches 0.9, the battery is able to give the required power to the grid.

The control system for a battery energy storage system is shown in Figure 2, which is modelled in a per unit system.

The control signal for the circuit breaker block, which works according to the signal, is shown in fig.

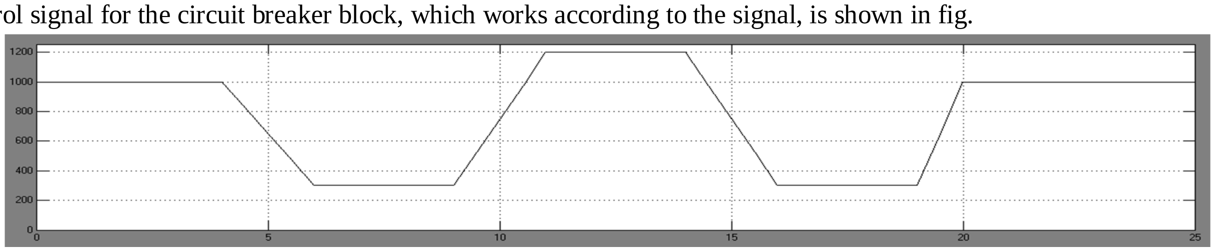


Figure 4 Irradiation change

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When the irradiation changed from 1000W/m2 to 300W/m2 at t=4 sec, the battery began producing power and continued to do so until the irradiation changed and the battery began to deplete. One circuit breaker is closed when the battery is being discharged, while the other is open. The battery was started charging at t= 9 sec after the irradiation was changed from 300 to 1200W/m2, and the battery was able to store energy throughout this time.

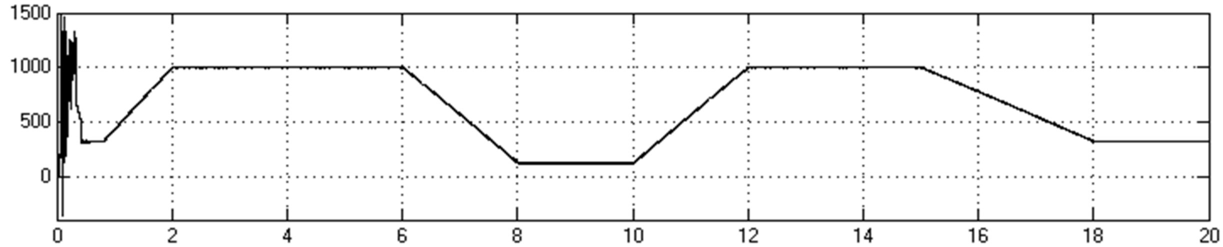

Figure5 Battery current

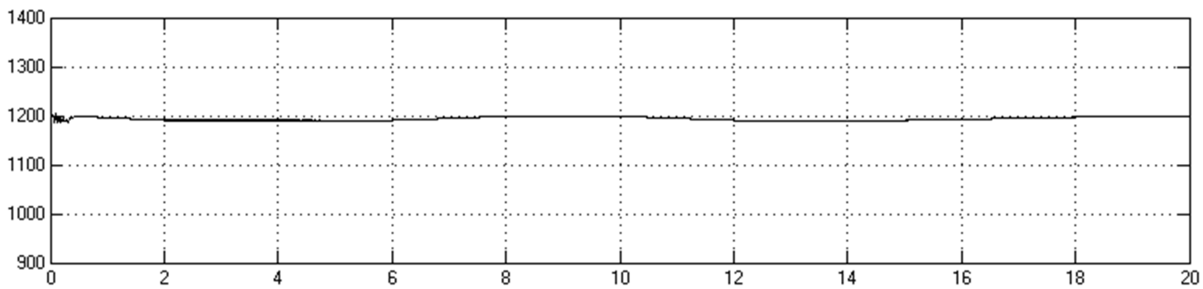

Figure 6 Battery voltage

The current and voltage responses of the battery during charging and discharging are shown in Figures 5 and 6. When the battery is discharged, the voltage drops and the current rises; similarly, when the battery is charged, the voltage rises and reaches its nominal value, while the current falls and the wave shape remains constant until the next irradiation change occurs.

VI. CONCLUSION

In this study, a mathematical model of a battery is presented, as well as a battery control system that protects the battery from overcharging and discharging. For a 1 MW solar PV system, BESS was built and modelled. According to the study, battery energy storage is essential to give electricity to the system when the sun is not present or when the weather is cloudy.

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