International Journal for Modern Trends in Science and Technology, 7(12): 235-240, 2021

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0712046
Available online at: http://www.ijmtst.com/vol7issue12.html

A Novel Integrated Converter with Demand Side Management in Stand Alone PV/Battery Hybrid Microgrid

Tadiboina Titumala Rao, K Venkata Kishore

Department of Electrical and Electronics Engineering, NRI Institute of Technology, Agiripalli, Vijayawada, Andhra Pradesh, India.

To Cite this Article
Tadiboina Titumala Rao and K Venkata Kishore. A Novel Integrated Converter with Demand Side Management in Stand Alone PV/Battery Hybrid Microgrid. *International Journal for Modern Trends in Science and Technology* 2021, *7* pp. 235-240. https://doi.org/10.46501/IJMTST0712046

Article Info
Received: 12 November 2021; Accepted: 05 December 2021; Published: 16 December 2021

ABSTRACT

Energy produced from conventional sources like coal and diesel is inadequate due to ever increasing demand for power. Generation of power from renewable energy sources to meet the gap of supply and demand is intermittent in nature. Hence there is need for storage of energy from renewable sources to ensure continuity of supply. Secondary batteries based on electrochemical principle are commonly used for energy storage in hybrid energy generation systems, portable devices, electric vehicles etc. Since batteries are also becoming the primary source of power for many small to large power applications, it is necessary to protect batteries from over charging and over discharging to ensure their efficient operation. Thus, battery protection system with Battery Management System (BMS) has become an integral part of all applications. The functions of BMS include monitoring and charging. Hybrid energy systems have also incorporated the energy management function into the BMS to ensure efficient and continuous power supply. Monitoring of batteries involves determination of state-of-charge (SOC), state-of-health (SOH), temperature monitoring and cell balancing. The types of charging include constant current, constant voltage and pulse charging. Energy management involves coordination of sources and loads for maximum utilization of available power. This thesis deals with some aspects of each of these three components, i.e., monitoring, charging and source/load management, of a BMS. In particular, monitoring of battery from the source side is examined for online determination of SOC and SOH

KEYWORDS: Solar PV System, Battery, SOC, SOH, Energy Management

1. INTRODUCTION

Batteries are used either as a primary or as a secondary storage of energy for many applications. The secondary storage batteries are subjected to charging and discharging periodically. The charging/discharging cycles degrade the performance of the battery, thus reducing its efficiency in terms of capacity to hold charge. Since batteries operate by converting the chemical energy in the electrolyte into electrical energy, the degradation affects the chemical reactions as well as the interaction between electrode plates and the electrolyte. The latter is also due to deposition on the electrodes. The battery performance is also affected due to aging.

The performance degradation of a battery needs to be monitored so that once the performance in terms of storage capacity and energy delivery falls below a threshold, the battery can be replaced. The performance degradation of a battery is measured in terms of state-of-charge (SOC) and state-of-health (SOH). The SOC is the total amount of charge left in the battery, and is expressed in terms of percentage of the total charge that the battery in its present condition can hold. The SOH is the percentage of the total charge of a fully charged new battery that a fully charged battery in the current condition can hold.

Battery protection scheme are developed to protect and monitor the battery condition to improve the battery operation. The protection scheme is also used to keep track of charging of the batteries as well as management of sources of energy and loads. Fig.1.1 shows the functions of a typical Battery Protection System (BPS).

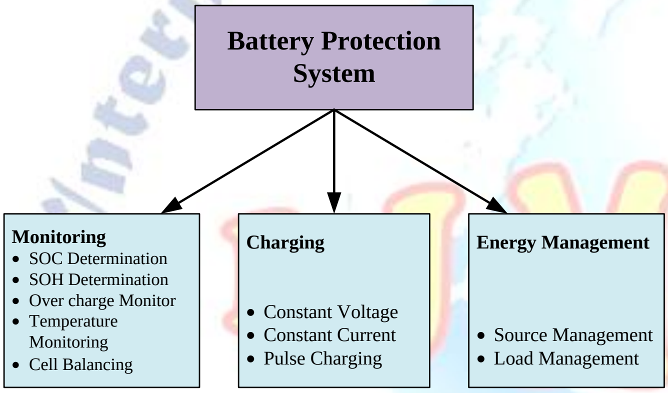

Figure 1.1 Functions of Battery Protection System

Impedance analysis of battery helps in understanding the battery behavior, and hence is useful for battery monitoring. Different models of battery are used to interpret the measured impedance. For example, by applying a known load, the discharge side measurement of voltage and current can give the ohmic resistance of a purely resistance model of the battery. The resistance indeed increases with decrease in the SOH of the battery.

Batteries are usually charged either by constant current charging or constant voltage charging or pulse charging. Pulse charging is shown to be effective for charging the batteries, as it reduces the gassing effect and depositions on the electrodes. The ON/OFF pulses at some specified rate are applied. Since in the OFF period the battery circuit is disconnected, the resulting responses are for two different states, namely for the ON state when the battery is connected and for the OFF state when the battery is not connected. While the purpose of pulse charging is only to charge the battery, the battery conditions can also be evaluated from the time it takes to charge fully. A degraded battery takes more time to reach fully charged condition. Also, during pulse charging, if the voltage is restricted to within certain limits, then it is observed that the width of the pulse reduces with time for a degraded battery.

For pulse charging the applied voltage of the pulse is higher than the rated voltage of the battery. It is interesting to note that the transient response of the battery to such large amplitude voltage pulses indicate the battery condition, as the transient responses during the rising and falling parts of each pulse are dependent on the internal resistance and capacitance of the battery.

The proposed system consists of three stages: power management system, battery protection and supervisory control. Power management system is responsible for scheduling power flow between the microgrid sources, battery and loads on economic analysis. Battery protection scheme is responsible for protection of battery from overcharging and over discharging. Supervisory control is responsible for compensating the mismatch power between the schedule power and microgrid power. This paper is organized as follows: Section 2 explains DC microgrid, section 3 explains power management system, section 4 deals with battery protection control scheme, section 5 deals with simulated performance. Finally section 6 conclusions are reported.

Battery Model:

Equivalent circuit modelling of electrical systems is used to represent the phenomenon of the system with electrical elements, like resistors, capacitors and electrical sources [1]–[2]. Battery models are also developed to represent the chemical behavior either in combination of resistors and capacitors, or as mathematical equations. Changes in the model parameters are interpreted in terms of changes to the phenomenon of the battery to express the state of the battery in terms of state-of-charge (SOC) and state-of-health (SOH).

Electrochemical models are used for studying the chemical behavior of the battery, enabling optimum design of batteries [3]-[8]. These models are generally used to model the power generation mechanisms, and relate the battery design parameters with macroscopic (battery voltage and current) and microscopic (concentration distribution) information. The study of electrochemical models is complex and time consuming, because they involve a system of coupled time varying partial differential equations [9], the solution of which requires days of simulation time with complex numerical algorithms. Also, the battery-specific information is difficult to obtain from the solution.

Mathematical models are mostly used to predict the battery system level behavior like battery runtime, efficiency and capacity [10]-[13]. They do not offer any relationship between the voltage and current of the battery. They are mostly abstract, and are not useful to study the chemical behavior. Designers adopt the empirical equations or mathematical models in specific applications [14]. The results are also not very accurate. For example, the maximum error of Peukart's law for predicting runtime behavior can be more than 100% for time variant loads [15].

Electrical models, based on universal equivalent circuit concepts, model the battery behavior in terms of electrical elements like voltage source, resistors and capacitors [16]-[18]. The variation of the circuit parameters values is correlated with the battery behavior. Most common electrical models are: Thevenin [19]. impedance and runtime-based models.

The simplest Thevenin model consists of a voltage source in series with a resistance. But modelling a battery as a source and resistance alone does not predict the runtime behavior, since during runtime the voltage and current change.

LOAD MANAGEMENT SYSTEM:

The proposed scheme is shown in Fig. 2. From this diagram it can be indicated that no dedicated converter is used to guarantee the MPP operation of the "photovoltaic generator", leading to a multiplied use of the converters involved. In addition, there is only one conversion step in the path between the PV array and the battery, which improves the battery's charging efficiency. The current inductor "iL is designed to be continuous. Switches S1 and S2 function complementarily. All semiconductor units and passive elements are considered the best in the following analysis. The autonomous controller of the machine should carry out the following activities: 1) remove most of the electricity from the PV array; 2) manipulate the use of the battery except violating overload and overload limits; and 3) DC-AC conversion keeping the charging voltage at the prescribed level. To achieve the desired functionality, the proposed system must operate in one of the following ways.

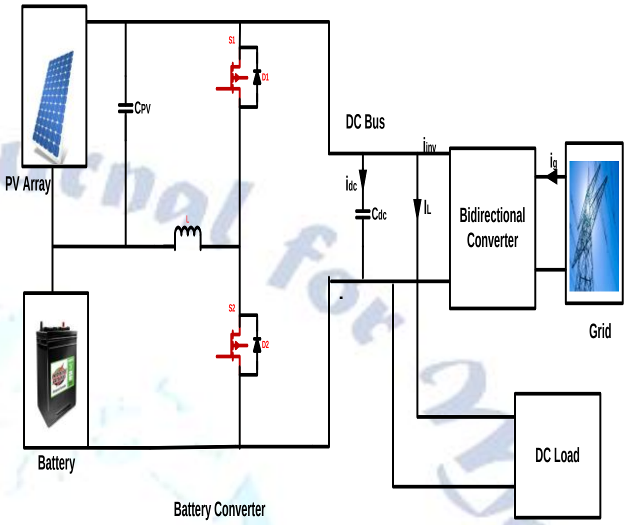

Fig 2: Proposed PV/Battery Hybrid System for Battery Protection Scheme

Three different operating modes of converter are considered for proving the performance of the proposed converter. To ensure the battery protection from overcharging and over-discharging the modes of operation is decided based on the inductor current direction. Switching sequence is shown in Table 1

Table 1: Switching Sequence of Proposed method

	S1	S2
Mode 1	ON	OFF
Mode 2	OFF	ON
Mode 3	OFF	ON

The switching sequence, current through and the voltage across the different vital elements are shown in Fig 3. (all Y-axis representation)

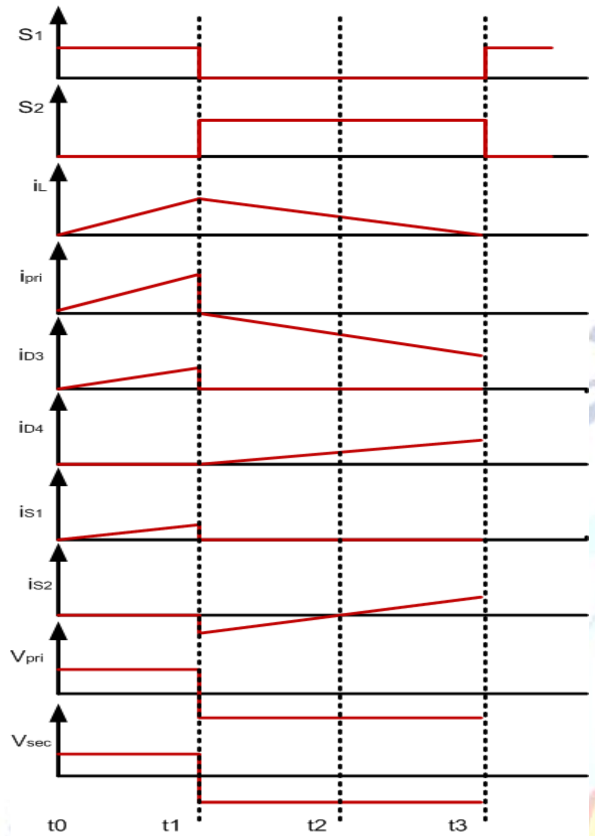

Figure 3: Switching Sequence, current through and voltage across key elements in the circuit.

BATTERY PROTECTION SYSTEM:

Battery protection scheme in the proposed system is explained briefly in this section. Depending upon the SOC of the battery and availability of power from the solar array a control strategy is developed for protection of battery from overcharging and over discharging.

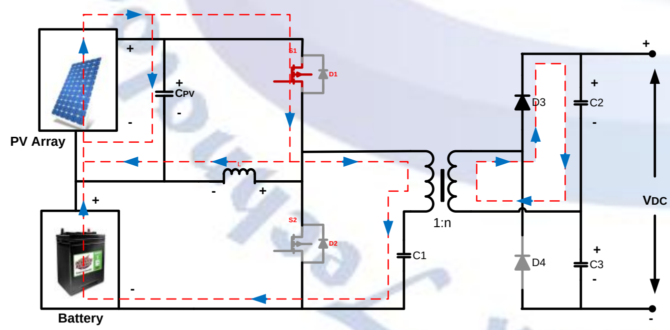

Fig 4: Proposed Equivalent circuit

From figure 4, when S1 is ON and S2 is OFF. The voltage across the inductor is V_{pv}

$$V_L = V_{PV} \quad (1)$$

When S1 is OFF and S2 is ON The voltage across the inductor is $-V_b$

$$V_L = -V_b \quad (2)$$

Average voltage drop across inductor is

$$V_{Lavg} = DV_{PV} - (1-D)V_b \quad (3)$$

Assuming average voltage drop across the inductor is zero

$$0 = DV_{PV} - (1-D)V_b \quad (4)$$

$$V_{PV} = \frac{1-D}{D} V_b \quad (5)$$

Applying KCL

$$I_L + I_{CPV} = I_b + I_{PV} \quad (6)$$

If average value of $I_{CPV} = 0$

$$I_b = I_L - I_{PV} \quad (7)$$

If $I_L > I_{PV}$ Battery Should be charge

If $I_L < I_{PV}$ Battery Should be discharge

There by controlling the I_L and I_{pv} battery charging and discharging can be controlled.

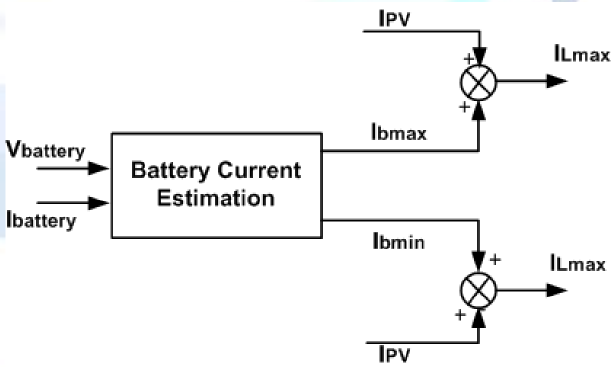

Figure 5. Control circuit

Figure 5 shows the battery estimation control circuit which finds the inductor minimum and maximum current. Figure 6 shows the control circuit 4 which estimates the inductor reference current I_{Lref}.

To prevent overcharging and overdischarging of the battery. These two limits are derived as follows:

$$I_{L\max} = I_{b\max} + I_{pv} \qquad (8)$$

$$I_{L\min} = I_{b\min} + I_{pv} \qquad (9)$$

wherein $I_{b\max}$ and $I_{b\min}$ are the maximum permissible charging and discharging current of the battery, respectively. These two limits are set based on the SOC level and the allowable depth of discharge of the battery

SIMULATION RESULTS:

The steady state response of the device during MPPT mode operation is shown in Fig. 6. The insolation level is chosen at 1 kW / m2 with Impp, Vmpp and Pmpp corresponding to 14.8 A, 35.4 V and 525 W, respectively. The load is kept at 450W, which is lower than MPP Power, Pmpp. From Figure 7, it can be deduced that Vpv and Ipv are in their respective MPP values, while ib is positive, indicating that the battery is charged to consume excess energy. The load voltage maintained at 230 V and the voltage profile of the intermediate circuit are shown in Fig. 7. The various parameters/elements used in the simulation model are provided in Table 2.

Table 2:Parameters of Proposed Hybrid System

Parameter	Value
Power Rating	800 VA
Voltage at Pmax, Vmp	36 V
Current at Pmax, Imp	14.8 A
Battery Bank	36 V, 7 Ah (12*3)
Transformer turns ratio	1:6

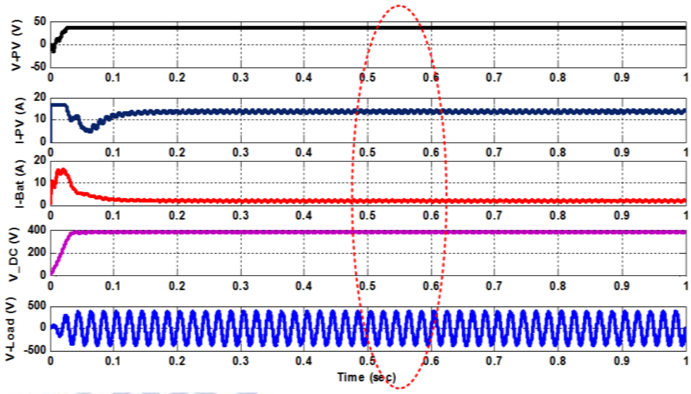

Fig 6: Simulation Response Steady State Operation (a)PV Voltage, (b) PV Current, (c)Battery Current; (d) DC Link Voltage; (e) Load Voltage

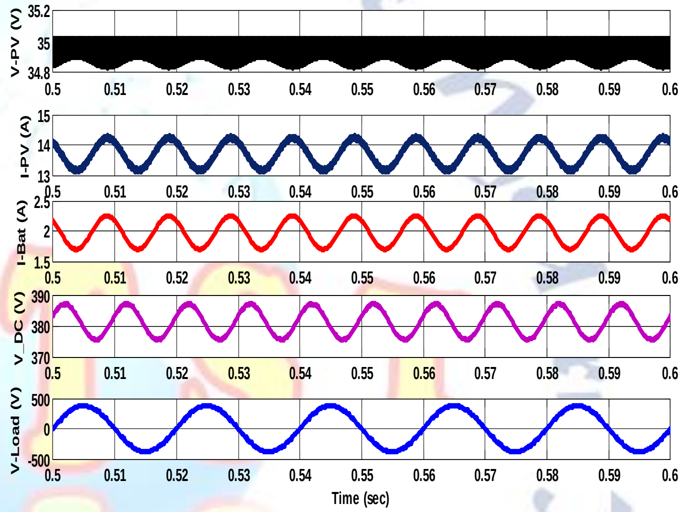

Fig 7: Simulation Response Steady State Operation from 0.5 to 0.6 sec time period (a)PV Voltage; (b) PV Current; (c)Battery Current; (d) DC Link Voltage; (e) Load Voltage

The simulation response (results) of the system under load and the level of variation of the sun during operation in MPPT mode (mode 1) are shown in Fig. 7. Initially, the level of sunlight is set to 0.75 kW / m2. At 0.28 s, the solar insolation level changes to 1 kW / m2

CONCLUSION:

In this proposed method, an independent scheme based on photovoltaic solar energy with a battery protection scheme in "Microgrid DC. and the increase of the DC voltage is obtained in a single converter 2) improving the battery charging efficiency since only one converter is present in the battery charging path; 3) Simple and efficient control structure that guarantees the correct selection of the operating mode and a gradual transition between the different possible operating modes. The feasibility of the proposed system is confirmed by detailed simulation studies.

REFERENCES

1. N. Hatziargyriou, "Microgrids: architectures and control," Wiley-IEEE Press, Athens, Greece, 2014.
2. T. Dragicevic, J. M. Guerrero, J. C. Vasquez, D. Skrlec, "Supervisory control of an adaptive-droop regulated DC microgrid with battery management capability," IEEE Trans. Power Electron. vol. 29, no. 2, pp. 695–706, 2014.
3. D. Salomonsson, L. Soder, A. Sannino, "An adaptive control system for a DC microgrid for data centers," IEEE Trans. Ind. Appl. 44 (6) (2008) 1910–1917.
4. Lie Xu, Dong Chen, "Control and operation of a DC microgrid with variable generation and energy storage," IEEE Trans. Power Delivery, vol. 26, no. 4, pp. 2513–2522, 2011.
5. Ma, W.; Wang, J.; Member, S.; Lu, X. Optimal Operation Mode Selection for a DC Microgrid IEEE Trans. Smart Grid. 2016, 7, 2624–2632.
6. Dou, C.; Yue, D.; Guerrero, J.M.; Xie, X.; Hu, S. Multiagent System-Based Distributed Coordinated Control for Radial DC Microgrid Considering Transmission Time Delays. IEEE Trans. Smart Grid. 2017, 8, 2370–2381.
7. Zhao, X.; Li, Y.W.; Tian, H.; Wu, X. Energy Management Strategy of Multiple Supercapacitors in a DC Microgrid Using. IEEE J. Emerg. Sel. Top. Power Electron. 2016, 4, 1174–1185.
8. Ac, H.; Microgrid, D.C.; Xiao, H.; Luo, A.; Member, S.; Shuai, Z. An Improved Control Method for Multiple Bidirectional Power Converters in. IEEE Trans. Power Electron. 2016, 7, 340–347
9. Meng, L.; Riva, E.; Luna, A.; Dragicevic, T.; Vasquez, J.C.; Guerrero, J.M. Microgrid supervisory controllers and energy management systems: A literature review. Renew. Sustain. Energy Rev. 2016, 60, 1263–1273.
10. Boukettaya, G.; Krichen, L. A dynamic power management strategy of a grid connected hybrid generation system using wind, photovoltaic and Flywheel Energy Storage System in residential applications. Energy 2014, 71, 148–159.
11. Liu, X.; Wang, P.; Loh, P.C. A hybrid AC/DC microgrid and its coordination control. IEEE Trans. Smart Grid 2011, 2, 278–286
12. E. Ragaini, E. Tironi, S. Grillo, L. Piegari, and M. Carminati, "Ground fault analysis of low voltage DC micro-grids with active front-end converter," *3rd Renew. Power Gener. Conf. (RPG 2014)*, Naples, Italy, pp. 1-6, 2014.
13. J. J. Justo, F. Mwasilu, J. Lee, and J. W. Jung, "AC-microgrids versus DC-microgrids with distributed energy resources: A review," *Renew. Sustain. Energy Rev.*, vol. 24, pp. 387–405, 2013.
14. H. Jiayi, J. Chuanwen, and X. Rong, "A review on distributed energy resources and MicroGrid," *Renew. Sustain. Energy Rev.*, vol. 12, no. 9, pp. 2465–2476, 2008.
15. E. Planas, J. Andreu, J. I. Gárate, I. Martínez De Alegría, and E. Ibarra, "AC and DC technology in microgrids: A review," *Renew. Sustain. Energy Rev.*, vol. 43, pp. 726–749, 2015.
16. C. N. Papadimitriou, E. I. Zountouridou, and N. D. Hatziargyriou, "Review of hierarchical control in DC microgrids," *Electr. Power Syst. Res.*, vol. 122, pp. 159–167, 2015.
17. Vellanki Mehar Jyothi, T. Vijay Muni, S V N L Lalitha, "An Optimal Energy Management System for PV/Battery Standalone System," International Journal of Electrical and Computer Engineering, vol. 6, pp. 2538, 2016.
18. T. Vijay Muni, D. Priyanka, S V N L Lalitha, "Fast Acting MPPT Algorithm for Soft Switching Interleaved Boost Converter for Solar Photovoltaic System", Journal of Advanced Research in Dynamical & Control Systems, Vol. 10, 09-Special Issue, 2018.
19. T Vijay Muni, SVNL Lalitha, B Krishna Suma, B Venkateswaramma, "A new approach to achieve a fast acting MPPT technique for solar photovoltaic system under fast varying solar radiation", International Journal of Engineering & Technology, Volume7, Issue 2.20, pp-131-135.