International Journal of Electrical and Computer Engineering (IJECE)
Vol. 8, No. 2, April 2018, pp. 730~740
ISSN: 2088-8708, DOI: 10.11591/ijece.v8i2.pp730-740

Design of Hybrid Solar Wind Energy System in a Microgrid with MPPT Techniques

D. Chinna Kullay Reddy[1], S. Satyanarayana[2], V. Ganesh[3]
[1]Department of Electrical and Electronics Engineering, Madanapalle Institute of Technology and science, India
[2]Department of Electrical Engineering, Raghu Engineering College, India
[3]Department of Electrical Engineering, JNTUCEP, Pulivendula, India

Article Info

Article history:

Received Dec 9, 2017
Revised Mar 20, 2018
Accepted Mar 27, 2018

Keyword:

Optimal Power Control
PV system
SVPWM technique
two-model MPPT
WECS

ABSTRACT

DC Microgrid is one feasible and effective solution to integrate renewable energy sources as well as to supply electricity. This paper proposes a DC microgrid with enhanced Maximum Power Point Tracking (MPPT) techniques for wind and solar energy systems. In this paper, the PV system power generation is enhanced by introducing a two-model MPPT technique that combines incremental conductance and constant voltage MPPT algorithms. Also, for the Wind Energy Conversion System (WECS) with pitch angle controlling technique, an Optimal Power Control MPPT technique is added. The Space Vector Pulse Width Modulation technique is introduced on grid side converter to improve the supply to the grid. The performance of proposed system is analyzed and the efficiency obtained with these methods is enhanced as compared with the previous methods.

Corresponding Author:

D. Chinna Kullay Reddy,
Departement of Electrical and Electronics Engineering,
Madanapalle Institute of Technology and Science,
Madanapalle, India.
Email: dkullayreddy@gmail.com

1. INTRODUCTION

The rapid depletion of conventional sources is increasing the demand for the use of alternating energy sources. Mainly wind and solar with their abundance and high potential gained the attention of the world. There are different concepts and technologies developed from years in order to utilize the available sources. Both wind and solar power system generations change with varying weather conditions. To best utilize the sources each are provided with some techniques. There are different MPPT techniques [1-5] generally being used in PV systems. The Perturb & Observe (P&O) [6], [7], the Incremental Conductance (INC), Open Circuit Voltage, Short Circuit Current are generally used MPPT techniques and each has its own drawbacks. The P&O produce oscillations around the Maximum Power Point (MPP) even under steady state illumination. The INC method is efficient and accurate even under varying weather conditions but its controlling circuit is complex than P&O. The OC voltage and SC current method are simple but not efficient for high energy generation units.

In PV system to improve the performance at any weather condition, the two-model MPPT technique is introduced. From the generally used techniques, any two techniques are combined based on the climatic conditions of an area and of all combinations; the Incremental Conductance and Open Circuit Voltage combination is efficient and accurate for all weather conditions[8], [9].

The Wind Energy Conversion System (WECS) has different concepts in terms of generators, fixed and variable speed wind turbine generators. Here, it is provided with a Permanent Magnet Synchronous Generator (PMSG), a pitch angle controlled wind turbine and also with an MPPT technique that acts in accordance with the wind speed. The PMSG is a variable speed wind turbine generator which is much efficient than Doubly Fed Induction Generator of the same type. The wind and solar power that was generated is integrated at the microgrid. The dc power is boosted and then converted to ac using an inverter. To control the power at the inverter end, it is provided with Space Vector PWM technique that eliminates the distortions in output voltage and improves the efficiency.

The novelty of this paper is to improve the power generation of both the PV system and WECS with enhanced techniques .The contributions of the paper include (1) Analysis of different MPPT techniques for a PV system and to design a two-model MPPT technique. (2) Development of a WECS with PMSG [10-12] and deploying the pitch angle controlling technique and an Optimal Power Controlling MPPT technique. (3) Integrating the PV system with WECS and implementing SVPWM technique [13-15] on the inverter side in order to improve the performance of output power.

The paper is organized in such a way that Section 2 discusses the design of the PV system, different MPPT methods used in the PV system and the design of two-model MPPT technique. Section 3 contains the modeling of WECS with MPPT technique. In Section 4, the integration of PV system with WECS and the SVPWM technique are discussed. The simulation results are shown and discussed in Section 5. Section 6 is the conclusion of the paper.

2. DIFFERENT MPPT METHODS FOR PV SYSTEM

The PV module is first modeled in Mat lab based on the following equations.

$$I = I_{PV}N_{PP} - I_O N_{PP}\left[e^{\left(\frac{V+IR_S\left(\frac{NSS}{NPP}\right)}{V_{ta}}\right)-1}\right] - \left[\frac{V+IR_S\left(\frac{NSS}{NPP}\right)}{R_P\left(\frac{NSS}{NPP}\right)}\right] \tag{1}$$

$$I_{PV} = (I_{PVn} + k_i \Delta T)\frac{G}{G_n} \tag{2}$$

$$I_O = \left[\frac{I_{PVn}+k_i\Delta T}{e^{\left[\frac{(V_{OCn}+k_v\Delta T)}{V_{ta}}\right]}}\right] \tag{3}$$

$$V_{ta} = \frac{q}{aKN_S T} \tag{4}$$

Where,

I= PV array terminal current
Ipv = PV Cell current
I_o= Cell reverse saturation current
Rs = Series resistance
Rp = Parallel resistance
Vt = Cell thermal voltage
a= Ideality factor
Npp= parallel in modules
Nss= Series in modules
Ns=cells series in a module

Table 1.Reference values for the designed PV System

$G=G_n=1000$	$N_S=54$	$N_P=2$	$K_i=0.0032$	$R_P=415.4$	$I_{SCn}=8.214$
$T=T_n=298.15$	$N_{SS}=15$	$I_{PVn}=7.61$	$K_v=-0.123$	$R_S=0.23$	$V_{OCn}=32.9$

With change of irradiation and other specifications of the module, the output varies. With the specifications stated above, the maximum output from the PV system is about 3W. To maintain the system at its maximum production, the Maximum Power Point Tracking (MPPT) techniques are introduced. The most generally used MPPT techniques are as:

2.1. Perturb & observe (P&O) MPPT Method

The P&O MPPT algorithm is a hill climbing technique in which, the operating voltage of the PV system is perturbed by the change in voltage (dv) is carried out according to change in power (dp) such that the variation of both the quanties need to be in the same direction. Figure 1 shows the flowchart of this MPPT algorithm. The drawback of this method every MPPT cycle the array terminal voltage is perturbed, resulting in a power loss in the PV system due to heavy oscillations of output voltage at the MPP. Furthermore, it sometimes fails to find the MPP.

2.2. Incremental Conductance MPPT Method

In the second method, the PV system voltage is regulated according to the voltage corresponding to maximum power based on conductance (I/V) and instantaneous conductance (d*I*/d*V*).The PV system voltage is increased or decreased by verifying the positive or negative variation of dP/dV respectively.Inorder to track the voltage corresponding to maximum power.The flow chart of the incremental conductance method as shown in Figure 2. The advantages of the INC algorithm are of its high stability and fine control of the system with rapid change of atmospheric conditions.

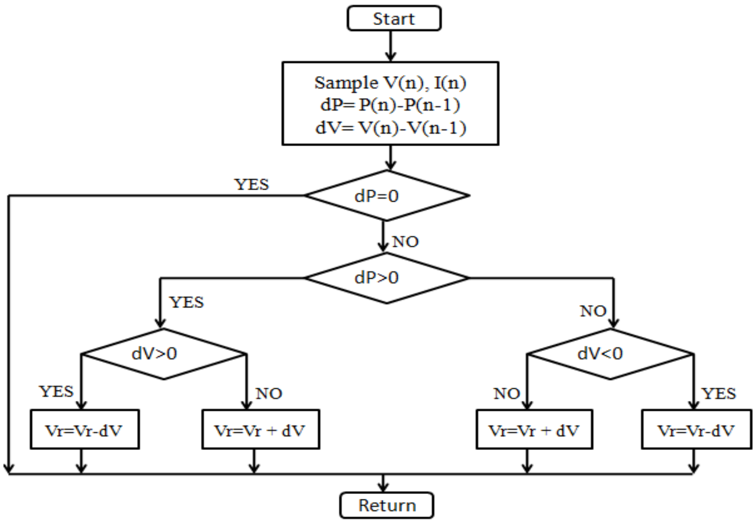


Figure 1. Flowchart of P&O MPPT algorithm

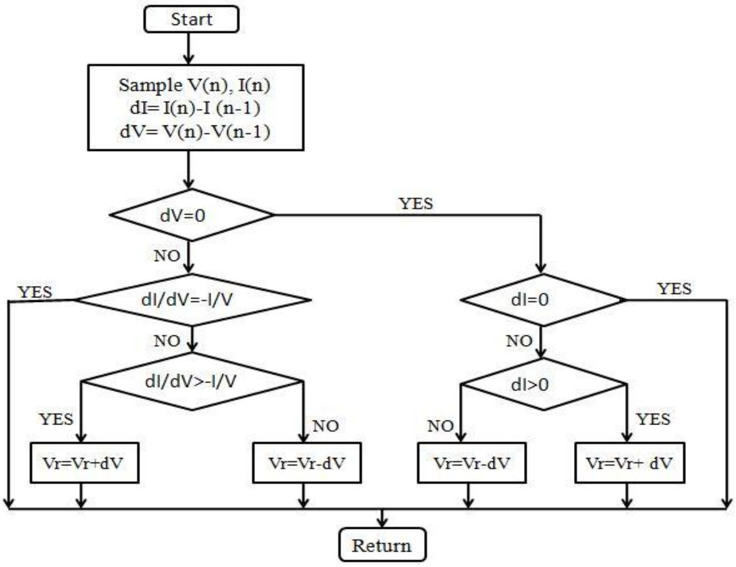


Figure 2. Flowchart of INC MPPT algorithm

2.3. Open Circuit Voltage MPPT Method

This method was the linearrelationship between open circuit voltage of PV panel and voltage corresponding to maximum power. The ratio of the aforementioned voltage quantities is indicated with a gain whose value typically lies between 0.71 to 0.80.open circuit voltage or Constant voltage algorithm is a simple MPPT technique and its flowchart is as shown in Figure 3.

$$\mathbf{V_{(MPP)} = k_1 * V_{oc}}$$

The type of the solar cell and its characteristics define the open circuit voltage of PV panel

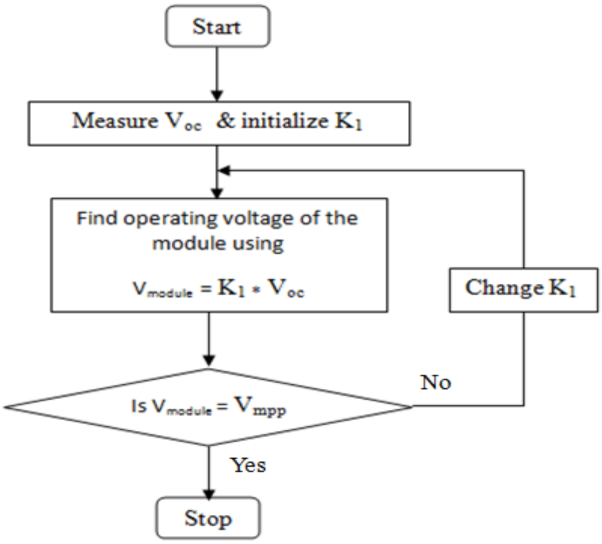


Figure 3. Flowchart of OCV MPPT algorithm

2.4. Short Circuit Current MPPT Method

The Short circuit current or constant current algorithm is a simple MPPT technique and its flowchart is as shown in Figure 4. I_{SC} is the PV Panel Short circuit current.This short circuit current depends on the solar cell parameters. The equation of the $I_{(MPP)}$ is

$$\mathbf{I_{(MPP)} = k_2 * I_{sc}}$$

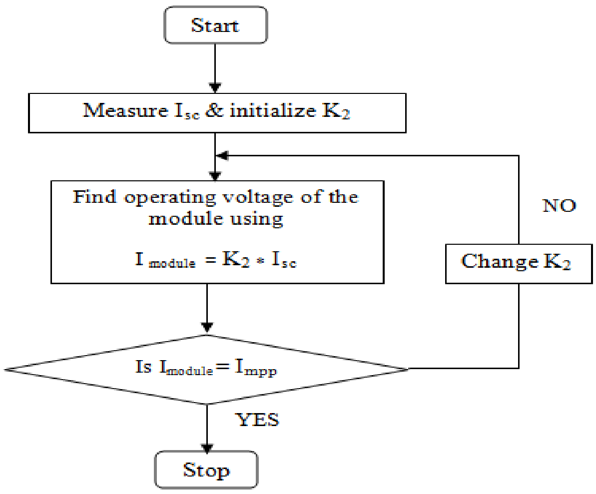


Figure 4. Flowchart of SCC MPPT algorithm

The relation between short circuit current and current corresponding to maximum power seems to be simple. However, the design of gain K_2 is complex. Typically the value of gain K_2 lies between 0.78 & 0.92.

2.5. Two-Model MPPT Method

The two-model MPPT can be designed with different techniques that are available. But, the most beneficial and efficient for the rapid changes is the combination of incremental conductance and Open Circuit Voltage MPPT techniques. The flowchart of proposed two model MPPT algorithm is shown in Figure 5 and Simulink model of two model MPPT method is shown in Figure 6. Here G_t is the threshold value of irradiation value and G_n is the irradiance value at particular value.

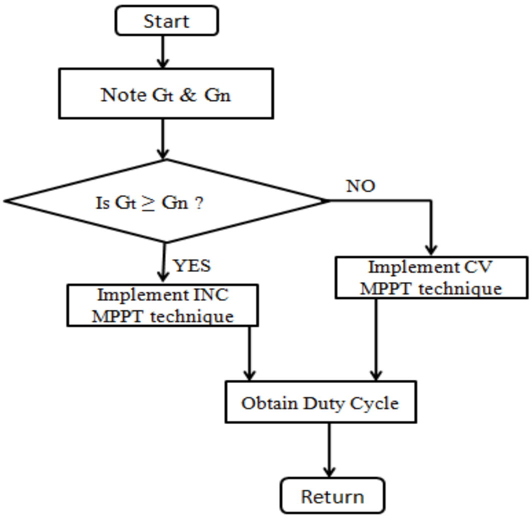


Figure 5. Flowchart of two-model MPPT

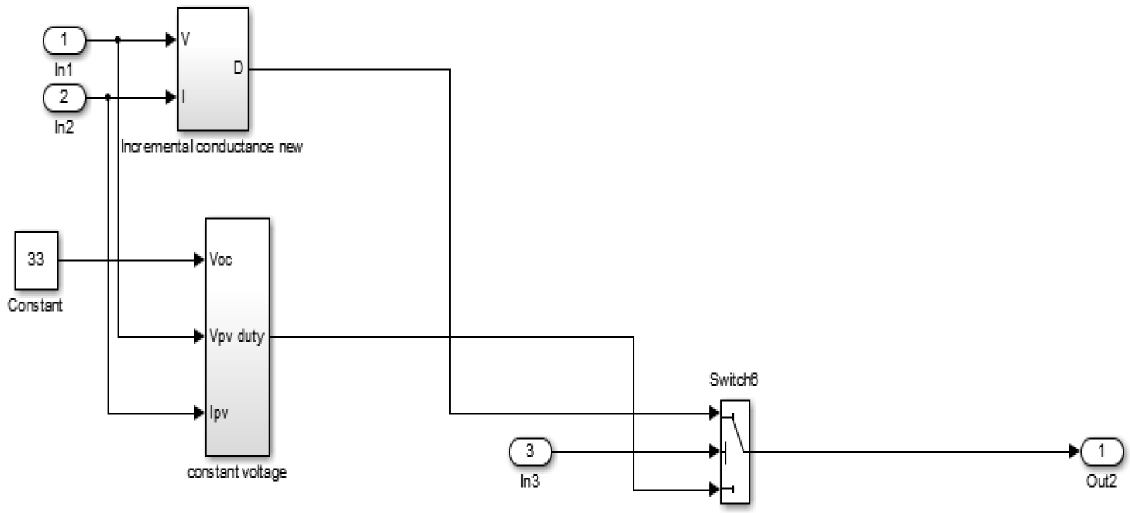


Figure 6. Simulink model of two-model MPPT

3. WIND ENERGY CONVERSION SYSTEM

The wind energy is the one which is much available after solar energy and is a promising source of electrical energy. The kinetic energy of the wind is used to rotate the turbines that generate mechanical energy. The generators convert the mechanical energy to electrical energy.

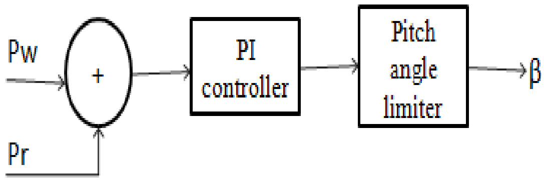


Figure 7. Pitch angle controller

The Wind Energy Conversion System (WECS) uses a Permanent Magnet Synchronous Generator (PMSG). The output power is enhanced by controlling the pitch angle (Figure 7) with respect to the change of wind speed. This is done to the pitch angle controlling technique. The WECS is also provided with an MPPT technique (Figure 8) calle d optimal power controlling technique.

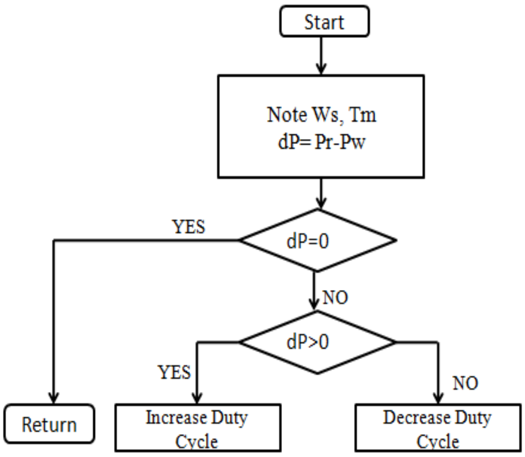


Figure 8. MPPT algorithm for WECS

4. INTEGRATION OF PV SYSTEM TO WECS

The PV system and the WECS are integrated at a point and it is supplied to an inverter to generate AC output. On the inverter side, SVPWM technique is provided to improve the quality of the power. Figure 9 shows the simulink block diagram of the proposed microgrid.

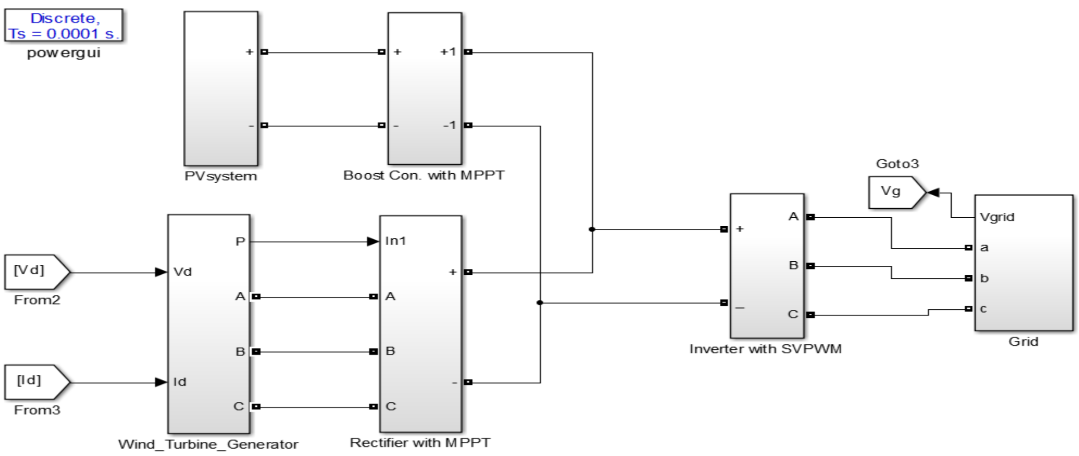


Figure 9. Simulink block diagram integration of PV system & WECS

The Space Vector PWM is preferred over sinusoidal PWM method for variable frequency drive applications. It improves the quality of the generated output. One important advantage of this technique is it reduces the Total Harmonic Distortion (THD) created by the rapid switching. Figure 10 show the space vector trajectory.

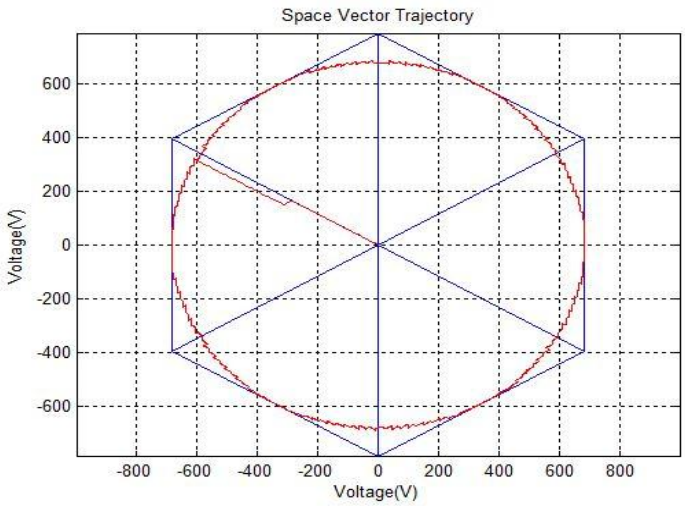
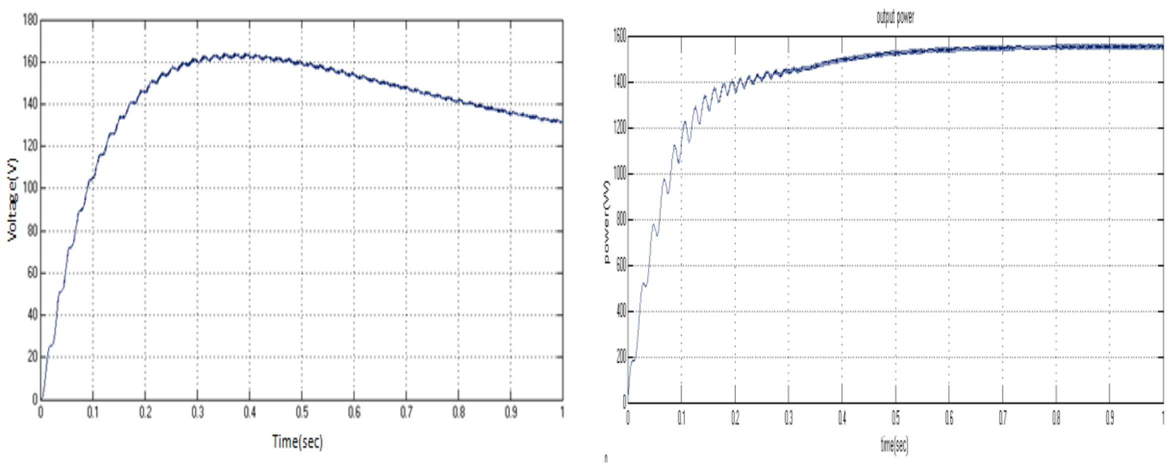


Figure 10. Space vector trajectory

5. SIMULATION RESULTS

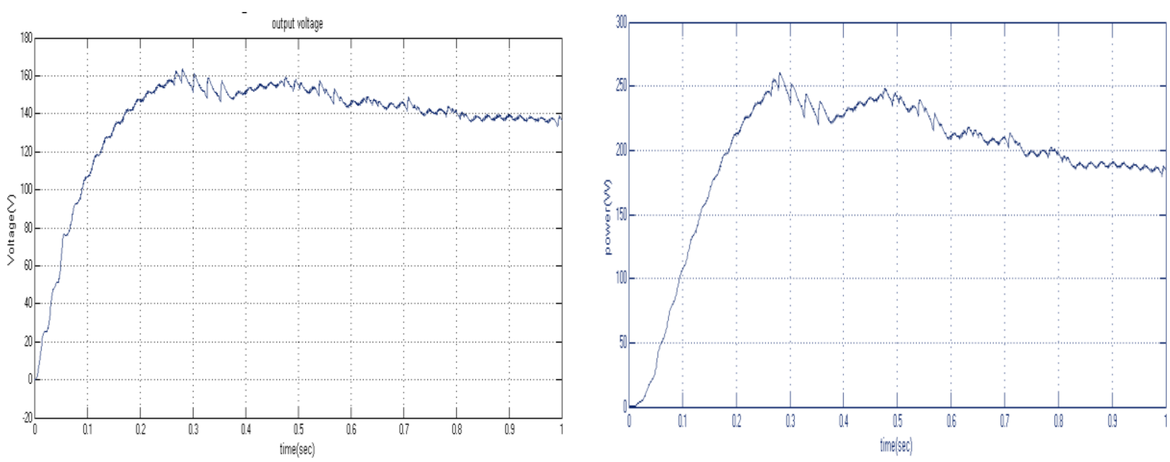
Output characteristics of PV panels for voltage and power at irradiation of 1000W/m^2 without using MPPT techniques (Figure 11), with constant voltage MPPT technique (Figure 12), with incremental conductance MPPT (Figure 13), with two model MPPT at irradiation of both 1000W/m^2 and 600W/m^2 (Figure 14 and Figure 15) are analyzed.

PMSG based Wind Energy Conversion System without MPPT and with MPPT at a wind speed of 12m/sec and pitch angle of 0˚ produced voltage of 200V and 350V, respectively (Figure 16). The output voltage waveforms of solar wind integration system without, with MPPT techniques, and SVPWM are depicted Figure 17.



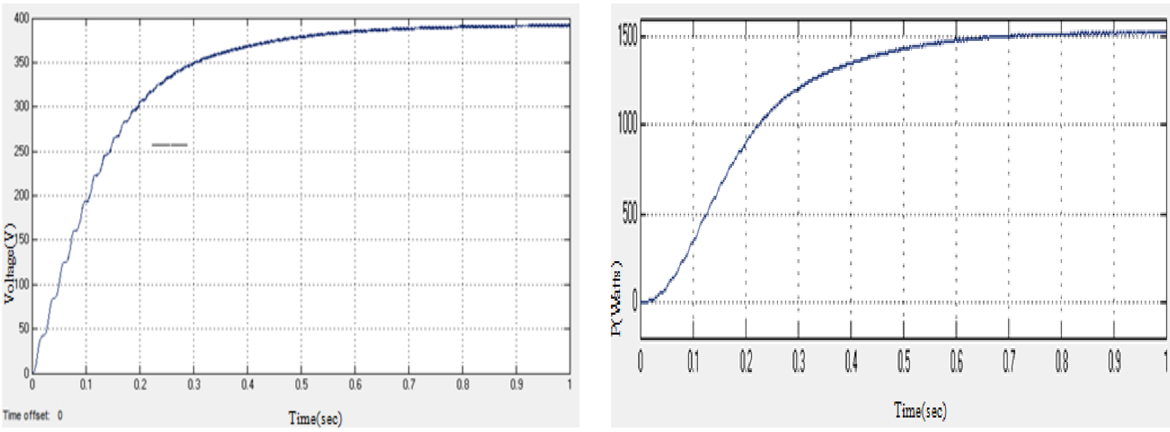
(a) (b)

Figure 11. PV system at irradiation of 1000W/m^2 (a) Voltage (b) Power



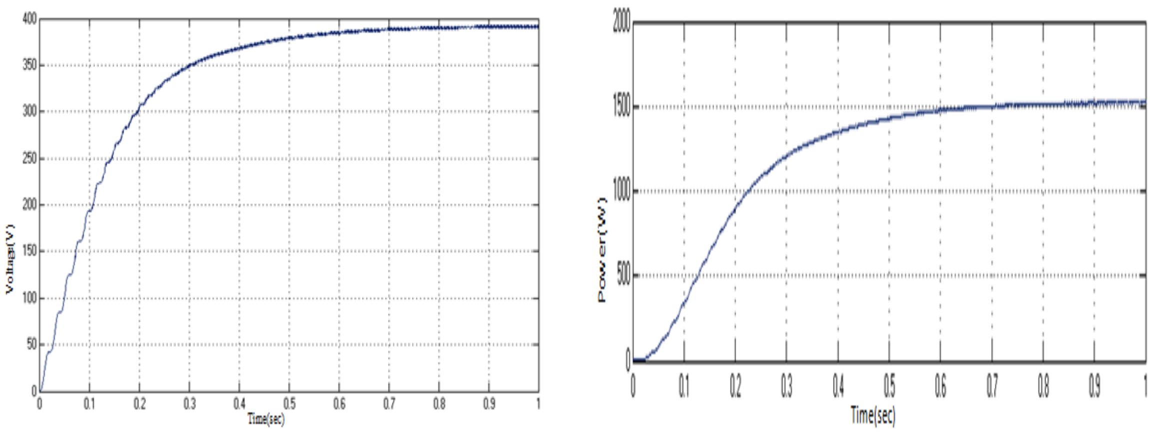
(a) (b)

Figure 12. PV system with Constant Voltage MPPT technique (a) Voltage (b) Power



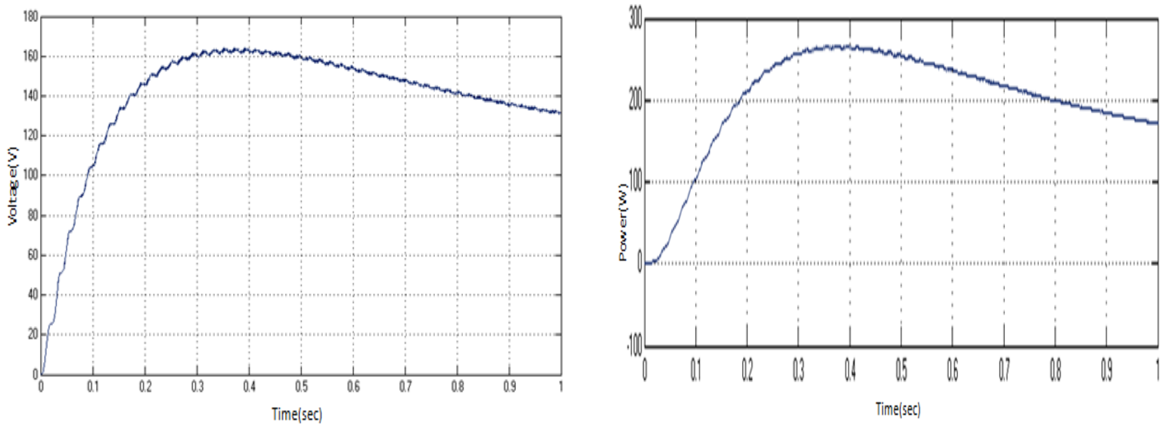
(a) (b)

Figure 13. PV system with INC MPPT technique (a) Voltage (b) Power



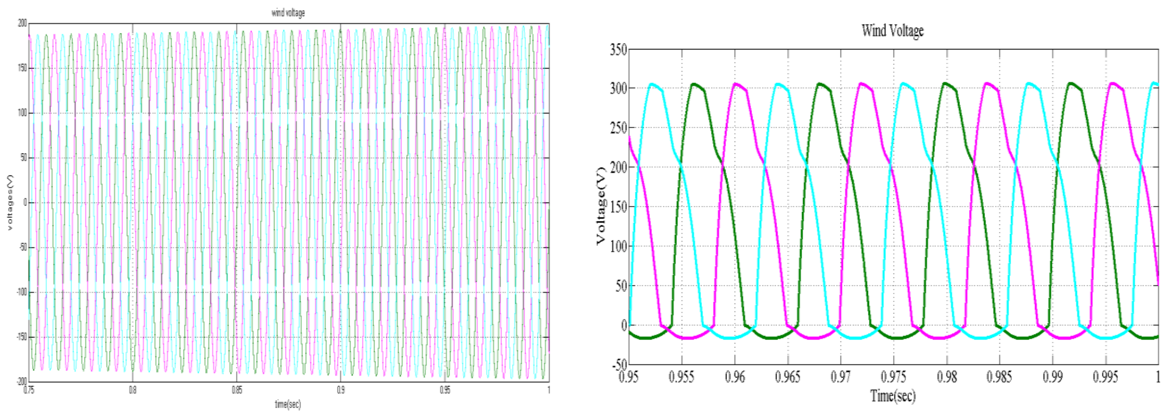
(a) (b)

Figure 14. PV system with two-model MPPT technique at 1000W/m^{2}irradiation (a) Voltage (b) Power



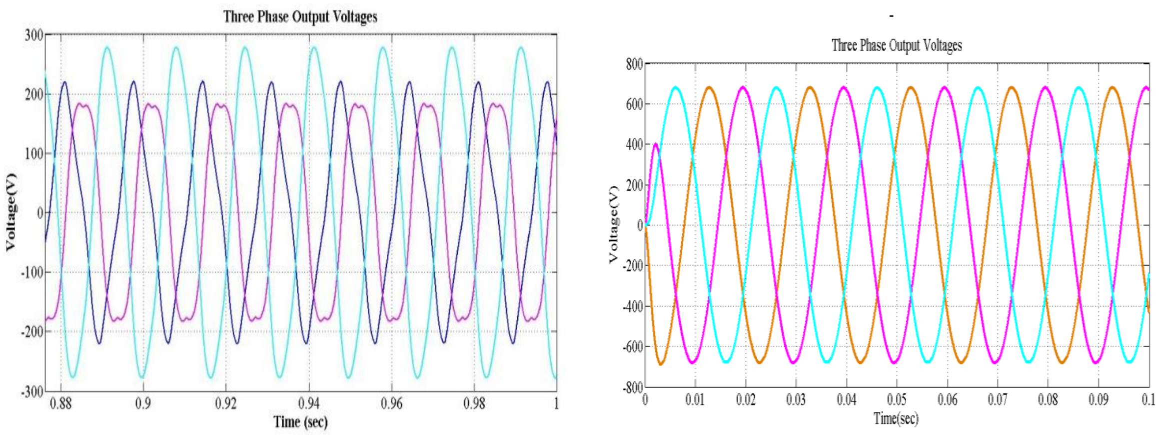
(a) (b)

Figure 15. PV system with two-model MPPT technique at 600W/m^2irradiation (a) Voltage (b) Power



(a) (b)

Figure 16. Voltage of a WECS (a) Without MPPT technique (b) With MPPT technique



(a) (b)

Figure 17. Output voltage of the integrated systems (a) in normal (b) with SVPWM and enhanced MPPT techniques

It was observed from the research carriedout that PV panel with Two model MPPT resulted higher voltage generation of about 380V (DC). Similarly, wind generator with MPPT resulted a higher voltage of about 300V (AC). Also, PV generator with short circuit MPPT resulted a lower voltage generation of about 120v (DC), where as wind generator without MPPT resulted lesser voltage of about 180V (AC) (Table 2).

Table 2. PV and Wind generation Voltages of different MPPT methods

PV generation		Wind power generation	
MPPT method	Voltage(V)	Without MPPT	180V
Short Circuit	120		
Constant Voltage	150		
Perturb &Observe	320	With MPPT	300V
Incremental Conductance	350		
Two model MPPT	380		

From the research results, integration of solar wind generation with MPPT and SVPWM generates greater voltage than without MPPT and SVPWM (Table 3).

Table 3. Integration of solar wind generation Voltages of withOUT and with MPPT and SVPWM methods

Integration of solar wind generation	
Without MPPT and SVPWM	300V
With MPPT and SVPWM	650V

6. CONCLUSION

This paper conferred a microgrid with an improved output from both PV system and WECS. The PV system output is improved with the Two-Model MPPT than the generally used P&O MPPT model and the WECS output also enhanced with a pitch angle controlled wind turbine model and an MPPT technique. The pitch angle control technique is actuated for high wind speeds and the MPPT algorithm is for driving the rectifier to track maximum power point. Also, the quality of AC output of the microgrid is much improved with the introduction of SVPWM technique on the inverter side. The improvement is well observed through the simulink results.

REFERENCES

[1] T.Esram and P.L.Chapman, “Comparison of photovoltaic array maximum power point tracking techniques,” *IEEE Trans. Energy Converse*., vol.22, no.2, pp.439-449, June 2007.
[2] Roberto Faranda, Sonia Leva, “Energy Comparison of MPPT techniques for PV Systems”, *WSEAS transactions on Power Systems*, Issue 6, Volume 3, 2008.
[3] F.Liu, S.Duan, B.Liu, and Y.Kang, “A variable step size INC MPPT method for PV systems”, *IEEE Trans. Ind. Electron*., vol.55, no.7, pp.2622–2628, July 2008.
[4] T.T.N.Khatib, A.Mohamed, N.Amin, and K.Sopian, “An efficient maximum power point tracking controller for photovoltaic systems using new boost converter design and improved control algorithm”, *WSEAS Trans. Power Syst*., vol.5, no.2, pp.53-63, 2010.
[5] J.M.Enrique, J.M.Andujar, and M.A.Bohorquez, “A reliable, fast, and low cost maximum power point tracker for photovoltaic applications”. *Solar Energy*, vol.84, no.1, pp.79-89, 2010.
[6] Ahmed, N.M., Farghally, H.M., Fahmy, F.H., “Optimal sizing and economical analysis of PV-wind hybrid power system for water irrigation using genetic algorithm,” 2017 *International Journal of Electrical and Computer Engineering*, 7 (4), pp. 1797-1814. DOI: 10.11591/ijece.v7i4.pp1797-1814
[7] Wijaya, F.D., Pribadi, K.D., Sarjiya, “Maximum power point tracking using particle swarm optimization algorithm for hybrid wind-tidal harvesting system on the south coast of Java,” 2017 *International Journal of Electrical and Computer Engineering*, 7 (2), pp. 659-666, DOI: 10.11591/ijece.v7i2.pp659-666.
[8] A. V. Pavan Kumar, Alivelu M. Parimi, K. Uma Rao, “A Discrete PLL based Load Frequency Control of FLC based PV-Wind Hybrid power system With Real Time Data”, *International Journal of Power Electronics and Drive Systems (IJPEDS)* Vol. 7, no. 4, PP-1320-1329, 2016. ISSN:2088-8694.
[9] Bidyadhar Subudhi, Senior Member, IEEE, and Raseswari Pradhan, “A Comparative Study on Maximum Power Point Tracking Techniques for Photovoltaic Power Systems”, *IEEE Transactions on Sustainable Energies*, Vol.4, No.1, January 2013
[10] E.Denny and M.O'Malley, "Wind generation, power system operation, and emissions reduction," *Power Systems, IEEE Transactions*, vol.21, pp. 341-347, 2006.
[11] K.Tan, S.Islam, “Optimum control strategies in energy conversion of PMSG wind turbine system without mechanical sensors”, *IEEE Transactions on Energy Conversion*, vol.19, pp.392-99, June 2004.

[12] M.Chinchilla, S.Arnaltes and J.C.Burgos, "Control of permanent magnet generators applied to variable-speed wind-energy systems connected to the grid", *IEEE Transactions on Energy Conversion*, Vol.21, No.1, pp.130-135, March 2006.
[13] Palanisamy, R., Vijayakumar, K., "Wind-PV hybrid energy source fed three level NPC with quasi Z source network," 2017 *International Journal of Power Electronics and Drive Systems,* 8 (3), pp. 1285-1293. Zenned, S., Aridhi, E., Mami, A., "Modeling and control of micro-grid powered by solar and wind energies," 2017 *International Journal of Power Electronics and Drive Systems,* 8 (1), pp. 402-416.
[14] S.Das and G.Narayanan, "Novel switching sequences for a space-vector modulated three-level inverter", IEEE Trans.Ind. Electron., vol.59, no.3, pp.1477-1487, March 2012.

BIOGRAPHIES OF AUTHORS

D. Chinna Kullay Reddy has done his B.E and M.tech from JNTU, Hyderabad, in the years 2006 and 2010 respectively. He is presently a research scholar at JNTU, Kakinada, Andhra Pradesh. His research area is on Distributed Generation, Power industrial drives and Renewable energy sources.

Dr. S. Satyanarayana is graduated B.E from GITAM College of Engineering, Andhra University, Masters from University College of Engineering, Andhra university, Vishaka Patnam and Ph.D from J.N.T. University,Hyderabad, Andhra Pradesh, INDIA. He is presently working as professor and Principal in Tenali Engineering College, Tenali, Andhra Pradesh, INDIA. His areas of interest are Distributed generation, power electronics, Genetic algorithms, FACTS and power quality improvement in distribuion systems.

Dr. Ganesh Vualsala is graduated B.Tech in 1998 from JNTU University, Hyderabad, Masters from S.V.University, Tirupathi, and Ph.D from J.N.T.University, Anantapur Andhra Pradesh, INDIA. He is presently working as Professor for the Department of Electrical and Electronics Engineering, J.N.T.University, Pulivendula, Andhra Pradesh, INDIA. His areas of interest are Genetic Algorithms, FACTS and its applications to Electrical distribution systems and its automation. He is also doing research in smart grid, design of controllers for renewable energy sources and control systems etc.