MODELLING AND SIMULATION OF PV-BES BASED MICROGRID SYSTEM OPERATING IN STANDALONE MODE

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Abstract. This work presents, a novel PV-Battery Energy Storage based microgrid system operating in standalone mode. The output of Solar PV changes with varying atmospheric condition. A boost converter is utilized as a DC-DC converter which extracts the maximum power coming out from the solar PV array, with the use of P&O algorithm. Battery Energy Storage System (BESS) is introduced to supply load uninterruptedly. In this project, lead acid battery is used. The energy management is done by the battery control mechanism. Battery and load are connected in parallel with the dc-dc boost converter. Based on the power generation in PV, battery gets charged and discharged. There are two cases considered in this project. In first case, both the load and battery is supplied with generated PV power. In second case, load is supplied with the help of both battery and the Solar PV. The proposed system is modeled and simulated in MATLAB. Parameters like battery current and voltage (Vbat,Ibat),load current and voltage (Vdc,Iout), SOC level of battery are observed and analyzed.

Keywords: Converter, MPPT, PI controller, Photovoltaic (PV) array, State of charge (SOC), Battery.

1 INTRODUCTION

Sunlight energy is the best renewable resource in the world. It has many advantages. They are clean in nature, easily available and involve less maintenance [21]. Solar PV is dependent on atmospheric weather condition. As solar PV has non-linear characteristics, the output from the solar PV system will be changing with varying irradiation. To track the maximum power various maximum power tracking techniques are available. They are Perturb and Observe (P&O), fuzzy control, incremental conductance, fractional open circuit voltage and short circuit current based MPPT control approach. P&O technique (algorithm) is used to track the maximum power from the PV array in this paper, because it’s simple and need low computations. To have uninterrupted power supply, a battery charger with a controller is used. Here lead acid battery is used [4]. To maintain load in efficient condition, battery should be charged and discharged based on the power generation in PV side. Battery is controlled with help of PI controller through bidirectional dc-dc converter [2-3]. SOC is an indication of level of charge of electric battery relative to its capacity. There are some challenges in implementing the system. Load management will be poor, while there is deficit in power from both Solar PV and the battery. Maintaining the SOC level of battery would be challenge. As SOC level determines the lifecycle of battery, it should be maintained with minimum capacity. Grid incorporation with the Solar PV is a big challenge, while doing load and energy management. The designing of Voltage Source Converter (VSC) is necessary to invert the voltage as ac from dc, for supplying the ac load. In this paper, proper energy management is done with the help of battery and solar PV system with MPPT (P&O) technique.
In the paper [2], battery charging mechanism in High Penetration Photovoltaic Array is explained with the simple and efficient control algorithm, which charges and discharges the battery according to the SOC level. This method gives the proper energy management with the efficient working of battery and its lifecycle.

In the paper [3], the charge controlling techniques in Solar PV system is presented. Proposed system controls the charging mechanism with the help of switching operation. Switches are controlled using load switching control programmer and the battery is maintained in programmed SOC level.

In the paper [9], optimal battery charging technique based on decreased charging current method is presented. This method uniformly charges the battery. It reaches the full capacity (100%-SOC) in the short period without gauging batteries current. Thus it can be used in large battery strings effectively.

In the paper [1], the seamless transition of microgrid from GC mode to SA mode when the grid fails and the reconnection to the GC mode after the clearance of fault is carried out with effective battery management.

In the paper [4], they reviewed the lead batteries for utility energy storage, and the paper explained various lead related batteries and its capability according to its construction and designing methods. The comparative study is also done by comparing lead batteries with all other battery chemistries and highlighted how lead batteries have been adapted in recent developments.

**Solar PV System**

2 BATTERY CONNECTED SOLAR PHOTOVOLTAIC (PV) SYSTEM

Energy Storage System playing an important role in the Solar system. PV array will not supply constant voltage due to its non linear nature. Thus, to meet the load demand we need some energy storage to store the surplus of energy generated in PV and to use it while the lack of solar energy, to satisfy the load demands. In this paper lead acid battery is used because of its low cost and it is easily available and it has effective and efficient lifecycle. The energy management is done by battery which is connected in parallel to load through bidirectional dc-dc converter, which makes battery to charge and discharge effectively, based on the level of SOC. Bidirectional dc-dc converter (BDDC) is getting its switching signal from the PI controller through PWM generator, with which bidirectional dc-dc converter makes charging and discharging of the battery effectively. Similarly dc-dc (boost) converter plays an important role to convert varying dc to constant dc, which also performing the boosting of voltage with the switching (gate) signal obtained from the MPPT Controller. Thus, load is supplied either with Battery or Solar PV or with the both. Same time, battery is charging from PV while there is surplus of energy is detected in the PV side and discharging while deficit of energy detected in load side. Here all the charging and discharging mode is simulated and explained with the MATLAB simulation of Battery Connected Solar PV system.

2.1 PV Operation

Solar cells are wired together to form a module (PV Solar Panel). Solar Panel System is formed by joining PV Modules together. Solar PV is the collection of solar cell and is the basic building block of system. Solar PV system works with the photovoltaic effect, which converts light energy (solar energy) into electrical energy (direct current electricity). 1KW PV Panel is designed in this paper. Output voltage is varying in nature, due to non linear characteristics of PV. DC-DC converter (boost converter) is integrated with solar PV system to get the constant dc as output and is obtaining the maximum power from Solar with the help of switching signal obtained from the PWM generator [5]. With duty obtained from MPPT, PWM generates switching signal.
2.2 MPPT Technique

As solar modules are relatively high in manufacturing cost and having low efficiency (about 13%), it is really important and necessary to operate the Solar PV system at the Maximum Power Point, in all the environmental and atmospheric conditions. So, gate signal for dc-dc (boost) converter is obtained from the PWM (pulse width modulation) generator, which will get the duty signal from MPPT controller [17-18]. MPPT is nothing but the complex and expensive controller, which optimizes the match between Solar PV panels and battery or utility load without need of voltage matching [7]. This controller makes the system as more effective and performs an efficient operation in tracking maximum voltage. Maximum power of Solar panels are utilized by MPPT effectively, either to meet the load demand or to charge the battery. There are several Maximum Power Point Tracking techniques have been used, like Perturb and Observe (P&O), fuzzy control, incremental conductance, fractional open circuit voltage and short circuit current based MPPT control. In this paper, P&O (Perturb and Observe) technique is used because it is so simple and for that algorithm low computation is needed. In P&O technique small magnitude of voltage is perturbed and for that change of voltage, how much power is changing is observed. The working point of PV will be moved far away from the maximum power point and the perturbation’s direction will be inverted to return MPP when the change in power reaches less than zero. Climbing the power curve is done in this P&O method for reaching the MPP (Maximum Power Point). Thus the technique is also called as “Hill Climbing Technique”. By this technique, maximum power point is found and duty signal is generated and is given to the PWM generator which gives gate signal to the dc-dc (boost) converter [19]. The algorithm of P&O technique is shown in fig.1

![Fig.1 P&O Algorithm](image)

2.3 Battery Energy Storage System

Energy Storage System plays a vital role in energy management. Here lead acid battery is used to manage energy [16]. Since, load demand should be met by the system even the irradiance is less. That can be done only with the energy storage and is done with battery [20] in this paper. The paper took two cases to give good energy management with the battery and load. While the power generation in PV array is less than the required power for the demand, both the battery and PV should fed the load. Both battery and load is fed with PV power, while generated power from PV is greater than the required power for the load (that is if surplus of energy is available). Battery should get charged to increase the SOC level. This is done to maintain the constant voltage on the coupling point [6]. For that we need some battery control technique, which will control the battery accordingly to charge and discharge [8-10]. Here PI controller is used to control the battery, which generates duty signal. Duty is converted as switching gate signal by PWM generator. Gate signal is given to IGBT in the bidirectional dc-dc converter (BDDC). Then switches will switch accordingly to charge and discharge the battery.
3. BLOCK DIAGRAM

Fig. 2 shows the overall operation of the simulation done in this project. This project deals with the energy management. The power supply is obtained from Solar PV system, which supplies the load and the battery energy storage system (BESS)[1]. Loads considered in this project are dc loads like, dc fans, dc bulbs, mobile charger etc., Many control mechanisms has been employed to track maximum power from solar PV. In this project P&O (MPPT) technique is used [22]. The energy management is done by the battery control mechanism. Battery and load are connected in parallel with the dc-dc boost converter [11].

Based on the power generation in PV, battery gets charged and discharged. There are two cases considered in this project. In first case, while PV generates enormous power both the load and battery is supplied with PV power. In second case, load is supplied with the help of both battery and the Solar PV system. Those control techniques are explained and energy management is done in this project, which are simulated and shown with help of simulation diagrams. While comparing with existing models like Solar PV system supplying the load, this model works efficiently and simply with ease calculation and algorithm.

Simulation and Results

4 MATLAB MODEL OF THE PROPOSED CIRCUIT

The Solar panel generating 1KW is designed with the supply of irradiance and temperature. Since, irradiance and the temperature are the input for Solar PV generation. Boost converter is connected in parallel to the solar PV to convert the varying output from the PV to constant voltage and to boost the voltage. Boost converter’s switching gate signal is produced with the help of PWM generator by getting duty signal from the MPPT controller. MPPT controller is used to obtain the maximum power point in solar. P&O (Algorithm) technique is used here. Load is connected across boost converter, which is coupling point of battery, load and the boost converter. Battery is connected in parallel with the load through bidirectional dc-dc converter. To perform both the charging and discharging process of battery, Bidirectional dc-dc converter is used. To have the good energy management, Battery Energy Storage System is used [12-15]. Battery will supply the load when PV generates less power than the load demand (i.e. Battery is discharged). Similarly, Battery will get charged if the generated power is more than the load demand. In this paper, battery is controlled with PI controller. PI
controller generates duty according to the reference battery current and the actual battery current. Then
duty signal is sent to PWM generator to give switching gate signal the bidirectional dc-dc converter.
According to the gate signal given to converter, battery performs charging and discharging. The
MATLAB model for the circuit is given in the fig. 3

Fig. 3 Simulation Diagram of PV-BES microgrid system operating in standalone mode

Fig. 4 Output waveform of Solar PV system before connecting to the battery (scope)

Fig.4 shows the output waveform of the solar PV system alone, which is not connected to battery.
Output of the simulation without battery management and coupling point control is observed. Here,
V_{dc} (load voltage) and I_{pv} (PV array current) are changed with irradiation. I_{load} is changed because V_{dc}
is changed. P_{pv} is the PV power which is changing according to the irradiation. V_{pv} (PV voltage) has
been constant. These are all the output waveform of voltage and current for the respective irradiance and PV voltage and current.

Fig. 5 shows the output waveform of Solar PV system after connecting the battery to the system. Because of battery get connected to the system voltage is controlled and maintained as constant in common coupling point. As $V_{dc}$ is maintained as same as reference voltage given, load is supplied uninterruptedly. While irradiation reduces, battery supplies the load. Similarly, battery gets charged while PV power is surplus to fed the load. Ripples in $V_{dc}$ are due to change caused in irradiation. Fig. 4,5 shows that both the voltage in PV side and load side are kept constant after the system is connected to the battery. Thus the proper energy management of the solar PV system is done with the battery management technique.

Fig. 6 shows the output waveform of Battery connected Solar PV system supplying load (scope 1)
Fig. 6 shows the output waveform of Battery connected solar PV system connected to the load. Changes in SOC level is observed in the obtained waveform, which clearly shows all the charging and discharging conditions (modes) of battery according to the power generated in PV. While battery gets charging, its voltage increases with decrease in current decreases. Similarly, when the battery is discharging, the battery voltage decreases and the battery current increases and is shown in the fig. 6. The voltage at the load side is maintained as constant according to its reference voltage given, with some fluctuations which are caused due to change in the irradiation level. \( P_{pv} \) of the PV array is also shown in the fig.6. If the generated power in the PV is enough to supply the load, then battery will be in constant mode. If the generated power is surplus, then total load will be supplied with PV power. Battery will be charged according to surplus power generated. In other case, both battery and PV will supply the load while generation is not enough (i.e., in deficit condition). The same is shown in the fig. 7, which shows all the deficit and surplus condition of power generation.

![Fig. 7 Output waveform of Battery connected Solar PV system (scope 1)](image)

5 CONCLUSION

Thus the output waveform of the battery connected solar PV system is simulated and its effective operation is observed. This paper had discussed the Solar PV system with MPPT technique supplying load, which is connected with battery and battery control mechanism. The load and energy management operates effectively as anticipated and according to the algorithm.

As a future work, grid will be incorporated with this and the simulation should be done to have the effective and efficient load and energy management. Since, when both the battery and solar PV fails to supply load, grid should be connected to the load side to get the uninterrupted power supply, with which battery can also get charged. To have the good lifecycle of battery, it should be monitored in the basis of SOC and it should be used accordingly.

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