Grid Connected Solar Photovoltaic System with Converters Control

Vijay Kumar Garg[1] Reena Dhanda[2]
[1]Assistant Professor [2]M.Tech Scholar
[1]Department of Electrical Engineering
[1,2]UIET, KUK INDIA

Abstract— Solar energy computation systems contains Photovoltaic (PV) complex, in which power can be supplied exactly to an electrical equipment or energy is delivered in the public electricity grid. For the improvement of the efficiency of PV panels in the photovoltaic system, there is necessity of power electronic conversion and also the stability of system. The power circuit consists of a high step-up (Boost Converter) DC to DC converter and a multilevel inverter to convert DC to AC in these systems, as the in nature of grid voltage is pulsating (AC). Control circuit is required to get constant voltage at output with PV systems output voltage at load side as is continuously varying in nature. This analysis of Grid connected solar photovoltaic system using different types of converters. Here, in this paper the modelling of three types of converter is done (Boost converter, Battery converter, Main converter) A grid connected solar photovoltaic system represented by this paper and has been simulated and modelled using the Simulink in the MATLAB. The results of simulation shows that the system can balance with stable operation under the coordination control schemes during the switching of grid from one operating condition to another.

Key words: Battery converter, Boost converter, Grid, Photovoltaic Array

I. INTRODUCTION

With the accelerating concernment about the non-renewable sources of energy, the fossil fuel prices are constantly increasing, environment and ecosystem damaging, global warming, the renewable energy is befitting more promoted and is gathering more attention as a substitute to non-renewable sources of energy. Throughout the renewable sources of energy, the most crucial and sustainable sources of energy is Solar system energy in comparison with the other kinds of energy resources such as tidal, wind, fuel cell etc. In Solar energy system, the irradiation of PV Array converts into electricity. In Grid Connected PV System, The PV system connected with grid by using different types of converters for coordination control of grid system. Grid connected PV system have befitting more promoted due to their multifarious applications in distributed generation and also the effective use of the PV array power. Transmission line with high voltage long distance is no longer mandatory, when power is completely supplied by local renewable sources of power [1]. For the promotion of the connection of renewable sources of power to conventional ac systems, AC micro grids [2]–[5] have been contingent. On the other hand, dc power generated from fuel cells or photovoltaic (PV) panels has to be converted into ac with the help of, dc/ac inverters, photovoltaic (PV) panels and dc/dc boost converter for the sake of connection to an ac grid. In an ac grid, there is requirement of dc/dc and ac/dc converters for multifarious office facilities and home to accumulate distinct dc voltages.

II. DESCRIPTION OF SYSTEM

The different types of components used in grid-connected photovoltaic system with two levels to succeed PV power and transfer to the grid. The composition of system is mainly for, PV arrays matrix, which converts irradiation comes from sun into DC power, a DC to DC boost converter to step up the voltage of PV array to a greater level DC Voltage and DC/AC three level inverter which transform the DC power into AC power. The achieved AC power from an inverter is injected into the grid and is adapted by the local loads [6].

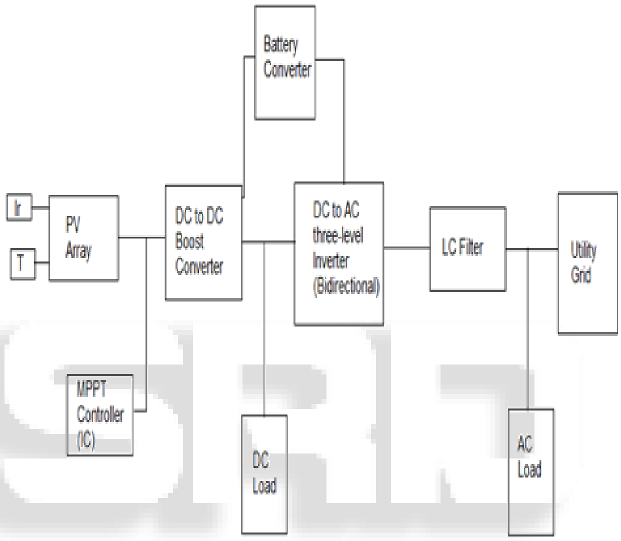

Fig. 1: Components of Grid connected PV systems

III. SYSTEM COMPONENTS WITH ITS OPERATING PRINCIPLE

A. Pv Array:

The equivalent circuit diagram of PV device can be characterized with the help of a current source (light generated) and a diode containing internal series and shunt resistances as shown in fig. 2.

A PV array is temperate of numerous PV cells and the examination of the characteristics at its termination results in formulating its output current with the following equation [14];

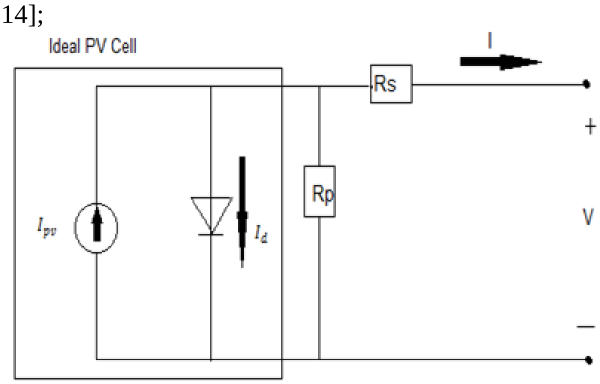

Fig. 2: PV cell single diode model

$$I = I_{pv} - I_o\left[\exp\left(\frac{V+R_sI}{V_ta}\right)-1\right] - \frac{V+R_sI}{R_p} \quad (1)$$

Where,

I= the output PV array current (A), V= the output PV array voltage (V), I_o= the saturation current of the array (A), I_pv= the photovoltaic array current (V),R_p, R_s= the internal parallel and series resistances of the PV array (Ohm), a = the idealistic constant of diode, V_t = the thermal voltage of the array (V),N_s= PV cells connected in series.

$$V_t = N_s k\left(\frac{T}{q}\right) \quad (2)$$

Where,
q = the electron charge (C),
k = Boltzmann constant (J/K),
T = the temperature of the p–n junction (K)

B. Dc/Dc Boost Converter:

DC/DC Converters are used for transforming one level of DC voltage (unregulated) to distinct level of DC voltage (regulated). This conversion is done with the help of a network containing storage elements such as capacitor and inductor [7].

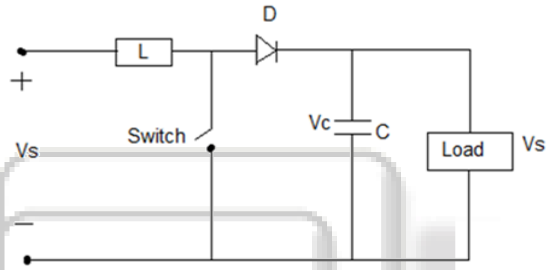

Fig. 3: Configuration of Boost converter

The main convention that drives the boost converter is the capability of an inductor to cramp changes in current. In a boost converter, the output voltage is higher than the input voltage. Here, IGBT is used as a switch. The current circulates through the inductor in the circuit when the switch is turned-ON and energy is accumulated in it. The accumulated energy in the inductor tends to disintegrate when the switch is turned-OFF and inductor changes its polarity such that its voltage adds up with the input voltage.

The design of boost converter, shown in fig. 3, can be summarized as follows [15];

$$V = V_{battery}(1-D) \quad (3)$$

$$\Delta i_L = \frac{VD}{Lf} \quad (4)$$

$$\Delta V = \frac{VD}{8LCf_{sw}^{\ 2}} \quad (5)$$

Where,

V = the output PV array voltage (V), D = the duty ratio of the boost chopper, V_battery= the battery load voltage (V), ΔV = the change in the PV array voltage (V), f_sw= the chopper switching frequency (Hz), Δi_L=the change in inductor current (A), L= the chopper inductor and C = the chopper input capacitor.

C. Mppt Algorithms:

It is shown in Equation (1) that I-V characteristics of PV array is non-linear that based on PV cells' temperature and the irradiance level. The P-V and I-V curves of a PV array are shown in Fig. at particular irradiance level and cell temperature, on which it's observable that the PV panel has a maximum (peak) operating point, known as the maximum power point (MPP). The PV current is relatively homogenous, in the left region to the MPP and the PV array can be almost as a constant current (CC) source. Moreover, the PV current starts a edged falling in the right region to the MPP and the PV array can be approximated as a constant voltage (CV) source. With distinct irradiance levels, the PV array MPP varies. Thus for maximizing the efficiency of PV system, continual tracking to the MPP is necessary. By using an MPPT algorithm, a maximum level of voltage can be achieved which determines the applicable duty ratio (D) for controlling the gate pulse of the DC-DC converter situated between the load and the PV module to establish that the maximum power of PV panel is extracted. A favourable MPPT technique accommodates between the steady-state accuracy and tracking speed and shows quick response while sudden changes in environment. According to this paradigm, the Incremental Conductance algorithm can be contemplated as a strong MPPT technique [8-12].

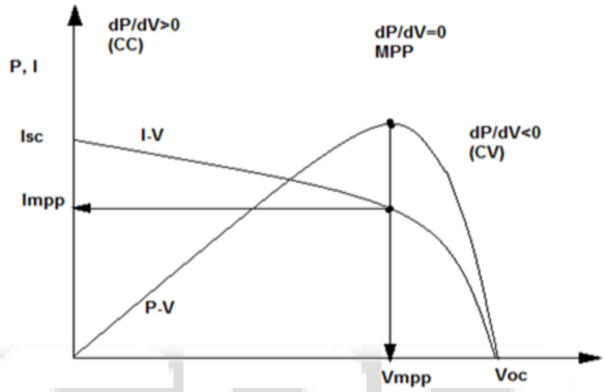

Fig. 4: PV array I-V and P-V characteristics

D. The Battery Model:

The battery model assumes the same characteristics for the charge and the discharge cycles. The open voltage source is determined by using a non-linear equation based on the actual SOC of the battery.

Equation (1) describes the controlled voltage source is:

$$V_b = V_o + R_b . i_b - K\frac{Q}{Q+\int i_b dt} + A.\exp(B\int i_b dt) \quad (7)$$

$$SOC = 100\left(1+\frac{\int i_b dt}{Q}\right) \quad (8)$$

Where,

ib= the battery charging current, Rb = internal resistance, Vo = open circuit voltage, A = the exponential voltage, K = the polarization voltage of battery, B = the exponential capacity, Q = the battery capacity, [13].

C_{pv}	Capacitor across the PV Array	1100uF
L_1	Inductor for the boost converter	80uH
C_{DC}	Capacitor across the dc-link	5900uF
L_2	Filtering inductor for the inverter	75uH
R_2	Equivalent resistance of the inverter	10ohm
C_2	Inverter filtering capacitor	5uF
L_3	Inductor for the battery converter	5mH
R_3	Resistance of L3	0.008ohm
f	AC grid frequency	50Hz
f_s	power converters Switching frequency	10kHz
V_d	Rated DC bus voltage	400V
	AC Load	20-40KW
R	Load resistance	7ohm

Table 1: Component Parameters for System

IV. SIMULATION RESULTS

A. Modelling of PV Array with Boost Converter Using MPPT:

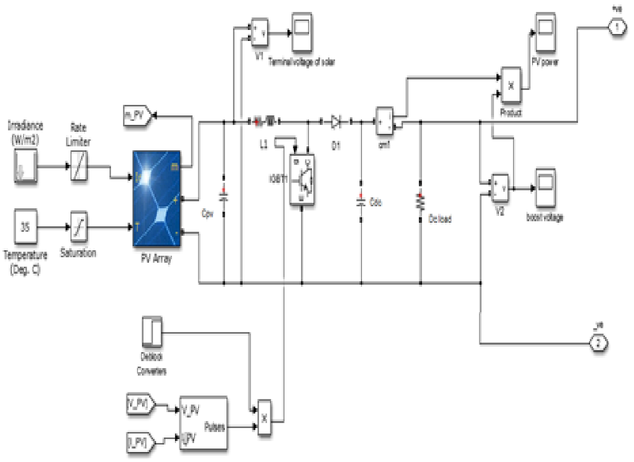

Fig. 7: Simulation of PV Array with Boost Converter

The PV array consists of 36 strings in parallel and 850 series-connected modules per string connected in series. The boost converter connected with PV Array and operated by MPPT controller after 0.1 s. Specifications for PV Array are:

Short-circuit current: I_{sc}= 3.27 A
Open-circuit voltage: V_{oc}= 400 V
Voltage and current at maximum power: V_mp =395.8V, I_mp= 2.78 A

The solar irradiation remains constant at 1000W/m2, from 0.0 s to 0.4 s. The initial voltage is obstinate at 250 V for the IC. Here, the IC is tracing the peak voltage continuously from 0 to 0.1 s. The tracing rate of algorithm is very slow, due to which, the peak voltage search by the algorithm is only at 0.05s. The algorithm finds a new peak (optimal) voltage from 0.2 s and finds the peak voltage at 0.4 s. The primitive algorithm can accurately follow the change of solar irradiation but require some time to find the peak voltage.

The curve of Terminal voltage of PV Array and the output power of the PV Array are shown in Fig. 6 and Fig. 7 and the output power variation from 10 kW to 30 kW, when the solar is operated at fixed temperature and follows the solar irradiation level approximately. The boost converter output voltage is shown in Fig. 8. The voltage level of solar terminal is boosting up (step up) by boost converter. The load voltage is always greater than the source voltage in boost converter (V_load>V_source).

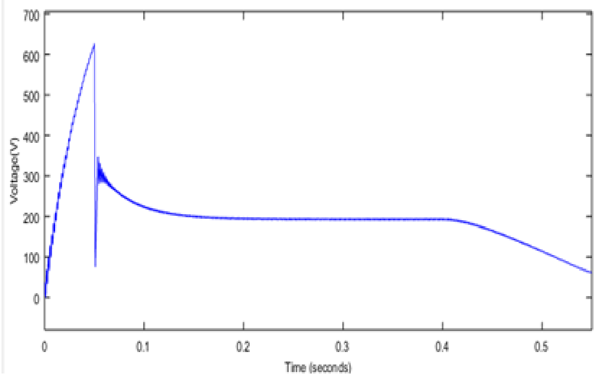

Fig. 8: Terminal voltage of PV Array

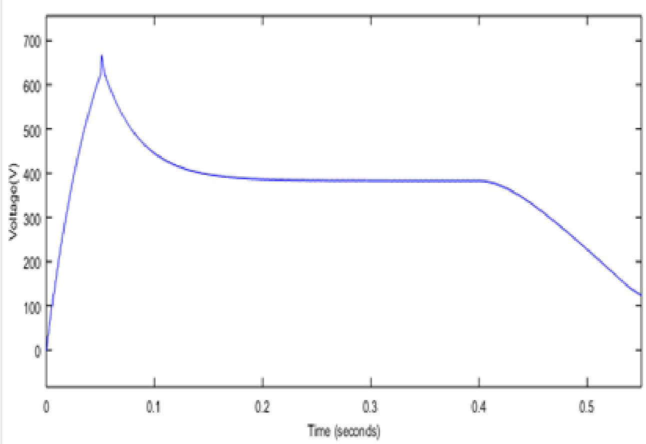

Fig. 9: Output of Boost Converter

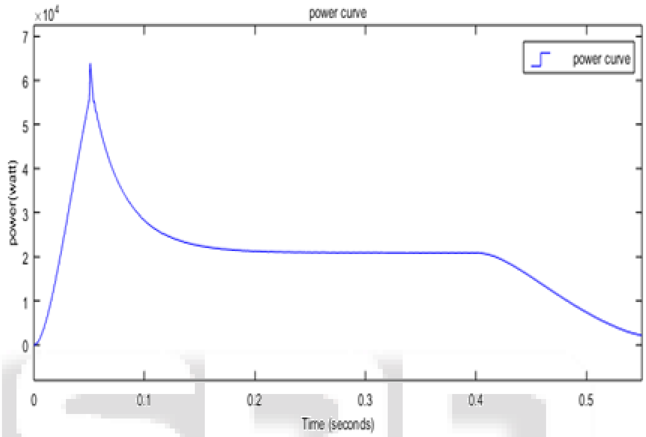

Fig. 10: Output Power of PV Array

B. Modelling Of Battery Converter:

The current, voltage and SOC of the battery are shown in Fig. 11, Fig. 12 and Fig. 13. The total produced power is greater than the total load before 0.05 s, and after 0.1 s lesser than the total load. Before 0.15 s, the battery works in charging mode because of the positive current of battery and works in discharging mode after 0.15 s because of the negative current of the battery. The increases and decreases in SOC (state of charge) of battery before and after 0.1 s.

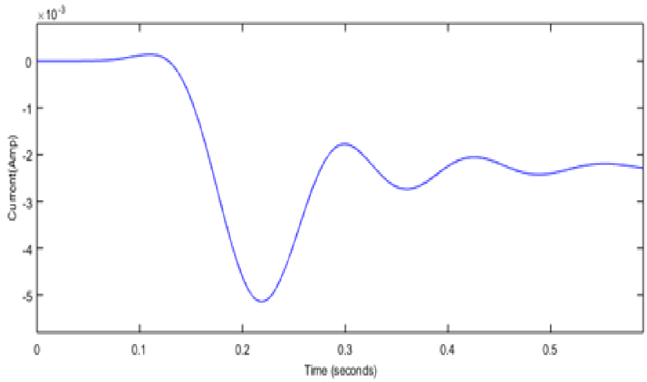

Fig. 11: Charging current of Battery.

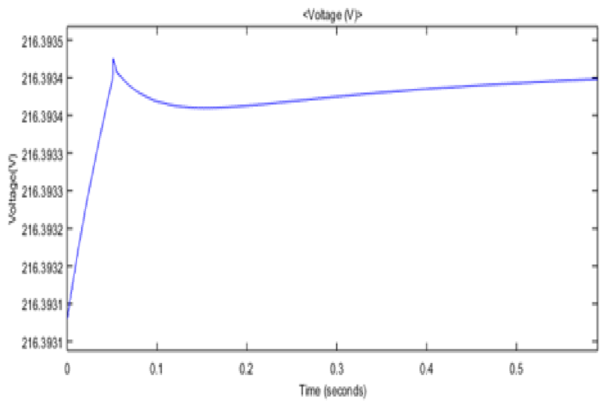

Fig. 12: Battery output Voltage.

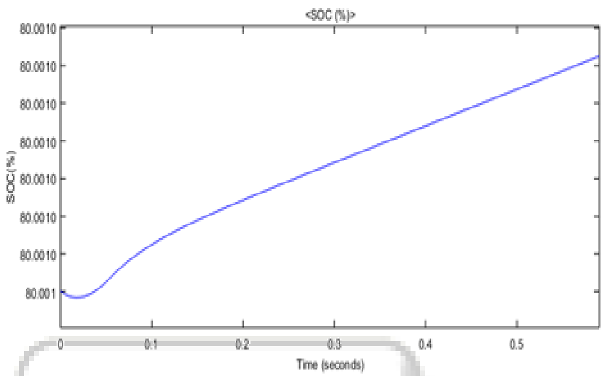

Fig. 13: SOC of Battery.

C. *Modelling Of Main Converter:*

Model of a Main Converter (three level six pulse converter [15]) is as shown in Fig. 14. Input signal to the converter is DC voltage with magnitude of 400 Volts, and is the boost converter output voltage. In this model, R shows load resistance with value of 50 Ω.

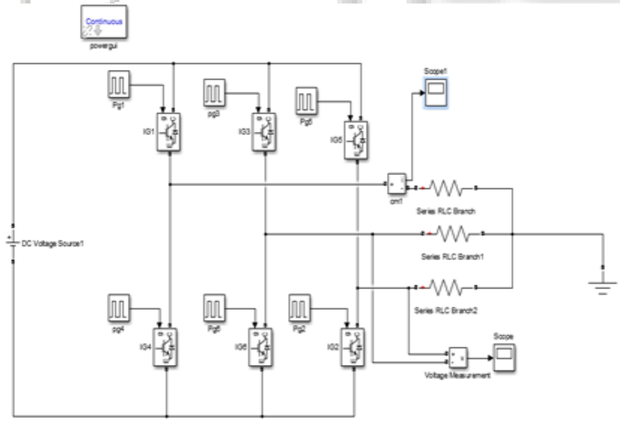

Fig. 14: Simulation of Main Converter

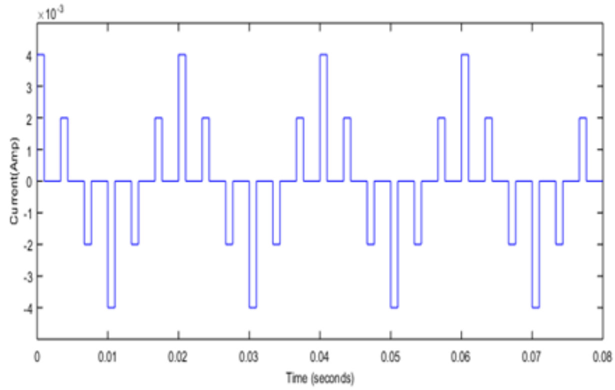

Fig. 15: Output current of main converter

D. *Simulation of Grid Connected PV System:*

PV array, boost converter, battery converter and main converter are simulated and modelled separately and then subsystem of each model is connected together. The combination is then connected to resistive load and grid through an LC filter. Fig.16 shows the complete simulation of grid connected PV system and Fig. 17, Fig. 18 shows the voltage and current of main converter. Here, it is noted that there is injection of voltage from PV system before 0.1 s and after that Grid provide the voltage to the loads.

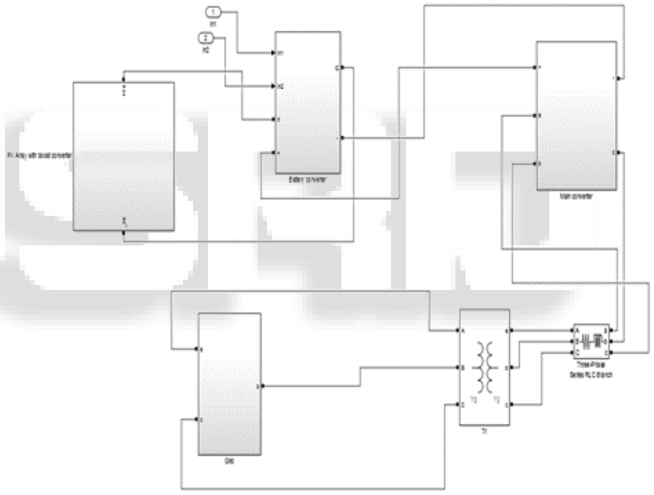

Fig. 16: Simulation of Grid connected solar system

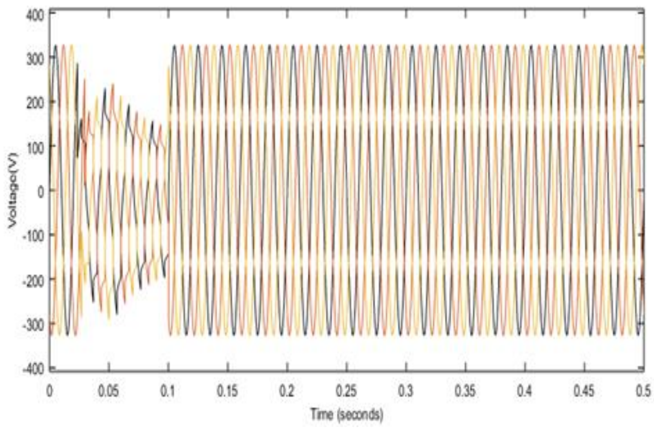

Fig. 17: Grid side voltage of main converter

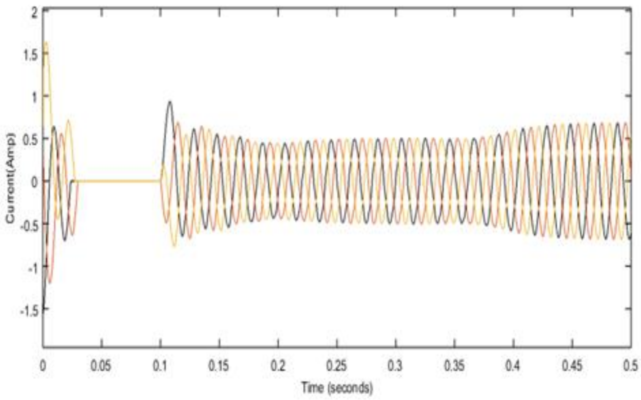

Fig. 18: Grid side current of main converter

V. CONCLUSION

Simulation of Grid connected solar PV system is accomplished in this work. The Parameters of system are determined and by using these parameters model is composed and simulation results are conferred. The result of simulation shows that the contemplated control execution regulates the boost converter output voltage.

By using the converters, the coordination control between grid and PV system is done. Load output voltage is purely sinusoidal in nature, with frequency 50 Hz synchronised with grid frequency and voltage. With this, the overall efficiency, reliability and power quality of the system is improved.

REFERENCES

[1] R.H. Lasseter, "MicroGrids," in Proc. IEEE Power Eng. Soc. Winter Meet., Jan. 2002,vol. 1, pp. 305-308.
[2] Y. Zoka, H. Sasaki, N. Yorino, K. Kawahara, and C. C. Liu, "An interaction problem of distributed generators installed in a MicroGrid," in Proc. IEEE Elect. Utility Deregulation, Restructuring. Power Technol., Apr. 2004, vol. 2, pp. 795-799.
[3] R. H. Lasseter and P. Paigi, "Microgrid: A conceptual solution," in Proc. IEEE 35th PESC, Jun. 2004, vol. 6, pp. 4285-4290.
[4] C. K. Sao and P. W. Lehn, "Control and power management of converter fed MicroGrids," IEEE Trans. Power Syst., vol. 23, no. 3, pp. 1088-1098. Aug. 2008.
[5] T. Logenthiran, D. Srinivasan, and D. Wong, "Multi-agent coordination for DER in MicroGrid," in Proc. IEEE Int. Conf. Sustainable Energy Technol., Nov. 2008, pp. 77-82.
[6] Manisha Joshi, Prof. Dr. Mrs. G. A. Vaidya, "Modeling and Simulation of Single Phase Grid Connected Solar Photovoltaic System" 2014 Annual IEEE India Conference (INDICON), June 2014, pp. 1-6.
[7] Chetan Singh Solanki, Solar Photovoltaics-Fundamentals, Technologies and applications, PHI learning private limited, 2009, New Delhi.
[8] N.E. Zakzouk, A.K. Abdelsalam, A.A. Helal, B.W. Williams, "Modified Variable-step Incremental Conductance Maximum Power Point Tracking Technique for Photovoltaic Systems," Industrial Electronics Society, IECON 2013 – 39th Annual Conference of the IEEE, Aug. 2013. pp. 1741-1748.
[9] M. Adly, M. Ibrahim, and H. El Sherif, "Comprehensive study of improved energy generation maximization techniques for photovoltaic systems," in Proc. IEEE Asia-Pacific Power and Energy Engineering Conf. (APPEEC), pp. 1-5, March 2012.
[10] G.M.S. Azevedo, M.C. Cavalcanti, K.C, Oliveria, F.A.S.Neves and Z.D. Lins, "Evaluation of maximum power tracking methods for grid connected photovoltaic systems", in Proc. IEEE Power Electronics Specialists Conf., 2008, pp. 1456-1462.
[11] G. Spiazzi, S. Buso, P. Mattavelli, and P. Tenti, "Low complexity MPPT techniques for PV module converters," in Proc. IEEE Power Electronics Conf., pp. 2074-2081, June 2010.
[12] X. Zhang, L. Zha, F. Liu, L. Tao, and W. Chen, "The analysis of power loss caused by the truncation error of MPPT algorithms," IEEE Symposium on Power Electronics for Distributed Generation Systems(PEDG), pp. 7-11, June 2010.
[13] O. Tremblay, L. A. Dessaint, and A. I. Dekkiche,"A generic battery model for the dynamic simulation of hybrid electric vehicles," in Proc. IEEE Veh. Power Propulsion Conf. (VPPC 2007), pp. 284-289.
[14] H. S. Rauschenbach, Solar Cell Array Design Handbook. Van Nostrand Reinhold, New York, 1980.
[15] D. W. Hart, Power Electronics handbook. McGraw Hill, New York, 2011.