iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** IX **Month of publication:** September 2018

DOI:

Performance Enhancement Strategies for Grid Connected Photovoltaic Energy Systems

B. Srinivas[1], Dr. N. Bhupesh Kumar[2]
[1, 2]EEE Department, Sir C R Reddy College of Engineering, Eluru.

Abstract: The irregular nature of renewable energy resources presents the significant challenges like voltage variations, harmonic distortions during the integration of their generation to the grid. In this paper a mathematical analysis of PV array with different MPPT topologies in a grid connected mode is formalized. Due to non-uniform irradiation and temperature the characteristics of PV array are highly non-linear. Along with PV array, converter and grid interfacing scheme are simulated in MATLAB/SIMULINK environment. The primary objective of the project is to utilize the deficient power required for PV energy through grid system and to fed excess power of the energy to the utility grid.
Keywords: Maximum Power Point Tracking (MPPT), Incremental Conductance (INC), Artificial Neural Networks (ANN), Grid Interfacing Systems, Photovoltaic (PV).

I. INTRODUCTION

The grid connected photovoltaic power generation is one of the rapid growing energy resources techniques. The renewable energy resources like solar generation is integrated to utility grid carrying significant challenge both for utilities and system operator. As solar generation is very uncertain in nature and drastically affects the performance of connected systems.[1]. In such scenario requires fast and dynamic responding compensation devices which can assist to provide least undesirable effect to mitigate this high solar PV generation penetration. In spite of advantages, the energy conversion efficiency of PV generation is currently low, and the initial cost for its execution is still considered as high. Hence the use of MPPT approaches is necessary to extract the optimal power from PV panels, in order to achieve extreme efficiency in operation.[2]

II. SIMULATION OF THE PV SYSTEM

The operation of solar panel or solar cell is explained by the process of photovoltaic effect [3]. The below figure shows the corresponding circuit of PV cell and specifications are also tabulated.

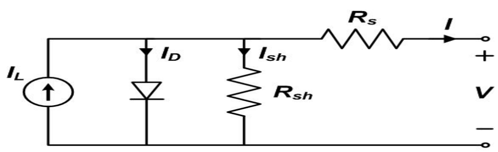


Fig 1: Equivalent Circuit of PV Cell

From the Equivalent circuit, the Characteristic equation of PV cell is

$$I = Iph - Id - Ish \longrightarrow \quad (2.1)$$

By placing all the values of currents, we calculate the current obtained from a PV cell. Diode current

$$Id = I0 * \left(\exp\left(\frac{q*(Vpv + Ipv*Rs)}{aKT} - 1 \right) \right) \longrightarrow \quad (2.2)$$

I0 is the reverse saturation current which is varied with temperature, and it is given by the following equation

$$I0 = I0ref \left({}^{T}/_{Tref} \right)^3 * \left(\exp\left(\frac{qEg}{K\gamma} \left(\frac{1}{Tref} - \frac{1}{T} \right) \right) \right) \longrightarrow \quad (2.3)$$

$$I0ref = \frac{Isc}{\exp\left(\frac{Voc}{a} - 1\right)} \longrightarrow \quad (2.4)$$

The current Iph depends on temperature (T) and the solar irradiation (G). The equation can be expressed as

$$Iph = \frac{G}{Gref} \left(Iref + \mu (T - Tref) \right) \longrightarrow \quad (2.5)$$

The current flowing in the shunt resistance is given by

$$Ish = \frac{V+I*Rs}{Rsh} \rightarrow \quad (2.6)$$

By placing the equations 2.2, 2.5 and 2.6 in equation 2.1 we get

$$I = Iph - I0 * \left(\exp\left(\frac{q*(Vpv+Ipv*Rs)}{aKT}\right) - 1\right) - \left(\frac{V+I*Rs}{Rsh}\right)\Big) \rightarrow \quad (2.7)$$

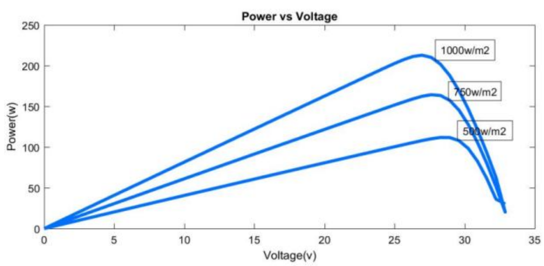
To simulate the PV array from the above equation, the mathematical model contains Np cells in parallel and Ns cells in series. Assuming that the solar array has cells in parallel ,Np equal to 1 and then the equation is

$$I = Iph - I0 * \left(\exp\left(\frac{q*(Vpv+Ipv*Rs)}{aKTNs}\right) - 1\right) - \left(\frac{V+I*Rs}{Rsh}\right)\Big) \rightarrow \quad (2.8)$$

Table 1: Description of the PV array

At Temperature=25°c		
Open circuit voltage	Voc	32.9V
Short circuit current	Isc	8.21A
Voltage at max power	Vm	26.3V
Current at max power	Im	7.61A
Maximum power	Pm	200Wp
Temp coefficient of Isc	α	$3.18*10^{-3} A/°C$

In Figs.2a and 2b, the power characteristics of the analyzed PV cell, considering solar irradiation and temperature changes, are shown.



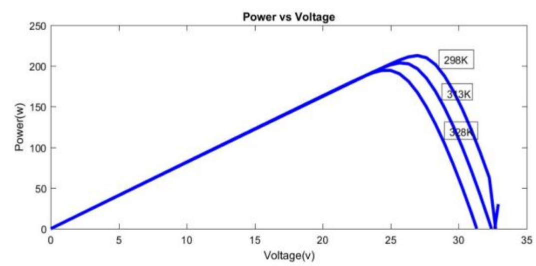


Fig 2a: PV power characteristic for different irradiation levels. Fig 2b: PV power characteristic for different temperature levels.

The above curves represent non-linear characteristics, and they are strongly influenced by climatic changes.

III.MPPT TECHNIQUES

A. MPPT by P& O method

Perturb and observe method is one of the hill climbing technique based on the voltage -power characteristics of PV array. This algorithm is mostly used for PV systems because of its low complicatedness and easy to implement.[5]

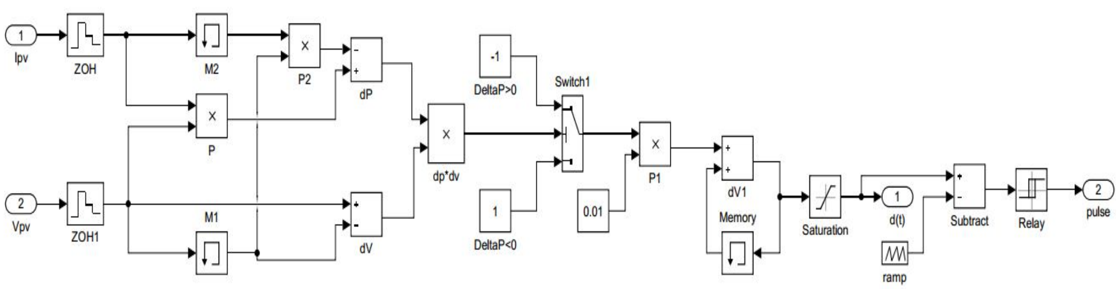


Fig 3a: Implementation of P&O method using MATLAB/Simulink.

The P&O method operates by periodically incrementing or decrementing the output terminal voltage of the PV panel and comparing the power obtained in the current cycle with the previous cycle power (performs dP/dV).[4]

$$\text{Signal}\left(\frac{dp}{dv}\right) * (-Kr) = d \rightarrow \quad (3.1)$$

B. MPPT by Incremental Conductance method

This method is more efficient than the P&O algorithm in terms of tracking the maximum power point of PV array correctly.
The oscillations around the MPP are eliminated by this method. Due to this state, the MPP can be develop in terms of increase in the array conductance.[6]

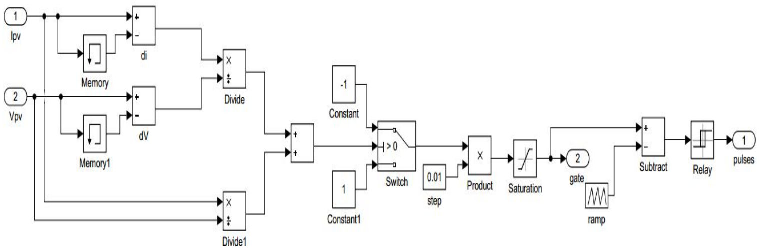


Fig 3b: Implementation of INC method through MATLAB/Simulink.

By using the equation (3.2), it is possible to find the IC conditions presented by (3.3)

$$\left(\frac{dp}{dv}\right) = \frac{d(v*I)}{dv} = i + V\frac{di}{dv} = 0 \rightarrow \quad (3.2)$$

$$\frac{\Delta i}{\Delta v} = -\frac{i}{v} \rightarrow (a)\ ;\ \frac{\Delta i}{\Delta v} > \frac{i}{v} \rightarrow (b)\ ;\ \frac{\Delta i}{\Delta v} < \frac{i}{v}\ (c) \rightarrow \quad (3.3)$$

The equation (a) represents condition at the MPP, (b) represents the condition at the left side of MPP and the equation (c) represents the condition at the right side of MPP.

C. MPPT by Constant Voltage method

This algorithm is based on the fact that the voltage of PV array at MP is linearly proportional to its open circuit voltage at maximum power point.

$$K = \frac{V_{mp}}{V_{oc}}$$

Where 'k' is a proportional constant and its value depends on technology of the material used, fill factor and climatic conditions. The value of 'k' is ranging from 0.71 to 0.86 [7],[8].

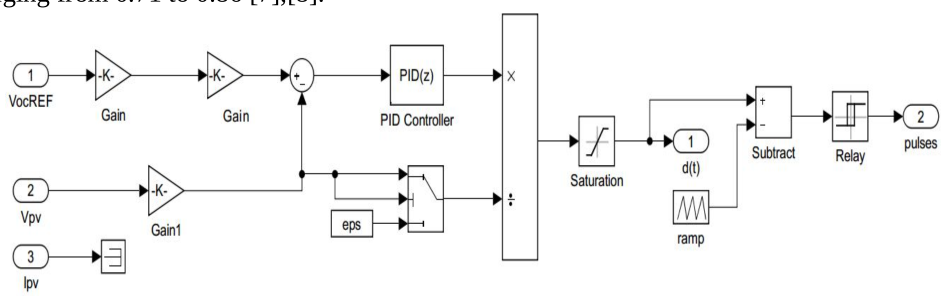


Fig 3c: Implementation of CV method through MATLAB/Simulink

The CV technique uses empirical results, representing that voltage at MPP (V_{MPP}) is around 70% to 80% of the V_{OC}, during the standard climatic conditions. This is favourable method because only the PV module voltage is sufficient to measure and a simple control loop can reach the MPP.

D. INC method using ANN controller

Along with fuzzy logic controllers another technique of implementing MPPT are the artificial neural networks. Neural networks generally have three layers. They are input layer, hidden, and output layers. The input parameters of neural network can be PV array variables like Voc, Isc, and climatic data like temperature (T) and irradiance (G) or any combination of these[9]. The output is generally one or more reference signals like a duty cycle ratio, used to drive the power converter to operate at or near to the MPP. How nearer the operating point gets to the MPP depends on the algorithms used by the hidden layer and how good the neural network has been trained [11],[12].

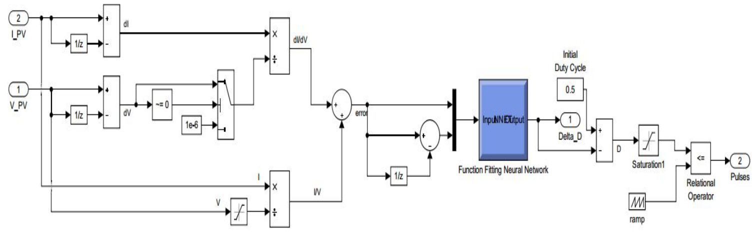


Fig 3d: Implementation of INC method using ANN controller MATLAB/Simulink

IV. CONVERTER

Fig4a. Shows the system configuration of the proposed converter, which has a capacitor, two inductors and four switch-diodes. Two of the switches work as power switches and the remainders are applied for the synchronous rectifiers. MPPT has basically a load matching problem. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required [10]. The steady-state analysis of the proposed converter in step-up mode is discussed as follows.

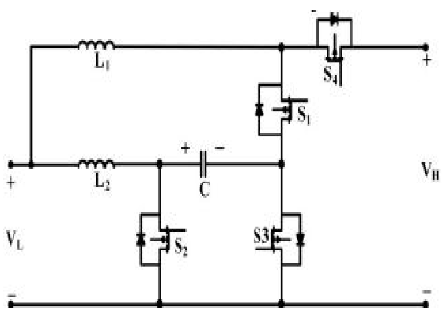


Fig 4a: proposed converter circuit

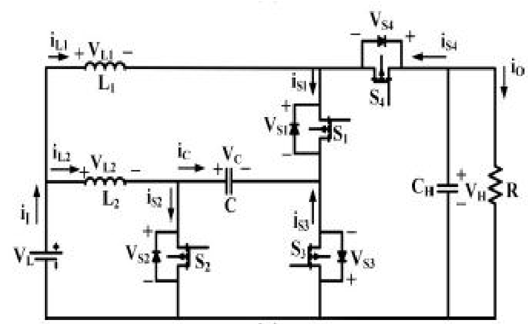


Fig 4b: Proposed Converter in step up mode

A. *Operating Principle of proposed converter in Step Up Mode*

In this operation mode, S1 and S2 work as power switches and S3 and S4 are the synchronous rectifiers. The steady-state analyses are described as follows. The operating principle of Converter can be explained in two modes.

Mode1 switches S1 and S2 are turned on

Mode2 when switches S3and S4 are turned on

During the interval S_1 and S_2 are turned on and S_3 and S_4 are turned off.

1) *Mode 1:* During the interval $S_1$and S_2 are turned on and S_3 and S_4 are turned off. In this interval the energy of the DC source V_L is transferred to inductor L_2. Inductor L_1 is magnetized by the DC source V_L and the energy stored in capacitor C. Capacitor C_H is also discharged to the load. The following equations can be obtained in this mode.[13].

$$V_{L1} = V_L + V_C \rightarrow \quad (4.1) \; : \quad V_{L2} = V_L \rightarrow (4.2)$$

2) *Mode 2:* During this interval S_1 and S_2 are turned off and S_3 and S_4 are turned on. Here capacitor C is charged by the input source V_L and the energy stored in inductor L_2.Capacitor C_H is also charged by the input source V_L and the energy stored in inductor L_1. Therefore the voltages across the inductors can be written as

$$V_{L1} = V_L - V_H \rightarrow \quad (4.3) \; : \quad V_{L2} = V_L - V_C \rightarrow \quad (4.4)$$

Applying volt second balance at inductors L_1 & L_2 results in

$$V_L = D(V_L + V_C) + (1 - D)(V_L - V_H) = 0 \quad ; \quad V_{L2} = DV_L + (1 - D)(V_L - V_C) = 0$$

On simplifying above equations we get

$$(V_C/V_L) = 1/(1 - D) \; : \; (V_H/V_C) = 1/(1 - D)$$

$$(V_H/V_L) = 1/(1 - D)^2$$

Hence voltage gain of the proposed converter is higher than conventional buck/boost converter in step up mode.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IX, Sep 2018- Available at www.ijraset.com

V. GRID INTERFACING SCHEME

In our proposed control strategy the RES is connected to a voltage source inverter (VSI) as a DC source.

If the RES generates AC voltage, that can be connected to the VSI after rectifying it. The DC link capacitor acts as an isolator in between the converters (the rectifier and the inverter) providing the freedom for independent control of both the converters.

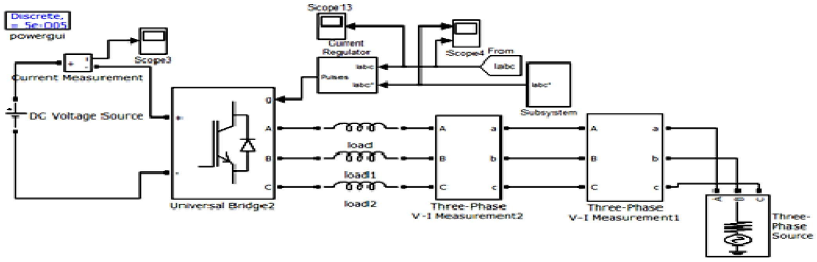


Fig 5: Simulation of the proposed control scheme

The c of the control strategy has been discussed in [14].The DC link transfers the power from the RES to the grid. The control scheme is shown in Fig 5.

VI. SIMULINK REPRESENTATION AND RESULTS

In order to access the implementation of all algorithms, a PV module with a maximum output power 200W, short circuit current 8.21AMP and open circuit voltage 32.9V under standard temperature and irradiance conditions was simulated using MATLAB. The basic representation of simulation diagram is shown in the figure 6.

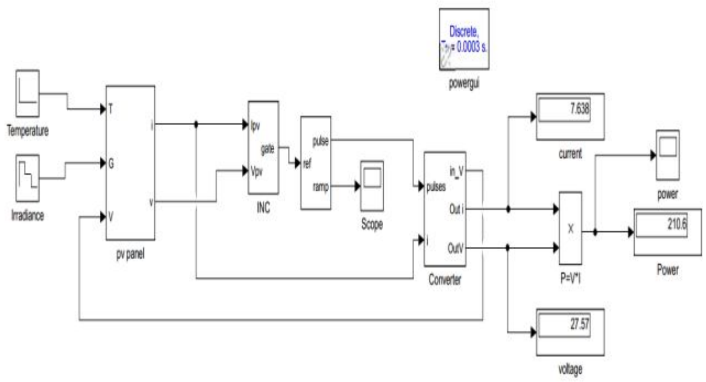


Fig 6: Basic Simulink Representation

At radiation=1000w/m^2		
MPPT techniques	Maximum power obtained(W)	Settling time(sec)
P&O algorithm	210.02	Oscillated around its MPP
INC algorithm	210.6	0.488
Constant voltage algorithm	208.8	0.497
INC method using ANN controller	203.3	0.466

Table 2: Pmax at Constant Irradiation for Different MPPT Techniques.

At constant temperature and constant irradiation the maximum power obtained for different MPPT techniques is shown in the table 2.

Figure 6(a) and 6(b) shows the PV array output power, output voltage & output current with respect to change in irradiations.

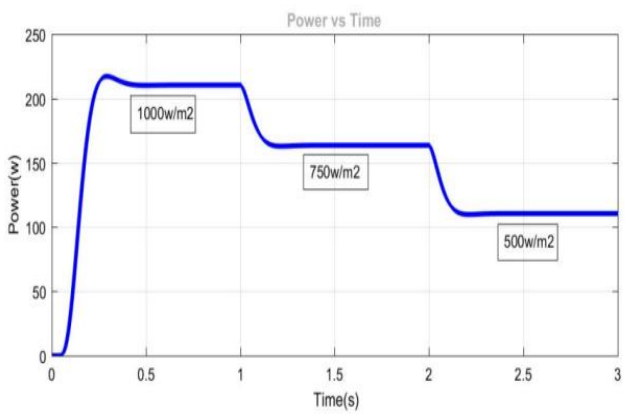


Fig 6(a): PV Panel Output Power at Various Irradiations

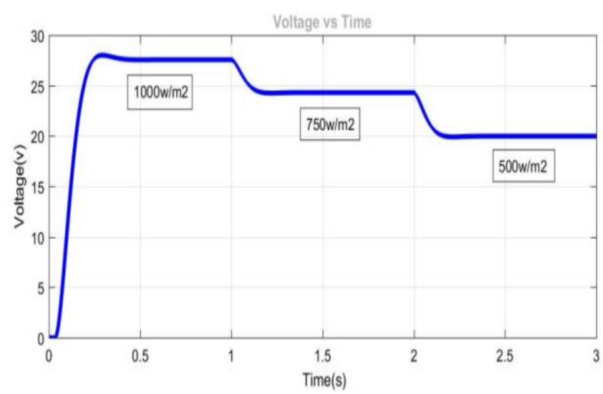


Fig 6(b): PV Panel Output Voltage at Various Irradiations

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IX, Sep 2018- Available at www.ijraset.com

Figure7 shows the comparison of converter output power with various MPPT techniques at various irradiations.

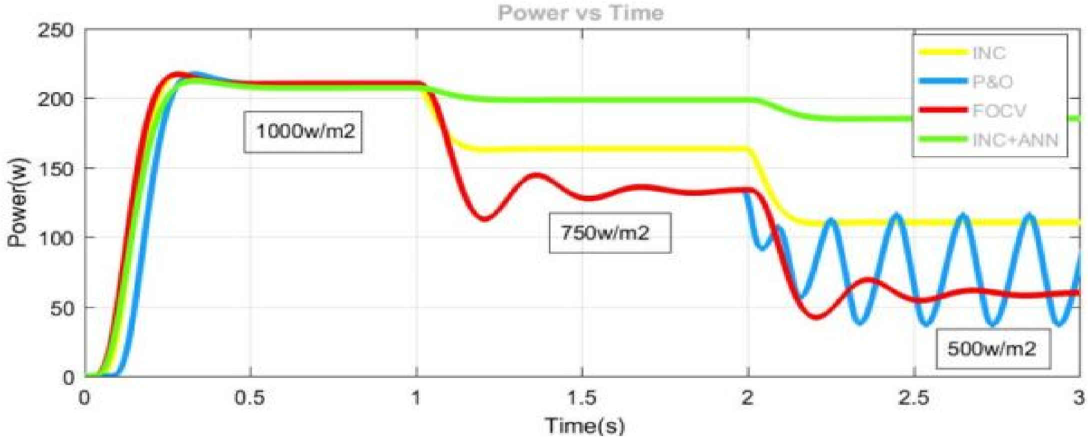


Fig 7: Converter Output Power with Different MPPT Techniques at Various Irradiations

Figure 8(a) and 8(b) shows the output power, output voltage and output current of converter by Incremental Conductance with ANN MPPT controller.

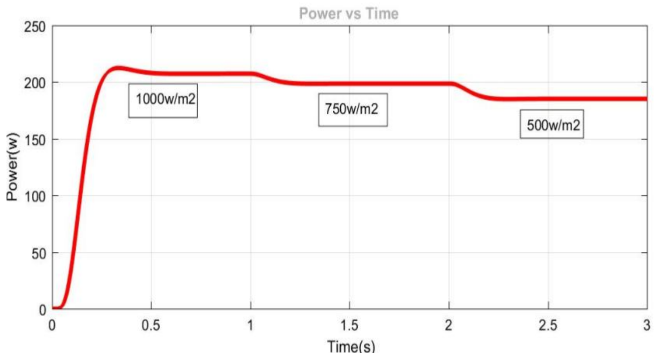


Fig 8(a): INC with ANN output power at various irradiations

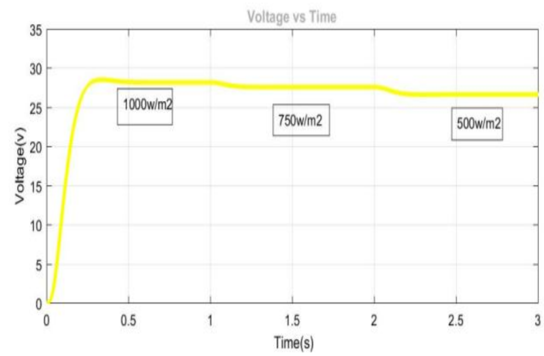


Fig 8(b): INC with ANN output voltage at various irradiations

MPPT algorithm based on Incremental Conductance with ANN controller provides efficient and accurate tracking efficiency to extract maximum possible power from PV array as shown in figure 8(a).

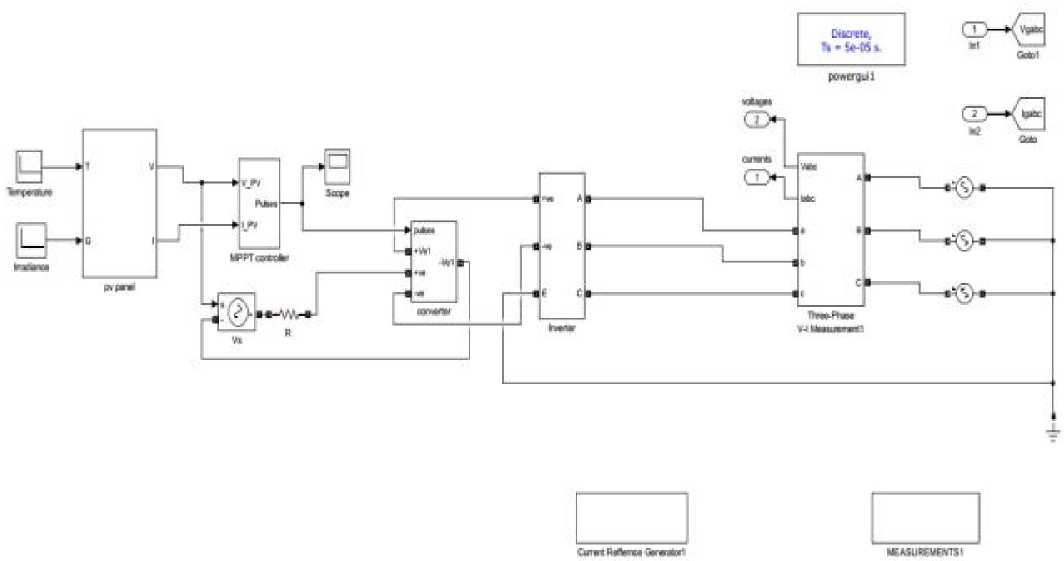


Fig 9(a) simulation diagram of Grid Integrated Photovoltaic system

Grid utility side voltage source converter control strategy perfectly matching the voltage and current at the grid.

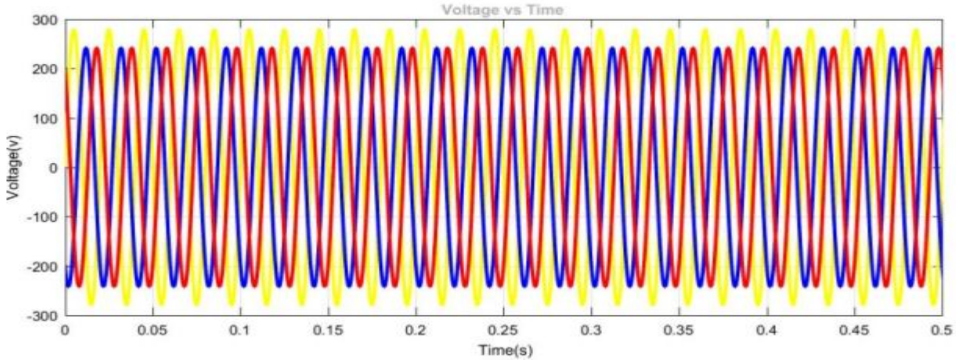


Fig 9(b) Grid side voltages

VII. CONCLUSIONS

The control strategies for performance enhancement of grid connected photovoltaic system is proposed and evaluated by Simulink. The control scheme consist for operation of MPPT based on incremental conductance with ANN controller extract the maximum possible power from PV array with good tracking efficiency. Hence the proposed control schemes enhance the performance of whole system and overcome the challenges associated with integration of renewable energy to the utility grid.

REFERENCES

[1] Xianjun Li,Dong Hui,Xiaokang Lai,.''Battery Energy storage station Based smoothing control of photovoltaic and wind power generation fluctuation''.IEEE Transaction on sustainable energy.vol 4,pp-464-473,jan 2013.

[2] J.-M. Kwon, K.-H. Nam, and B.-H. Kwon, “Photovoltaic power conditioning system with line connection,” IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1048–1054, Jun. 2006

[3] W. Kim and W. Choi, “A novel parameter extraction method for the one diode solar cell model,” Solar Energy, vol. 84, no. 6, pp. 1008–1019, Jun. 2010.

[4] A. K. Abdelsalam, A. M. Massoud, S. Ahmed, and P. N. Enjeti, “High-performance adaptive perturb and observe MPPT technique for photovoltaic-based microgrids,” IEEE Trans. Power Electron., vol. 26,no. 4, pp. 1010–1021, Apr. 2011

[5] N.Bhupesh Kumar and Dr.K.Vijaya Kumar Reddy, “Maximum Power Point Tracking of PV Arrays using Different Techniques,” Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 7(Version 6), July 2014, pp.49-57.

[6] N.Bhupesh Kumar, Sr. Assistant Professor, Department of EEE, Sir C R Reddy College of Engineering, Eluru “Advanced Fuzzy Logic Controller for Tracking the Maximum Power Point of PV Arrays” (IJERT) ISSN: 2278-0181 Vol. 2 Issue 11, November – 2013.

[7] C.Hua and C.shen, “Study of maximum power point tracking techniques and control of dc-dc converters for photovoltaic power systems”, in proc.29th Annu. IEEEPESC, vol.1, pp. 86-93, May 1998.

[8] G. J. Yu, Y. S. Jung, I. Choi, and J. H. Song, “A novel two-mode MPPT control algorithm based on comparative study of existing algorithms,” in Proc. PVSC, 2002, vol. 29, pp. 1531–1534

[9] M. K. Naga Mounika, N. Bhupesh Kumar, “Optimization of Power Generation and Reliability Enhancement of Photovoltaic System” (IJEAT) ISSN:2249-8985, volume-7 Issue-2,December2017

[10] S. Sumathi, L. Ashok Kumar, P. Surekha, “Solar PV and wind energy conversion systems,” ISSN 1865-3529, Green Energy and Technology, ISBN 978-3-319-14940-0.

[11] M. H. Rashid, “Power Electronics Handbook,” 2nd Edition, Academic Press, New York, 2007

[12] D. W. Hart, “Power Electronics,” McGraw-Hill Companies Inc., New York, 2010.

[13] Hossein Ardi, Ali Ajami, Faezeh Kardan, Shahla Nikpour. Analysis and Implementation of a Non-Isolated Bidirectional DC-DC Converter with High Voltage Gain.

[14] "Overview of control and grid synchronization for distributed power generation systems, R. Teodorescu, M. Liserre, and A. V. Timbus, F. Blaabjerg, "IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1398-1409,Oct.2006