International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 1, January- 2013

Comprehensive evaluation of photovoltaic system using MATLAB/Simulink

Jayshree sahu*, M. Ashfaque Khan**,Dr. S. K. Sahu***

*NIIST,Bhopal,**NIIST,Bhopal,***RGPM Bhopal

Absract-This paper presents modeling and simulation of PVA system in matlab simulink. The model based on exponential equation of pv module. It needs less input values and is more accurate. Here by varying temperature and irradiance as input variables we obtained the I-V, P-V characteristics and hence the harmonic distortion analysis can be made in different phases of supply system. The model has been validated with experimental data of a commercial PV module KC200GT.

Key Words

Photo voltaic (PV), Matlab, Modelling, (RES)-Renewable energy source, MPPT.

Non linear I-V characteristics of P-V Cell(Nomenclature)

Ipv,cell-	**current generated by incident light**
Id	**shocley diode equation**
I0,cell	**Reverse saturation current q electron charge**
k	**Boltzman constant**
T	**temperature of p-n junction**
a	**diode ideality constant**
I_O	**saturation current of array**
Vt	**thermal voltage or array**
Ns	**cell connected in series**
Np	**cell connected in parallel**
Rs	**equivalent series resistance**
Rp	**equivalent parallel resistance**
Isc	**short circuit current**
Voc	**open circuit voltage**
(O,Isc)	**short circuit point**
Kv	**voltage coefficient**
Ki	**current coefficient**
P max,m	**maximum power**
Pmax,e	**maximum experimental Power from data sheet**
(Voc ,0)	**open circuit point**
(Vmp,Imp)	**Maximum power point**
Ipv,n	**Light generated current at nominal condition at (25^0c and 1000 W/m^2)**
T	**actual Temperature**
Tn	**nominal temperature**
G	**Solar irradiance**
Gn	**nominal irradiance**

Introduction-With the rapid development of study on solar cells, many models are presented to describe the characteristics of solar cells. This method helps us to construct the circuit model of pv cell. Computer simulation seems to reduce the tests for solar cells .This model accepts irradiance and temperature as environmental parameters as input variables, simulate the I-V characteristics of solar cells.

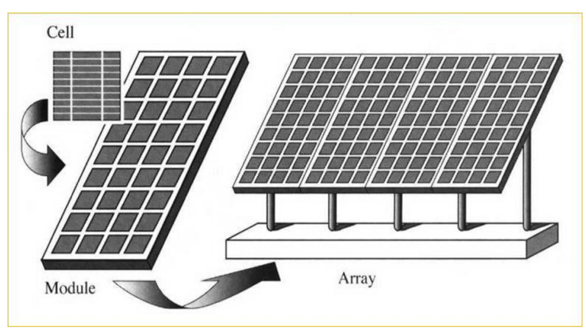

Fig-a, **P-V Cell, P-V Module, P-V Array** combine to form PV module, no of module combine to form PV array.

Maximum power point tracker system(MPPT)

MPPT controller is a power electronic DC/DC chopper or DC/AC inverter system inserted between the PV array and its electric load to achieve the optimum characteristic matching.The p-v array simulation model helps in study of MPPT. Is very important consideration that is taken into account when building a new photovoltaic power system. In order to extract maximum power output from a PV array under varying atmospheric conditions to maximize the return on initial investments. This technique is based on their speed of locating the maximum power point (MPP) of a PV array under given atmospheric conditions, besides the cost and complexity of implementing them.

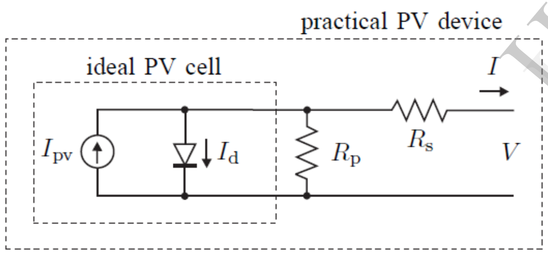

Fig-b**, P-V Cell model-Circuit Diagram**

Shunt diode ideality factor is set to achieve the best curve match.

Series resistance (**R_s**)**:** gives a more accurate shape between the maximum power point and the open circuit voltage.

Temperature dependence of the reverse saturation current of the diode is (**I_d**)**.**

Temperature dependence of the photo-generated current is (**I_{pv}**). Current source: proportional to the light falling on the cell in parallel with a diode.

The photovoltaic array can be simulated with an equivalent circuit model based on the photovoltaic model given below,

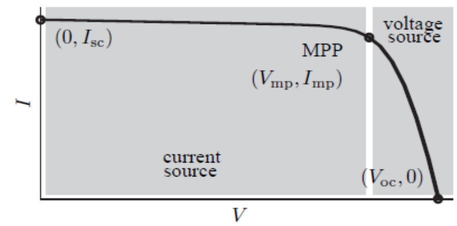

Fig-c, characteristics I-V curve of a practical PVA device and the three remarkable points: short circuit (0,I_{sc}), maximum power point ($V_{mp,}I_{mp}$) and open circuit (V_{oc},0).

The I-V characteristic of the ideal photovoltaic cell is

$$I = I_{pv,cell} - I_{0,cell}\left[\exp\left(\frac{qV}{akT}\right) - 1\right] \quad \ldots.1$$

The light generated current of the photovoltaic cell depends linearly on the solar irradiation and is also influenced by the temperature is given by

$$I_{pv} = I_{pv,n} + K_I \Delta_T \frac{G}{G_n} \quad \ldots.2$$

The diode saturation current I_o and its dependence on the temperature may be expressed by

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)^3 \exp\left[\frac{qE_g}{aK}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \quad \ldots.3$$

where Eg is the bandgap energy of the semiconductor (Eg ≈ 1.12 eV for the polycrystalline Si at 25 ◦C , and $I_{o,n}$ is the nominal saturation current. V_t= NskT/q is the thermal voltage of the array with Ns cells connected in series. I_o,n is the nominal saturation current, with Vt,n being the thermal voltage of Ns series-connected cells at the nominal temperature T_n.

$$I_{0,n} = \frac{I_{sc,n}}{\exp\left(\frac{V_{oc,n}}{aV_{t,n}}\right) - 1} \quad \text{....4}$$

Maximum experimental power from datasheet

$$P_{max,e} = V_{mp}\left\{I_{PV} - I_0\left[\exp\left(\frac{q}{kT}\frac{V_{mp}+R_s I_{mp}}{aN_s}\right) - 1\right] - \frac{V_{mp}+R_s I_{mp}}{R_p}\right\} \quad \text{....5}$$

For any value of Rs there will be a value of Rp that makes the mathematical I-V curve cross the experimental (Vmp, Imp) point.

$$R_p = V_{mp}\left(V_{mp}+I_{mp}R_s\right) / \left\{V_{mp}I_{pv} - V_{mp}I_0\exp\left[\frac{V_{mp}+I_{mp}R_s}{N_s a}\frac{q}{kT}\right] + V_{mp}I_0 - P_{max,e}\right\} \quad \text{....6}$$

Algorithm to adjust the I-V model

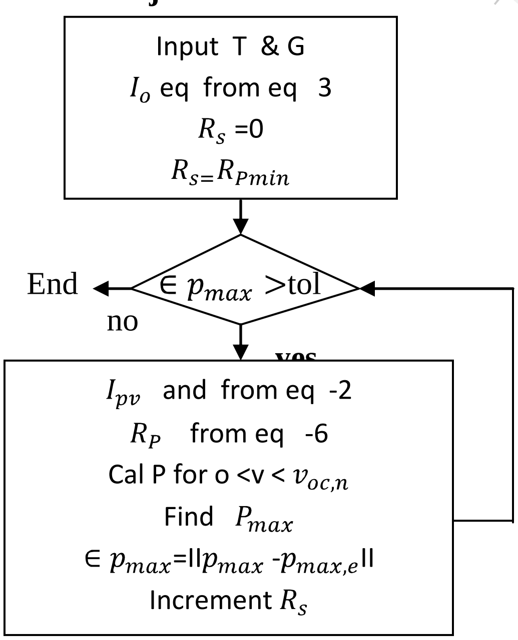

Fig.d-Flowchart

P-V Array equivalent circuit block model using Matlab / Simulink

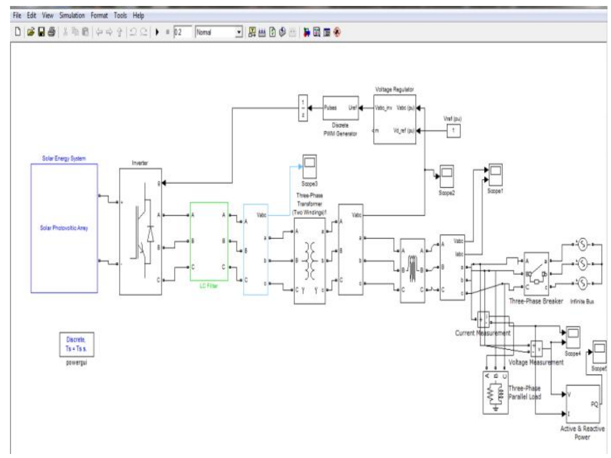

Fig .e-Matlab model of P-V system

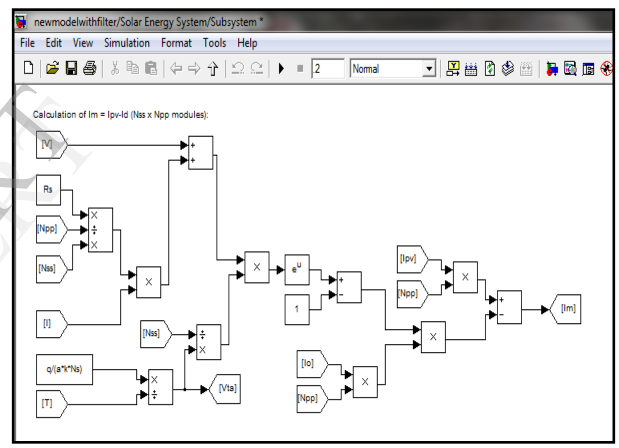

Fig.f- Subsystem for calculation of I_m

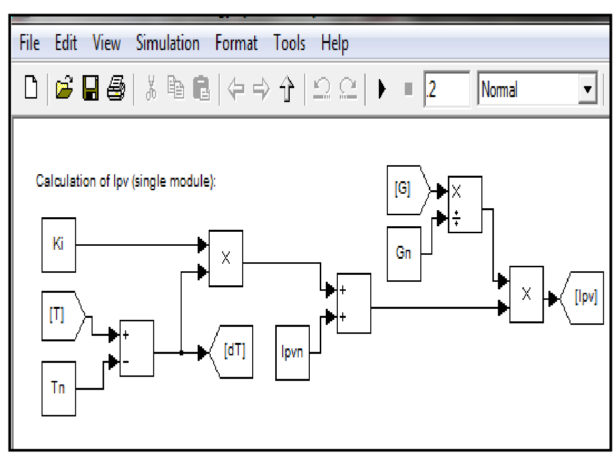

Fig.g- Subsystem for calculation of I_{pv}

ISSN: 2278-0181
Vol. 2 Issue 1, January- 2013

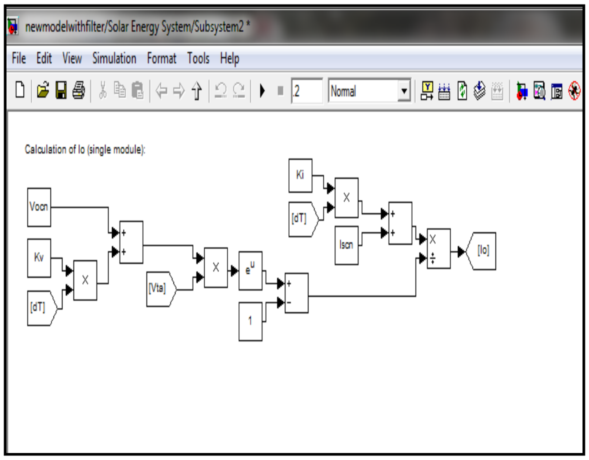

Fig.h- Subsystem for calculation of I_o

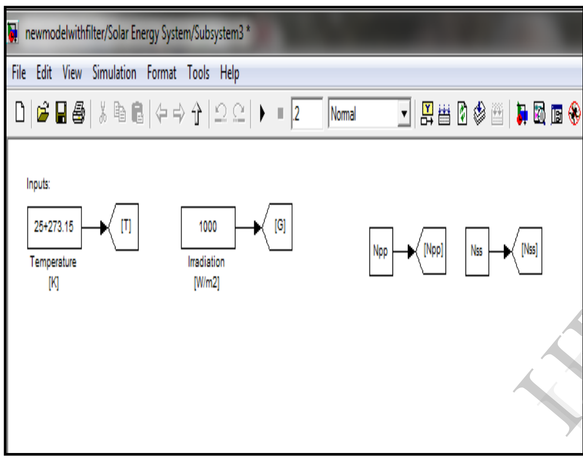

Fig.i-subsystem of input as temperature and irradiance

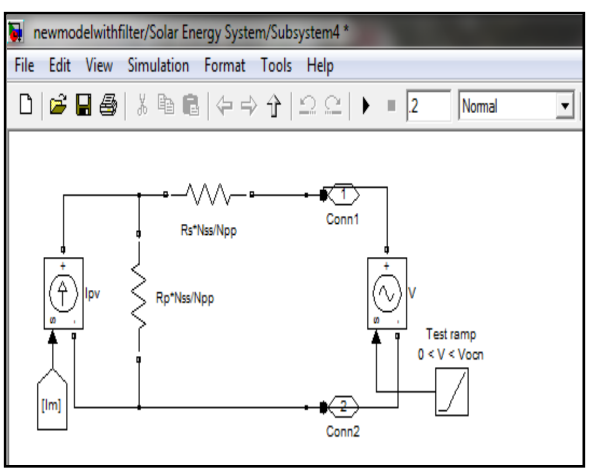

Fig.j-Subsystem of Photovoltaic Array Model

Simulation Results

The output of a model is evaluated with typical Parameters of the KC200GT solar array at 25˚C, 1.5AM, 1000W/m^2

TABLE I

Imp	7.61A
Vmp	26.3V
Pmax,e	200.143W
Isc	8.21A
Voc	32.9V
Kv	-0.123 v/k
Ki	0.0032 A/k
Ns	54

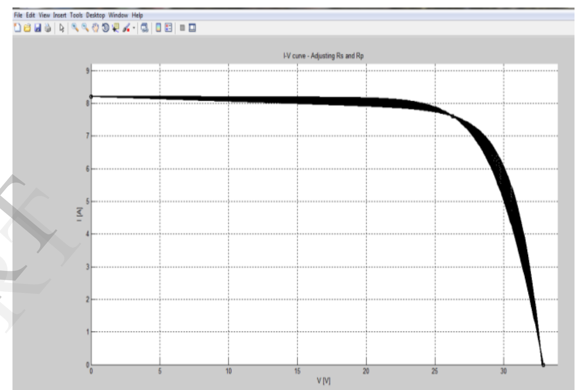

Fig.k-Simulated Current and voltage curve of KC200GT at 25^0c and 1000 W/m^2

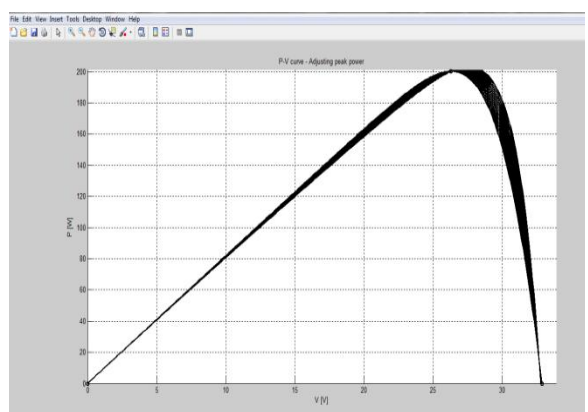

Fig.l-Simulated Power and voltage curve of KC200GT at 25^0c and 1000 W/m^2

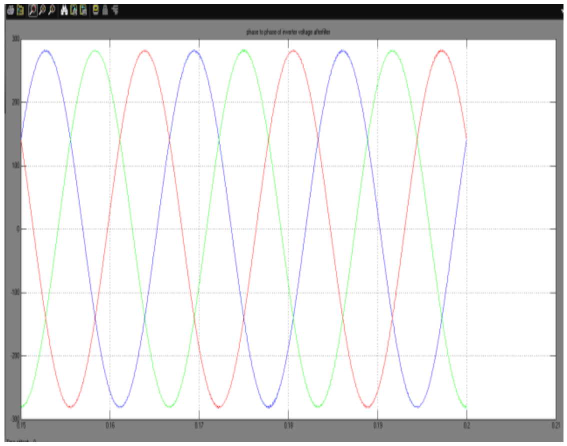

Fig.n- Phase to phase inverter voltage after filter

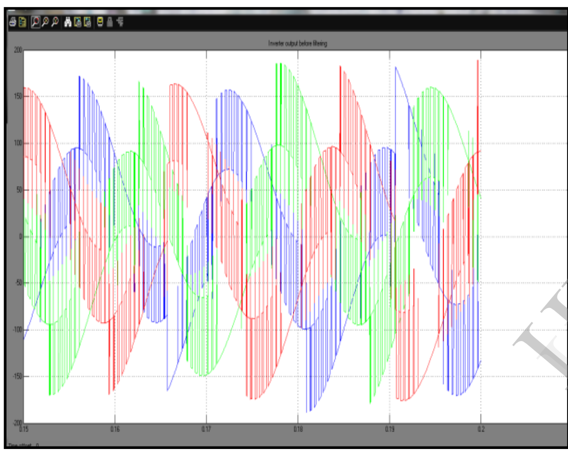

Fig.o-Phase to phase Inverter voltage without filtering

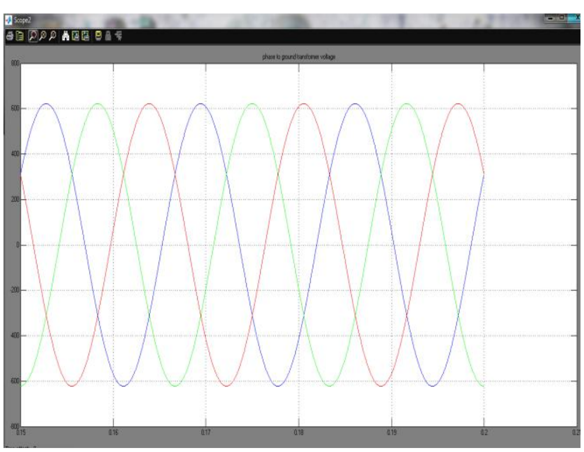

Fig.p- Phase to ground transformer voltage

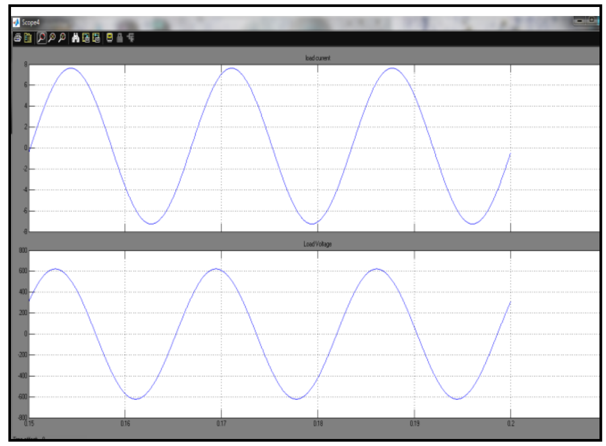

Fig.r- grid current and grid voltage

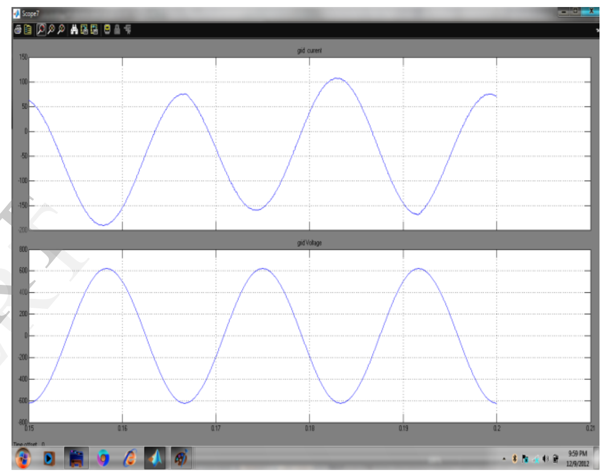

Fig.q- load current and load voltage

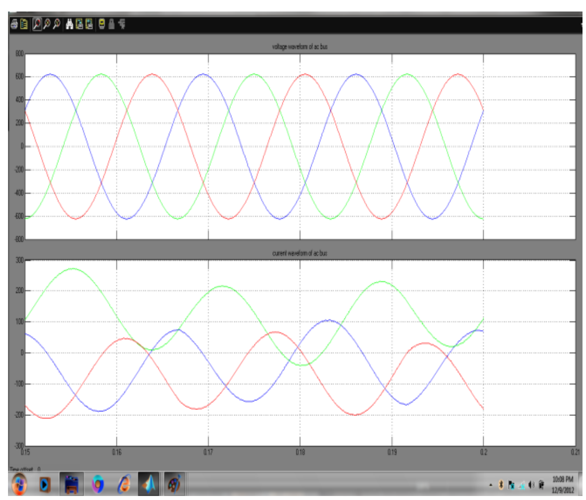

Fig.s- V-I waveform of ac bus

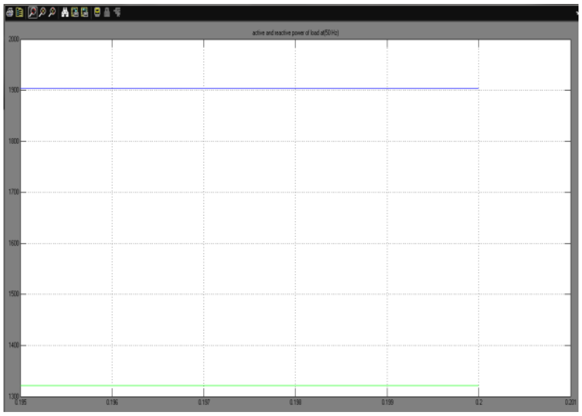

Fig.t- Active and Reactive power at load

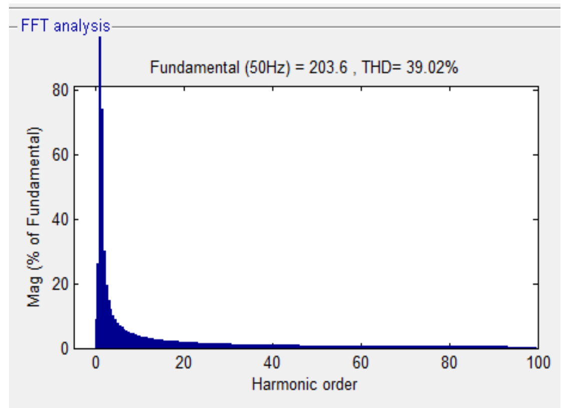

Fig.w- THD of simulated output(50 hz)

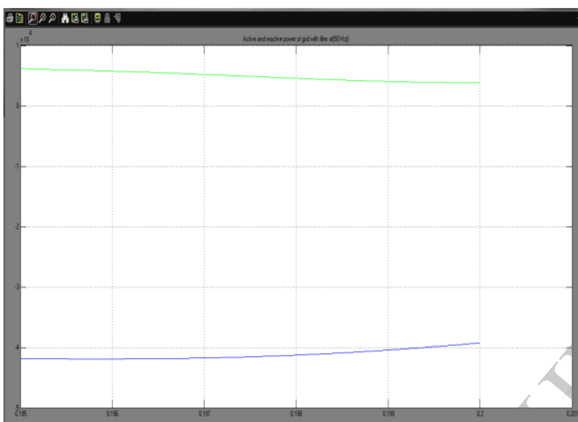

Fig.u- Active and Reactive power at grid

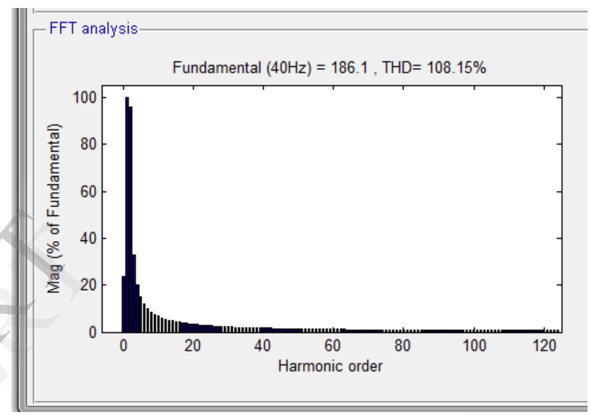

Fig.x- THD of simulatd output(40 hz)

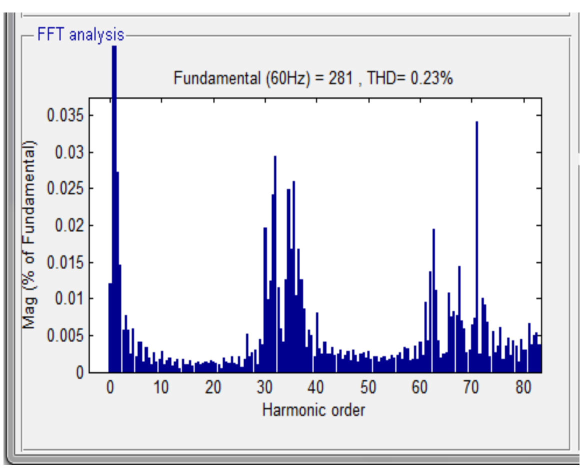

Fig.v- THD of simulated output at (60 hz)

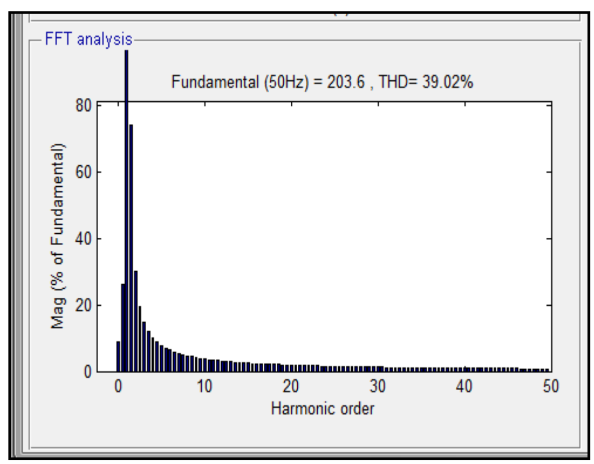

Fig.y-Total harmonic distortion with filter

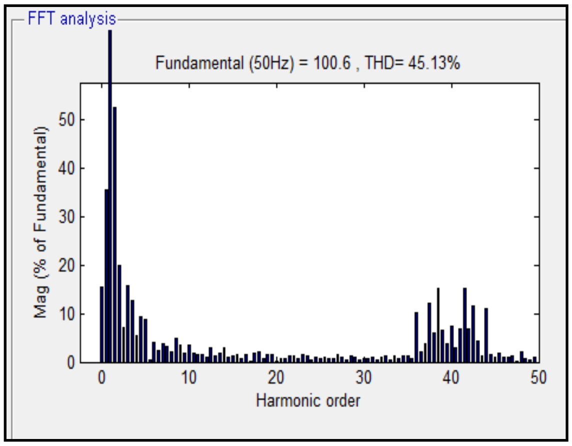

Fig.z-Total harmonic distortion without filter

Result Analysis

The maximum output power form the array under the stated conditions (1000 W/m2 and 25 C) should have been 200W.

Harmonic analysis of voltage waveform

Table-II

1. At 60 Hz	THD is-	.23%
2. At 50 Hz	THD is-	39.0%
3. At 40 Hz	THD is-	108.15%

Table-III

1.THD with filter	**39.02%**
2.THD without filter	**45.13%**

It can be seen a voltage waveform distortion caused by electronic devices — inverters used for energy conversion in DC/AC module,shows harmonic distortion in phase voltage. As we know due to non linear load a lot of harmonic distortion occurs in supply system, due to non linear load harmonic component occurred in voltage waveform of different phases .

The simulation model allows studies such as:

- renewable energy sources electrical parameters (powers, voltages, currents etc.)
- renewable energy sources constructive parameters (blades length and number of wind turbine, PV panels' number)
- voltage and frequency control (control algorithms)
- electrical energy conversion (type of DC/AC conversion)
- Consumer modeling and control.
- Power quality distortion phenomena and analysis.
- Renewable energy availability.

Conclusions

The full mathematical models for PV array modules were fully developed including the inherently nonlinear I-V characteristics and variations under ambient temperature and solar irradiation conditions.Grid connected renewable photovoltaic dynamic control strategies were digitally simulated and validated, using matlab/simulink/simpower system software environment.

The dynamic controllers require only the measured values of voltage and current signals in addition to the motor speed low cost sensors and transducers.

The proposed Grid connected renewable photovoltaic schemes are suitable for resort/village electricity application in the range of (1500 watts to 50000 watts), mostly for water pumping, ventilation, lighting, irrigation and village electricity use in arid remote communities.

Future scope

It is necessary to validate the proposed novel dynamic maximum photovoltaic power tracking control strategies by a specific laboratory facility using the low cost micro controllers.

The proposed dynamic effective and robust error driven control strategies can be extended to other control system applications. They are also flexible by adding supplementary control loops to adapt any control objectives of any systems. Further work can be focused on Artificial Intelligence (AI) control strategies.

The research can be expanded to the design and validation of dynamic FACTS with stabilization and compensation control strategies for other stand-alone renewable energy resource schemes as well as grid-connected renewable energy systems to make maximum utilization of the available energy resources.

References

1. D. Hansen et. al.," Models for a Stand-alone PV System", RisNational Laboratory, Roskilde, Norway, Dec. 2000. http://www.risoe.dk/solenergi/rapporter/pdf/sec-r-12.pdf.
2. Hang-Seok Choi,et.al. "Grid-Connected Photovoltaic Inverter with Zero-Current Switching", International Conference on Power Electronics ICPE 2001, Oct. 2001, pp.251-255.
3. Gregor P. Henze & Robert H. Dodier, "Adaptive Optimal Control of a Grid-Independent Photovoltaic System", Proc. on Journal of Solar Energy Engineering, Vol. 125, No. 1, February 2003, pp. 34-42.
4. Pedro Rosas, "Dynamic Influences of Wind Power on the PowerSystem", Ph.D. Thesis, ØRsted-DTU, Section of Electrical power Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark, 2003.
5. Geoff Walker. "evaluating mppt converter topologies using a matlab pv model"Journal of Electrical & Electronics Engineering, 2001, pp:49-55
6. S.Premrudeepreechacharn and N. Patanapirom. Solar-Array Modelling and Maximum Power Point Tracking Using Neural Networks.IEEE Bologana Power Tech Conference Proceedings, Vol.2, 2003
7. Algora, C. and Diaz, V. Design and optimization of very high power density monochromatic GaAs photovoltaic cells.

IEEE Transactions on Electron Devices, Vol. 45, No. 9, 1998,pp:2047-2054

8. Cheknane, T. Aerouts and M. Merad Boudia. "Modelling and Simulation of organic bulk heterojunction solar cells."ICRESD-07, Tlemcen , 2007,pp.83-90
9. N. vesseid, D. bonnet and H. richter.experimental investation of the double expontial model of a salor cell under illuminated conditions: considering the instrumental uncertainties in the circuit,voltage and temperature values. SOLID-STATE ELECTRONICS vol.38, no.11,1995,pp.1937- 1943.
10. Y.-C. Kuo, T.-J. Liang, and J.-F. Chen, Novel maximum-power-pointtracking controller for photovoltaic energy conversion system, IEEE Trans. Ind. Electron., vol. 48, no. 3, pp. 594—601, Jun. 2001.
11. IEEE Standard Definitions of Terms for Solar Cells, 1969. [12] W. Xiao, W. G. Dunford, and A. Capel, A novel modeling method for photovoltaic cells, in Proc. IEEE 35th Annu. Power Electron. Spec. Conf. (PESC), 2004, vol. 3, pp. 1950—1956.
12. H. S. Rauschenbach, Solar Cell Array Design Handbook.NewYork: Van Nostrand Reinhold, 1980.
13. J. A. Gow and C. D. Manning, Development of a photovoltaic array model for use in power-electronics simulation studies, IEE Proc. Elect. Power Appl., vol. 146, no. 2, pp. 193—200, 1999.
14. J. A. Gow and C. D. Manning, Development of a model for photovoltaic arrays suitable for use in simulation studies of solar energy conversion systems, in Proc. 6th Int. Conf. Power Electron. Variable Speed Drives, 1996, pp. 69—74.
15. N. Pongratananukul and T. Kasparis, Tool for automated simulation of solar arrays using general-purpose simulators, in Proc. IEEE Workshop Comput. Power Electron., 2004, pp. 10—14.
16. M. T. Elhagry, A. A. T. Elkousy, M. B. Saleh, T. F. Elshatter, and E. M. Abou-Elzahab, Fuzzy modeling of photovoltaic panel equivalent circuit, in Proc. 40th Midwest Symp. Circuits Syst., Aug. 1997, vol. 1, pp. 60—63.
17. S. Liu and R. A. Dougal, Dynamic multiphysics model for solar array, IEEE Trans. Energy Convers., vol. 17, no. 2, pp. 285—294, Jun. 2002.
18. Y. Yusof, S. H. Sayuti, M. Abdul Latif, and M. Z. C. Wanik, Modeling and simulation of maximum power point tracker for photovoltaic system, in Proc. Nat. Power Energy Conf. (PEC), 2004, pp. 88—93.