International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS)
Volume IX, Issue IV, April 2020 | ISSN 2278-2540

Control and Power Management Scheme for PV – Battery Based Hybrid Microgrid Using Hybrid Adaptive MPPT Algorithm

Esther Jebarose G[1], C.Ponmani[2]
[1]PG Scholar, [2]Associate Professor, Department of Electrical Engineering, Government College Of Engineering, Tirunelveli, Tamil Nadu, India

***Abstract*: The papers incorporate with Photovoltaic (PV) - Battery based hybrid micro-grid for both grid connected and islanded modes using hybrid adaptive MPPT algorithm. Control and power management is done by hybrid adaptive Maximum Power Point Tracking (MPPT) algorithm followed by SEPIC converter with battery. Solar PV used as an input source for both battery and grid. PV cells which have non-linear P-V characteristics differ with changing solar radiation. In this adaptive hybrid MPPT algorithm is used to track the peak power point of solar PV and which is helps to improve the efficiency of the system. The hybrid adaptive MPPT is combination of Adaptive Incremental conductance (AIC) and Adaptive Perturb and Observe (APO) method. Battery storage is employed to mitigate the power fluctuations due to the characteristics of PV panels and continuously varying solar irradiation. The proposed project is tested by using MATLAB/SIMULINK environment and the results are verified using simulation results.**

***Keywords*: Photovoltaic system (PV), Battery, Single-Ended Primary-Inductor Converter (SEPIC), Micro-grid, Adaptive Incremental Conductance (AIC), Adaptive Perturb and Observe (APO), Maximum Power Point Tracking (MPPT).**

I. INTRODUCTION

Renewable energy is an ultimate energy source to reach high energy demand and alleviate the green house effect [1]. PV has emerged as the most convenient choice, because it is easily obtained in every part of the world, free of cost, clean energy source that does not have any harmful effect on the environment [2-6]. The P-V and I-V graphs of a photovoltaic panel at any temperature and irradiance are nonlinear. Furthermore, the variation in the weather conditions affects the power output of the PV array. The fluctuations in temperature disturb the output voltage of the cell, and the fluxes in irradiation affect the output current of the PV. Moreover, there is a unique point on the P-V curve denoted as the Maximum Power Point (MPP), upon which the PV system operates with maximum productivity. The problem is that the location of the MPP is unknown and varies with changing weather conditions. Therefore, appropriate MPPT techniques are needed to ensure the operation of PV at its MPP at all time [7-11].Many MPPT techniques have been developed by the researchers for the quick and successful location of the MPP. In the recent years, researchers have proposed improved MPPT methodologies, because it plays a crucial role in PV system to utilize PV energy efficiently [12],[13]. In this paper, hybrid adaptive MPPT methodology is developed to track the maximum power from PV. By taking into consideration of the sunlight density and cell temperature as well as adaptive perturbation length, this is simple method, compared with conventional P&O and INC method, can achieve much faster tracking speed with minimum steady state oscillation which increases the overall system's performance and efficiency[14-16]. Solar PV energy conversion systems can be classified into: standalone and grid interfaced power generation system [17].Stand-alone systems can be designed to run with battery backup or without battery backup . Stand-alone home power systems, by comparison, often store energy generated during the day in a battery bank for night use. In order to maintain an uninterruptible power supply to stand-alone loads use of battery energy storage system (BESS) is essential for stand-alone applications [18]. Other PV systems are called "grid-connected systems" this grid interfaced solar energy conversion system do not require any other additional devices [19].Below Fig. 1 shows a typical block diagram of proposed system.

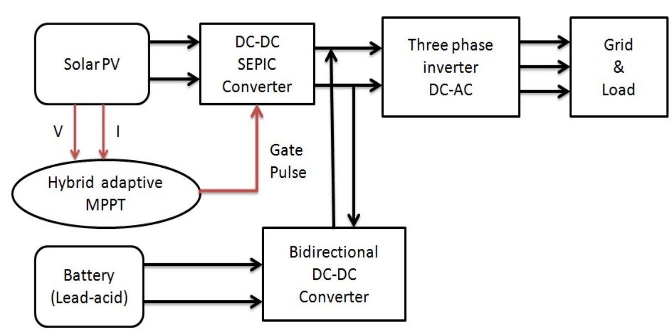


Figure 1: Simplified block diagram of proposed PV-Battery based hybrid micro-grid with hybrid adaptive MPPT

The forward power path from solar PV source to the load typically consists of two stages, as shown. The battery backup is interfaced with the DC link through a bi-directional dc-dc converter.

The proposed control and power management scheme for PV-battery based micro-grid used the hybrid adaptive MPPT technique has varies advantages that are

- Adaptive MPPT algorithm is effective than conventional MPPT.
- Adaptive incremental conductance method is suitable for rapidly changing atmosphere. It has good tracking performance and it may use Control variables as Voltage, Current and Duty cycle.
- Battery storage is used to mitigate the power fluctuations due to the unpredictable behavior of solar system.
- Provide continuous power supply to the load.
- Deep cycle is possible in Lead-acid battery.
- Lead-acid battery has a relatively long life and lower Depth of Discharge than other battery types.
- Simple construction and High efficiency.

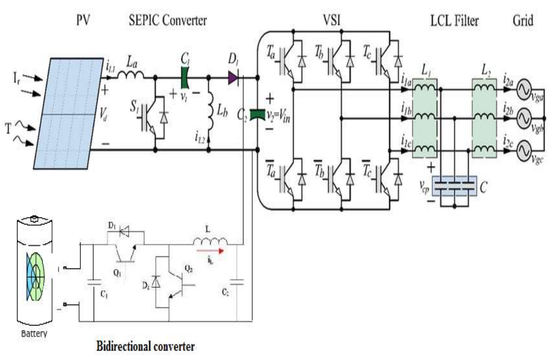


Figure 2: Circuit diagram of proposed system

II. PROPOSED ADAPTIVE MPPT METHODS

A. Adaptive Incremental Conductance (AIC)method

The adaptive Incremental conductance algorithm has the large correction term to find the MPP fast, and near the MPP the correction should become small to cause a reduction of the oscillation around the maximum power point, particularly in steady state conditions. The adaptive IC algorithm uses the absolute value of the slope (dP/dV) as adaptability rule to modify the correction term at subsequent times. Then, adaptive IC method determines the duty cycle by the below equation

$$\text{Dk} = \text{Dk-1-} \underbrace{\text{N}\ \frac{dP}{dV}\ \text{sign}\left(\frac{dI}{dV} + \frac{I}{V}\right)}_{\text{Dstep}}$$

Where N is a scaling factor that must be optimized. The flowchart for this method is given below figure no 5.2 in this algorithm often used for modern grid- connected PV systems.

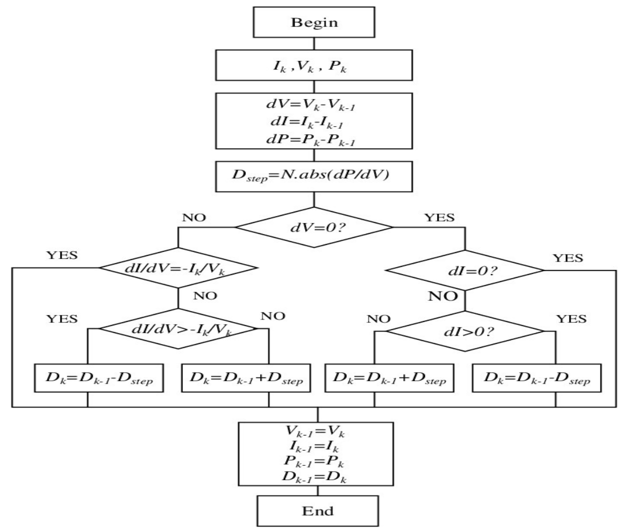


Figure 3: Adaptive Incremental Conductance MPPT flowchart

B. Adaptive Perturb and Observe MPPT(APO) Method

Various MPPT algorithms are available for monitoring the maximum power. But conventional P&O method is slow in nature and suffers from steady state oscillations to avoid this adaptive P&O MPPT is used to track the MPP rapidly with less steady state oscillation. The below figure 5.3 shows the flowchart of adaptive P&O MPPT algorithm.

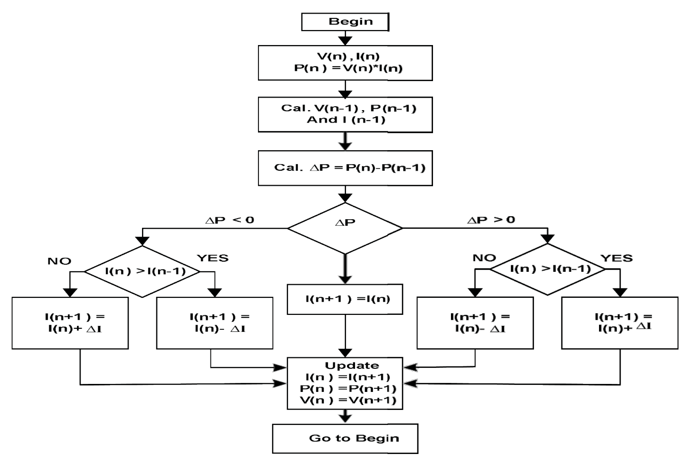


Figure 4: Adaptive Perturb and Observe MPPT flowchart

C. Proposed Hybrid Adaptive MPPT

This method used to get the maximum power from a varying source of solar PV under a variable temperature and irradiance conditions. The main operation of MPPT is to sample the output of solar cells and apply the proper load to obtain the maximum power for any given location, time, season and environmental conditions. Below figure shows the hybrid adaptive MPPT control the DC-DC converter duty cycle block diagram. The duty cycle is generated by PV array voltage and current value.

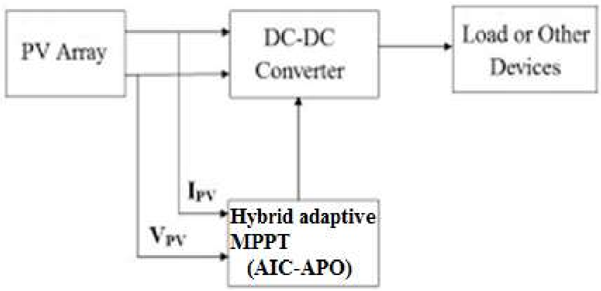
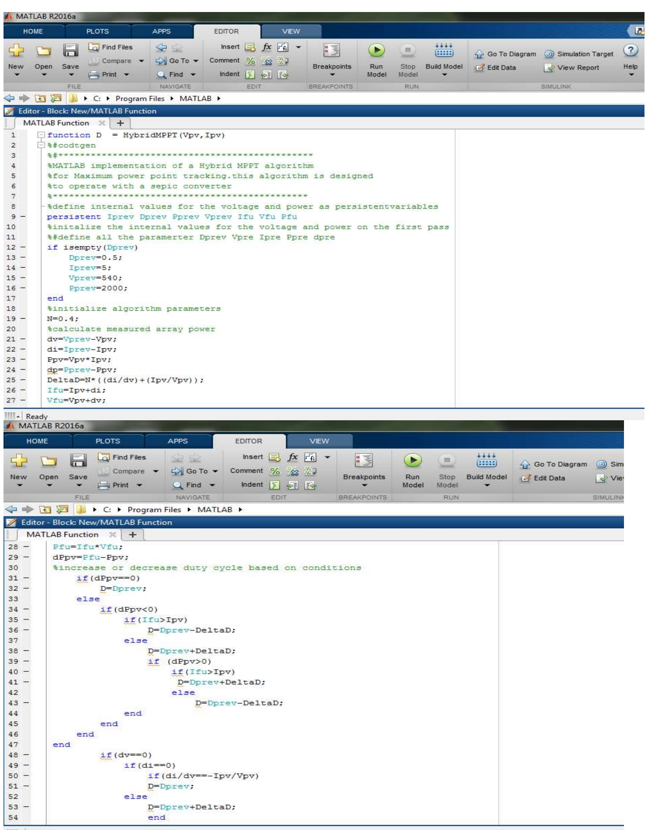


Figure 5: Solar array with hybrid adaptive MPPT controller

It designed for good performance, fast response, and less fluctuations. Since the efficiency of the PV is affected by the panel irradiance and temperature which are dynamic and unpredictable. For this reason, it is implemented to connect the load directly to the PV to obtain the maximum power, so it is necessary to balance the system. The main advantage of the converter is managing the power delivered to the load. The SEPIC converter is designed to transfer maximum power from the Solar PV module to the load.. This converter acts as an interface the duty cycle and matched at Point of peak power with source for maximum power transfer. There are several MPPT methods are used to extract the maximum power among all the MPPT methods in this paper used the AIC and APO method as a combined form and to overcome the drawback of other methods. The below figure 6 shows the proposed hybrid MPPT algorithm.



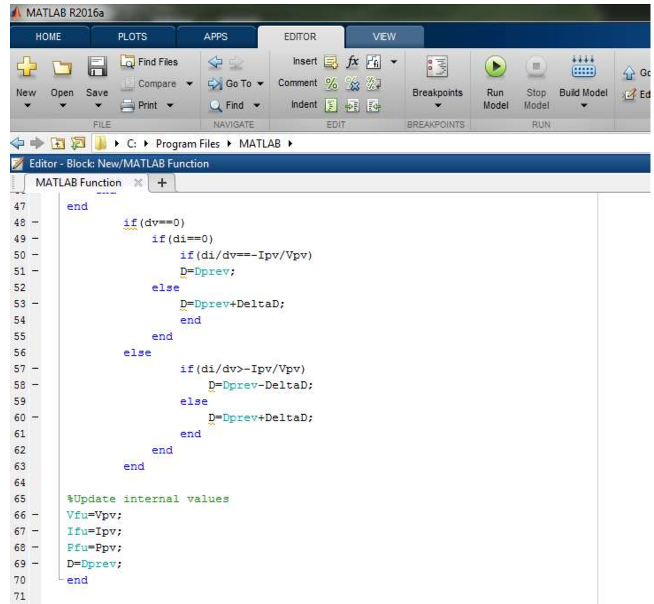


Figure 6: Proposed Hybrid Adaptive MPPT method in Matlab function Block

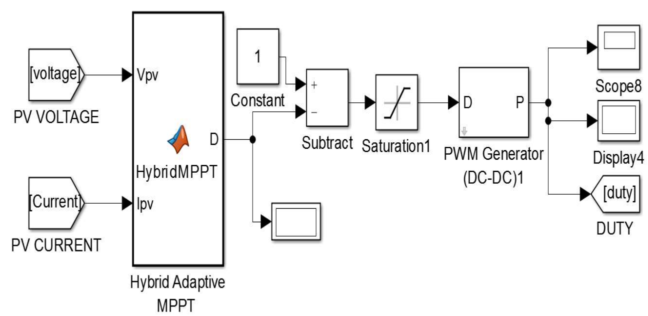


Figure 7: SEPIC converter switching control

III. PV PANEL AND SEPIC CONVERTER

A. *Solar panel design*

The PV panel is designed based upon the Vpv using function block arrangement in MATLAB/ SIMIULINK

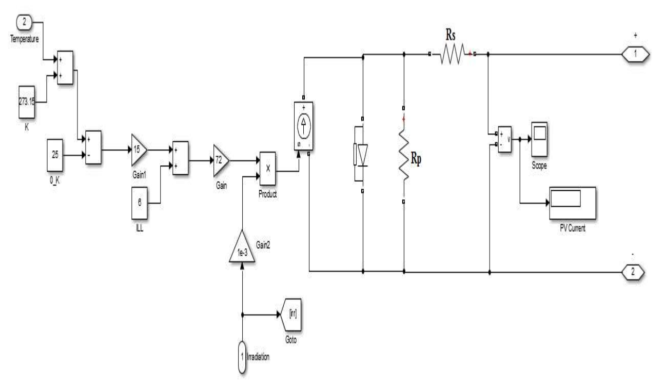


Figure 8: Simulink model of solar panel

Table 1: Specification of solar PV panel

Parameter	Value
Rp	415.405Ω
Rs	0.221 Ω
Number of parallel cell (Np)	1
Number of series cell (Ns)	72
Temperature	25ºC
Irradiations(W/m2)	800,1000

B. SEPIC converter

The Single-Ended Primary-Inductor Converter (SEPIC) is a type of DC / DC converter that allows for higher, lower or equivalent electrical potential (voltage) at its output. Which has the advantages of providing a non-inverted output, the output has the same voltage polarity as the input, using a series condenser to couple the energy from the input to the output and can therefore respond more graciously to a short-circuit output SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. It using a power MOSFET, the circuit diagram is given below.

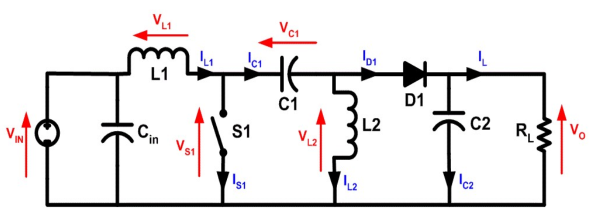


Figure 9: SEPIC converter

C. Equations for SEPIC converter design

The DC-DC SEPIC converter circuit consists of inductor, capacitor, diode, load resistor, and control switch. These components are connected with the input voltage source (Vin) so as to step up the voltage. The duty cycle of the control switch controls the output voltage of the SEPIC converter. Hence by varying the ON time of switch, the output voltage can be varied. So the average output voltage can be determined for the duty cycle "D"

D = Vout+ Vfwd/ Vin+Vout+ Vfwd (1)

The inductor value of the converter is calculated by

L1=L2 = Vin*D/2*Fs*ΔIL (2) $\frac{Vs}{Fs\Delta Il}$

The capacitor value can be obtained by

Cp= Io*D/Fs*Vrp (3)

Co = Io*D/Fs*ΔVrpp (4)

Table 2: Specifications of SEPIC converter

Inductor L1,L2	**2.075mH**
Primary capacitor	**2.711µF**
Output side capacitor	**2.875µF**
Switching frequency	**25kHz**
Switch	**MOSFET**

D. Bidirectional converter with battery controller

In Bi-directional converter power can flow at both directions it means can feed power to the load and the load can also feed the power back to the source. Battery bank is required for power balancing in PV systems. This system's battery bank is connected to the DC bus and operated with a bidirectional Ac / DC converter. It has the arrangement of capacitor, inductor, switching element with a battery input for this project. The operation of this converter based upon the switching signal generated by the control circuit based upon the value of solar input and battery voltage rating.

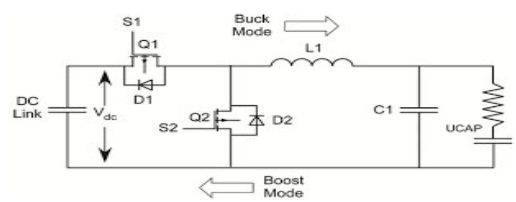


Figure 10: Bidirectional converter

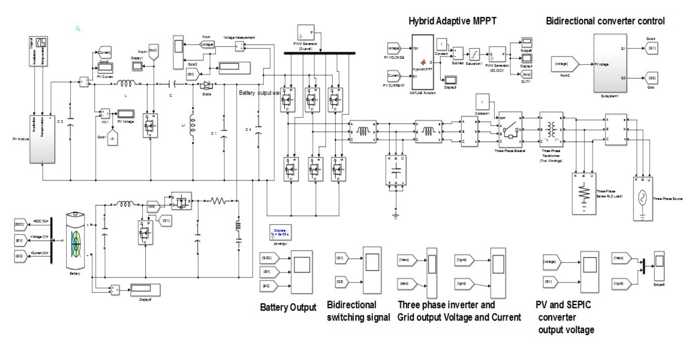


Figure 11: Simulation diagram of proposed system

IV. RESULTS

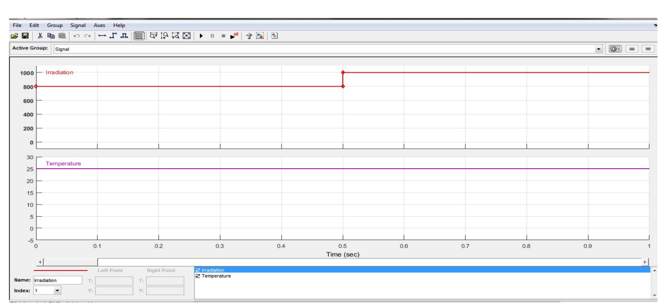


Figure 12: PV panel input irradiation and temperature

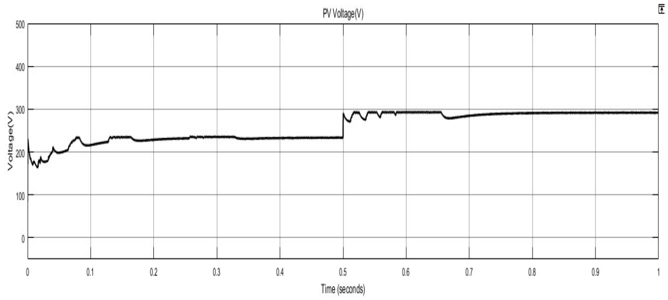


Figure 13: PV Output Voltage Under different Irradiation

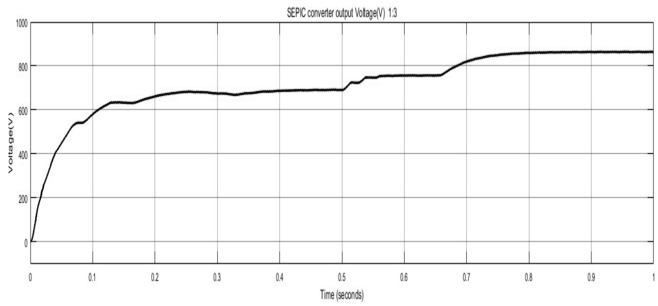


Figure 14: SEPIC converter output voltage

The below figure 15 and 16 shows the three phase inverter output of grid connected and islanded mode operation

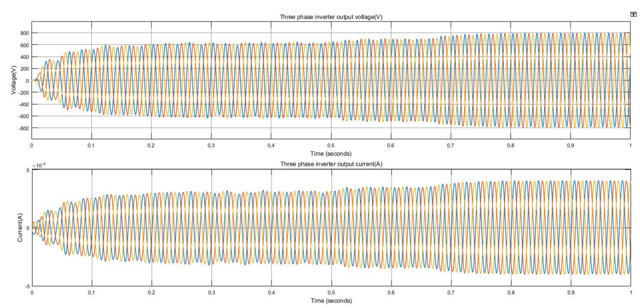


Figure 15: Islanded mode output voltage and current of three phase inverter

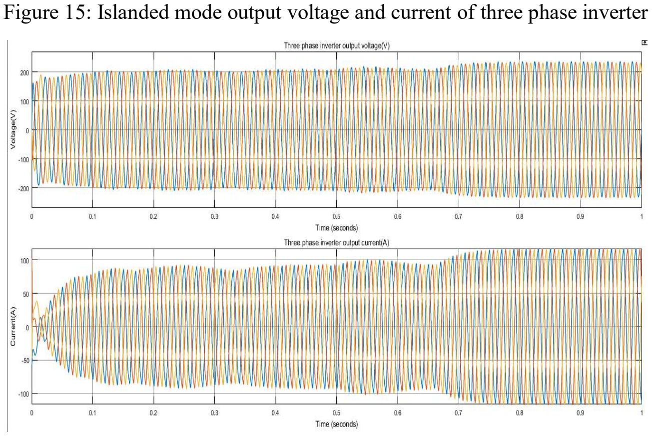


Figure16: Grid connected mode output voltage and current of inverter

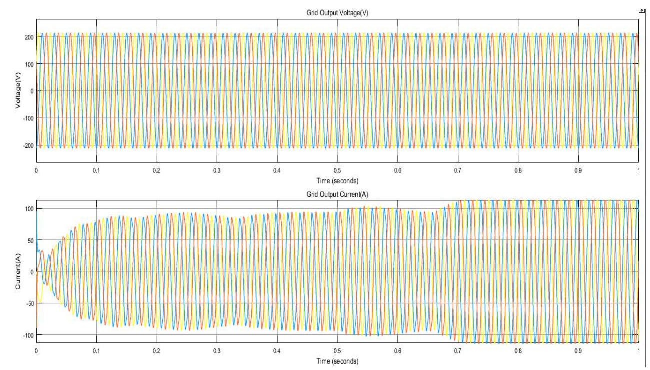
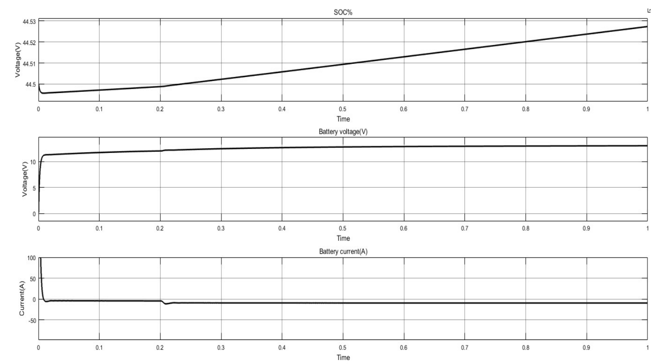
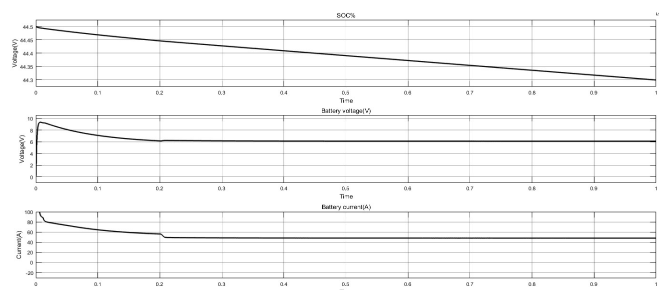


Figure 17: Grid connected mode output voltage and current of grid



(a)



(b)

Figure 15: Battery power changes with PV generation

(a) Charging state and (b) Discharging state

V. CONCLUSION

This paper proposes control and power management scheme for PV-Battery system with both grid connected and islanded mode operation using hybrid adaptive MPPT algorithm. PV fed SEPIC converter performance enhancement is accomplished with the use of combined Adaptive Incremental Conductance (AIC) MPPT and Adaptive Perturb and Observe (APO) MPPT with different irradiation condition and the SEPIC converter achieved 1:3 ratio output voltage. The battery is able to manage the power flow in an inverter and AC load of all units, flexibly, effectively and ultimately realize the power balance between the hybrid micro-grid and it ensure a reliable power supply to the system when PV power fluctuation due to unstable irradiance or PV array shutdown due to fault. The validation of result was carried out using MATLAB/ SIMULINK.

REFERENCES

[1]. Benner, J.P and L. Kazmerski, "Photovoltaic gaining greater visibility," *IEEE Spectr.*, vol. 36, no. 9, pp. 34–42, 1999.

[2]. point tracking in photovoltaic (PV) systems: A review of different approaches. *Renewable and Sustainable Energy Reviews, 65*, 1127- 1138.

[3]. P. Das, A. Mohapatra, and B. Nayak, "Modeling and characteristic study of solar photovoltaic system under partial shading condition," *Mater. Today Proc.*, vol. 4, no. 14, pp. 12586–12591, 2017.

[4]. T. A. Nguyen, X. Qiu, J. D. G. II, M. L. Crow, and A. C. Elmore, "Performance characterization for photovoltaic-vanadium redox battery microgrid systems," *IEEE Trans. Sustain. Energy*, vol. 5, no. 4, pp. 1379–1388, Oct 2014.

[5]. S. Kolesnik and A. Kuperman, "On the equivalence of major variable- step-size MPPT algorithms," *IEEE J. Photovolt.*, vol. 6, no. 2, pp. 590– 594, March 2016.

[6]. H. A. Sher, A. F. Murtaza, A. Noman, K. E. Addoweesh, K. Al-Haddad, and M. Chiaberge, "A new sensorless hybrid MPPT algorithm based on fractional short-circuit current measurement and P&O MPPT," *IEEE Trans. Sustain. Energy*, vol. 6, no. 4, pp. 1426–1434, Oct 2015.

[7]. Abdelsalam Ahmed K, Massoud Ahmed M, Shehab Ahmed, Enjeti Prasad N. (2011). High-performance adaptive perturb and observe MPPT technique for photovoltaic-based microgrids. *IEEE Trans Power Electron, 26*, 1010-20.

[8]. Ankit Gupta ⇑, Yogesh K. Chauhan, Rupendra Kumar Pachauri. (2016). A comparative investigation of maximum power point tracking methods for solar PV systems. *Solar Energy, 136*, 236-253.

[9]. David Sanz Morales. (2010). Maximum Power Point Tracking Algorithms for Photovoltaic Applications.

[10]. Deepak Verma n, SavitaNema, A.M.Shandilya,SoubhagyaK.Dash. (2016).Maximumpowerpointtracking(MPPT)techniques:Recapitulatin in solar photovoltaic systems. *RenewableandSustainableEnergyReviews, 54*, 1018-1034.

[11]. Esram Trishan, Chapman Patrick L. (2007). Comparison of photovoltaic array maximum power point tracking techniques. *IEEE Trans Energy Convers, 22*, 439-449.

[12]. T. Esram and P. L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," *IEEE Trans. Energy Convers.*, vol. 22, no. 2, pp. 439–449, 2007.

[13]. A. Mohapatra, B. Nayak, P. Das, and K. B. Mohanty, "A review on MPPT techniques of PV system under partial shading condition," *Renew. Sustain. Energy Rev.*, vol. 80, pp. 854–867, 2017.

[14]. N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," *Power Electronics, IEEE Transactions on,* vol. 20, pp. 963-973, 2005.

[15]. E. Mamarelis, G. Petrone, and G. Spagnuolo, "A two-steps algorithm improving the P&O steady state MPPT efficiency," *Applied Energy,* vol. 113, pp. 414-421, 2014.

[16]. S. K. Kollimalla and M. K. Mishra, "A novel adaptive P&O MPPT algorithm considering sudden changes in the irradiance," *Energy Conversion, IEEE Transactions on,* vol. 29, pp. 602-610, 2014.

[17]. S. Duryea, S. Islam and W. Lawrance, "A battery management system for stand-alone photovoltaic energy systems," *IEEE Industrial Application Magazine*, vol. 7, no. 3, pp. 67-72, June 2001.

[18]. D. Fuente, C. L. T. Rodríguez, G. Garcerá, E. Figueres and R. O. Gonzalez, "Photovoltaic power system with battery backup with grid-connection and islanded operation capabilities," *IEEE Transactions on Industrial Electronics,* vol. 60, no. 4, pp. 1571-1581, April 2013.

[19]. Y. Riffonneau, S. Bacha, F. Barruel, and S. Ploix, "Optimal power flow management for grid connected PV systems with batteries," *IEEE Trans. Sustain. Energy*, vol. 2, no. 3, pp. 309–320, July 2011.

[20]. S. Duryea, S. Islam and W. Lawrance, "A battery management system oltaic energy systems," *IEEE Industrial Application Magazine*, vol. 7, no. 3, pp. 67-72, June 2001

[21]. D. Fuente, C. L. T. Rodríguez, G. Garcerá, E. Figueres and R. O. Gonzalez, "Photovoltaic power system with battery backup with grid-connection and islanded operation capabilities," *IEEE Transactions on Industrial Electronics,* vol. 60, no. 4, pp. 1571-1581, April 2013.

[22]. Y. Karimi, H. Oraee, M. Golsorkhi, and J. Guerrero, "Decentralized method for load sharing and power management in a PV/battery hybrid source islanded microgrid," *IEEE Trans. Power Electron.*, vol. PP, no. 99, pp. 1–1, 2016.

[23]. Y. Riffonneau, S. Bacha, F. Barruel, and S. Ploix, "Optimal power flow management for grid connected PV systems with batteries," *IEEE Trans. Sustain. Energy*, vol. 2, no. 3, pp. 309–320, July 2011.

[24]. M. Andersen and B. Alvsten, "200 w low cost module integrated utility interface for modular photovoltaic energy systems," in Industrial Electronics, Control, and Instrumentation, 1995., Proceedings of the 1995 IEEE IECON 21st International Conference on, vol. 1. IEEE, 1995, pp. 572–577.

[25]. H. A. Sher, A. F. Murtaza, A. Noman, K. E. Addoweesh, K. Al-Haddad, and M. Chiaberge, "A new sensorless hybrid mppt algorithm based on fractional short-circuit current measurement and P&O MPPT" *Sustainable Energy,IEEE Transactions on,* vol. 6, no. 4, pp. 1426–1434, Oct 2015.

[26]. Y. M. Chen, A. Q. Huang and Y. Xunwei, "A high step-up three-port DC-DC converter for stand-alone PV/battery power systems, " *IEEE Transactions on Power Electronics,* vol. 28, no. 11, pp. 5049-5062, Nov. 2013.

[27]. B. S. Borowy and Z. M. Salameh, "Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system," *IEEE Trans. Energy Convers.*, vol. 11, no. 2, pp. 367–375, Jun 1996.

[28]. D. Abbes, A. Martinez, and G. Champenois, "Eco-design optimisation of an autonomous hybrid wind-photovoltaic system with battery storage," *IET Renewable Power Generation*, vol. 6, no. 5, pp. 358–371, Sept 2012.

[29]. H. Mahmood, D. Michaelson, and J. Jiang, "A power management strategy for PV/battery hybrid systems in islanded microgrids," *IEEE J. Emerg. Sel. Top. Power Electron*, vol. 2, no. 4, pp. 870–882, Dec 2014.

[30]. M. O. Badawy and Y. Sozer, "Power flow management of a grid tied pv-battery system for charging of electric vehicles," *IEEE Trans. Ind. Appl.*, vol. PP, no. 99, pp. 1–1, 2016.

[31]. H. Vahedi, P. A. Labb, and K. Al-Haddad, "Sensor-less five-level packed u- cell (puc5) inverter operating in stand-alone and grid-connected modes," *Industrial Informatics , IEEE Transactions on*, vol. 12, no. 1, pp. 361–370, Feb 2016.

[32]. Y. Riffonneau, S. Bacha, F. Barruel, and S. Ploix, "Optimal power flow management for grid connected PV systems with batteries," *IEEE Trans. Sustain. Energy*, vol. 2, no. 3, pp. 309–320, July 2011.

[33]. T. A. Nguyen, X. Qiu, J. D. G. II, M. L. Crow, and A. C. Elmore, "Performance characterization for photovoltaic-vanadium redox battery microgrid systems," *IEEE Trans. Sustain. Energy*, vol. 5, no. 4, pp. 1379–1388, Oct 2014