Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 4 January-March (2015) pp. 298-302

http://www.krishisanskriti.org/areee.html

Simulation and Design of Isolated Solar-PV Energy Generating System for Grid Connected Load

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Abstract—*The modeling description of current-voltage characteristics for photovoltaic cells is generally represented by a general equations, which is difficult to solve by analytical methods. In this paper, a modeling process is proposed to conFig. a computer simulation model (MATLAB), which is able to demonstrate the cell's output features in terms of environment changes in irradiance and temperature. Based on a simplified single-diode model, the parameters are shown in the sense of minimum model error and temperature effect. And after the designing of PV array with the help of MPPT technique P&O and Grid connected load is also described with the mathematical equations for maintaining the Total harmonic distortion of the output ac voltage which found in acceptable range under Grid connected load.*

Keywords: *MPPT, P&O, PI, PV array, VSC, PLL, Grid connected load.*

1. INTRODUCTION

Importance for renewable sources of energy is growing rapidly due to large consumption and enervation of fossil fuels. Among all these renewable energy sources, Photovoltaic arrays are used in many applications such as battery charging, water pumping, hybrid vehicles, and grid connected PV systems. By analyzing power voltage curve of solar panel we see that there is an optimum operating point where PV delivers the maximum possible power to the load which changes with the solar irradiation, and cell temperature. Therefore maximum power point tracking (MPPT) of a PV array is an essential part of any PV system. Variety of MPPT methods is developed that vary in implementation complexity, sensed parameters, convergence speed, and cost. Today solar energy increasing attention due to cleaning, non-pollution and ceaseless usage etc. However, presently photo electricity conversion efficiency of photovoltaic cell array is not high, there is need further improve in efficiency of this conversion process. In recent years, some researchers have applied swarm intelligent algorithm in the MPPT of photovoltaic system and got nice achievements. The tracking accuracy of swarm intelligent algorithms is determined by accuracy of models and external conditions. In this paper, a new intelligent perturbative method is put forward, which effectively raises the efficiency of the maximum power tracking. Here simulation model of photovoltaic cell is established under MATLAB (Simulink), and its output characteristic is analyzed under different situations.

2. SYSTEM DESCRIPTION

This system consists of a solar-PV array, a dc – dc boost converter with MPPT controller, PWM controller, a VSI and feedback controller for feeding consumer loads. The output voltage of the PV array is selected in between some value; a dc-dc converter boosts this dc voltage to high voltage. A solar photovoltaic (PV) converts the light energy to electrical and deploys it to the utility grid efficiently. DC power from the solar panels, which act like a dc current source, is converted to ac and fed onto the utility's grid in the correct phase relationship. The DC-DC converter is controlled by an algorithm, which calculates the value of the duty cycle for the converter, in order to ensure that the PV system operates at its MPP. Dc is converted to ac, typically using VSC inverter.

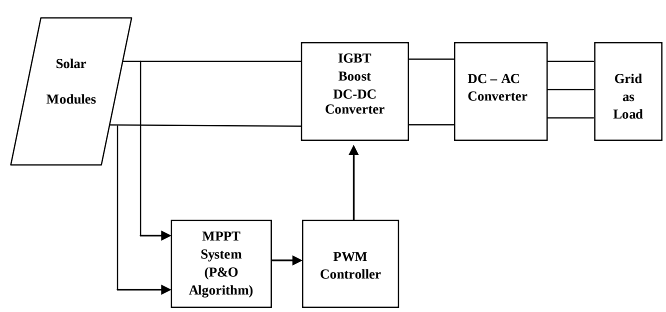


Fig. 1: Block Diagram of proposed model

Everyone is looking to new technology for solar inverter modules, to improve performance and reduce cost.

3. DESIGN AND MODELING OF THE SYSTEM

Designing of proposed system is made in Simulink. Her 5 PV modules are used in series and 66 in parallel per string. For absorbing the maximum power through PV system perturb & observe algorithm is used. IGBT based DC-DC boost converter is modeled to increase the voltage and then with the help of VSC converter, PLL and transformer, power supplied to grid.

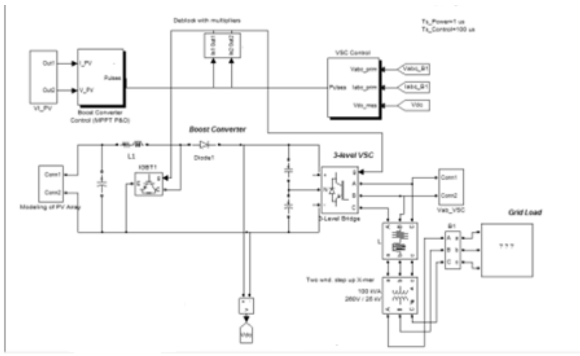
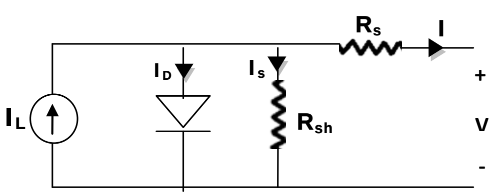


Fig. 2: Circuit diagram of proposed model

4. MODELING OF SOLAR-PV ARRAY

Solar panel is basically a p-n junction. The simple PV model consists of a current source in parallel with a diode, and includes a series resistor for a more accurate shape between MPP and the open circuit voltage. Output current of the photocell (I_L) is directly proportional to the irradiation level of the light falls on the solar cell.



The current through diode is given by:

$$I_D = I_0 [\exp (q(V + I\,Rs)/KT)) - 1] \quad (1)$$

The solar cell output current:

$$I = I_L - I_D - I_{sh} \quad (2)$$

$$I = I_L - I_O [e (q^{(V + I R_S)/KT}) - 1] - (V + IR_S)/ R_{sh} \quad (3)$$

Where:
I: Solar cell current (A)
I_L: Light generated current (A)
I_O: Diode saturation current (A)
q: Electron charge (1.6×10-19 C)
K: Boltzmann constant (1.38×10-23 J/K)
T: Cell temperature in Kelvin (K)
V: solar cell output voltage (V)
R_s: Solar cell series resistance (Ω)
R_{sh}: Solar cell shunt resistance (Ω)

5. MODELING OF MPPT ALGORITHM

Most popular PV MPPT algorithms are
- Constant Voltage
- Perturb and Observe
- incremental Conductance
- Short Circuit Current
- Open Circuit Voltage

These algorithms use the information of PV output voltage, current, or both, to perform the MPPT. PV module temperature can also be used to find the MPP of the PV system due to linear relation between the open circuit voltage value and the temperature of the PV module.

$$V_{mpp(T)} = V^{STC}_{mpp} + (T- T^{STC}) \times \mu_{Vmpp}$$

Here P&O algorithm has been taken into consideration for MPPT technique.

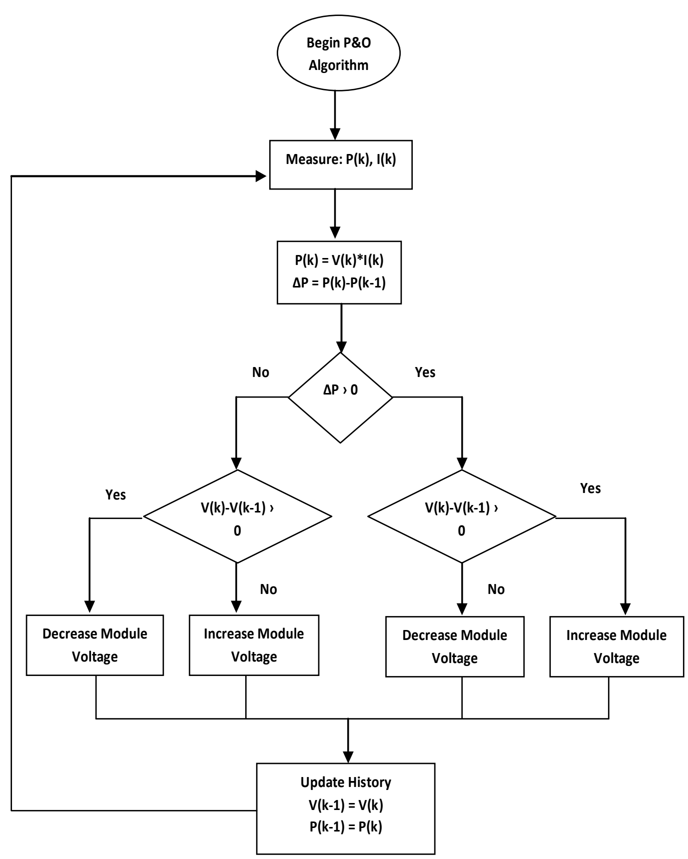


Fig. 4: Flow chart of Perturb and Observe Algorithm

In P&O algorithm a slight perturbation is introduced. This perturbation causes the changes in the power of solar module. If the power increases due to the perturbation then the slope of perturbation or direction is continued as previous cycle up to peak value. After that the power at the next instant decreases and hence after that the slope of perturbation reverses. When the steady state is attained the algorithm oscillates around the peak point. Here the perturbation size is kept very small. The algorithm sets a reference voltage of the module corresponding to the peak voltage of the module and a PI controller help in moving the operating point of the module to that particular voltage level.

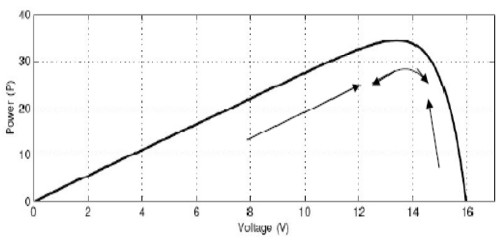


Fig. 5: Ideal Graph Power versus Voltage for Perturb and Observe Algorithm

6. DESIGN OF BOOST CONVERTER

Boost means the output voltage is greater than input voltage. Here the boost converter is designed using IGBT which combine the advantages of both BJT and MOSFET, has high input impedance and low on state conduction losses. Switching speed is inferior to MOSFET. It has ability to step up output voltage without a transformer.

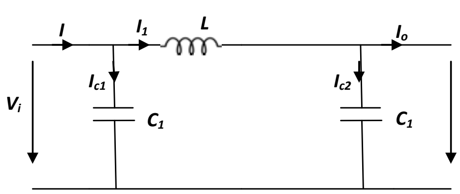


Fig. 6: Equivalent Circuit diagram of boost converter

7. DESIGN OF VSC

VSC utilizes several components like series-connected IGBTs with high voltage valves, dc capacitors which are compact and dry, control system and DC cable. PLL is used for controlling the VSC output. Each VSC is effectively grounded and coupled to the AC bus via phase reactors and a power transformer with shunt AC filters which are tuned to multiples of the switching frequency for minimizing harmonic content.

8. DESIGN OF UTILITY GRID

For designing grid as a load one step up (100 kVA,260V / 25 kV) & step down (120 kV / 25 kV,47 MVA) transformer are used and feeders are used at distribution end. Also R-L circuit used at load end.

9. MATALAB SIMULATION OF MODEL AND RESULTS DISCUSSION

PV array waveforms

I_r_ irradiance = (1000W/M^2),
No of cells per module = 96,
No of series connected module per string: 5,
No. of parallel string: 6,
Sample time = (Ts_Power=1 us,),

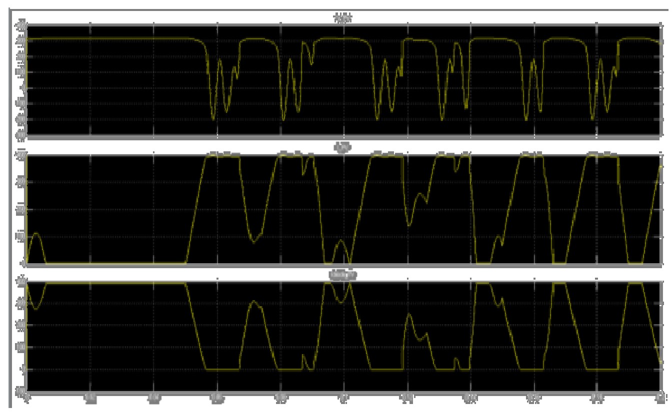


Fig. 7: PV array characteristics waveforms

10. MPPT VI CURVE

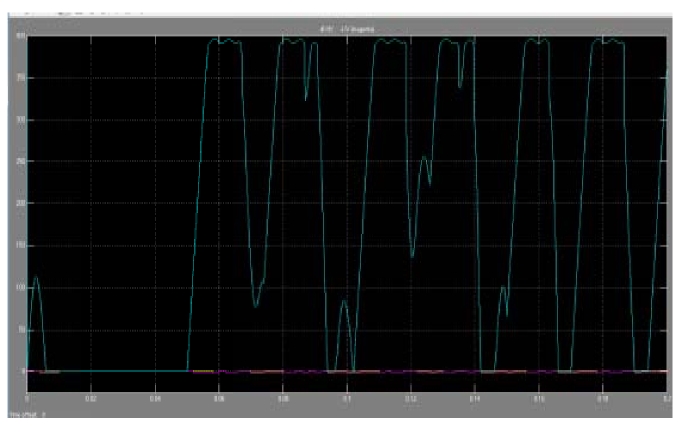


Fig. 8: MPPT characteristics

11. BOOST CONVERTER CH'S

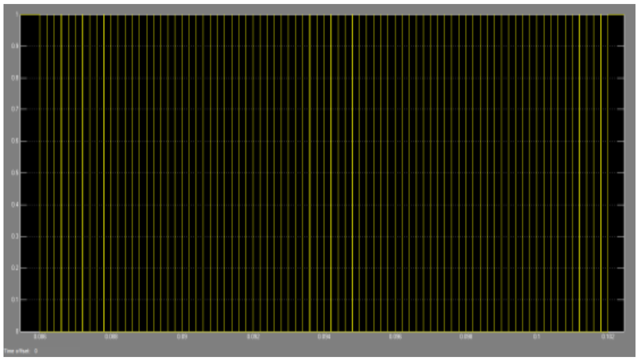


Fig. 9: Gate pulse of IGBT based boost converter

The duty cycle for IGBT Pulse generation = 0.5

The value of power is 32.16 KW and voltage is 276.48 V.

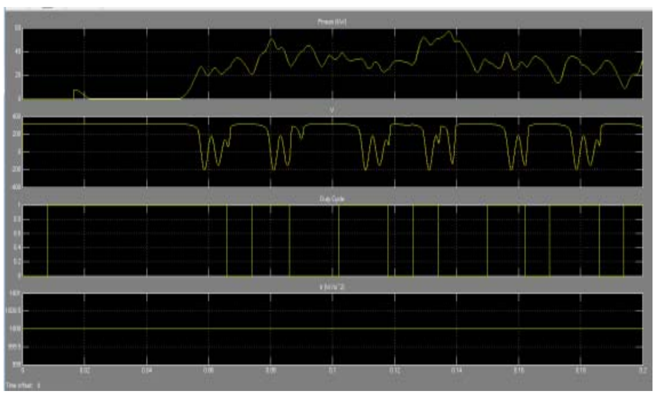


Fig. 10: Boost Converter characteristics

12. VSC WAVEFORMS

The maximum voltage of VSC inverter is 816.43.

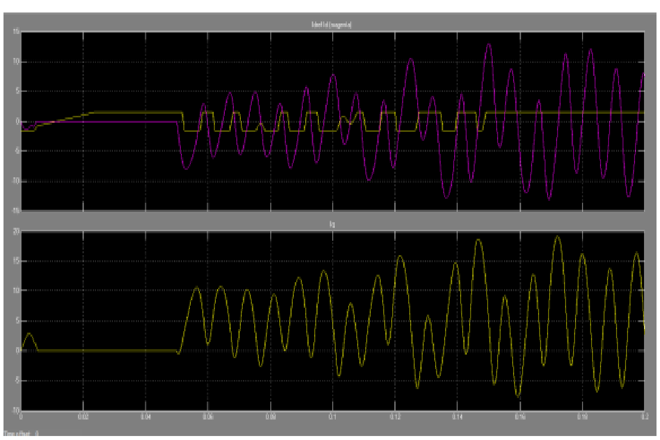


Fig. 11: Id reference and Iq wave form of VSC

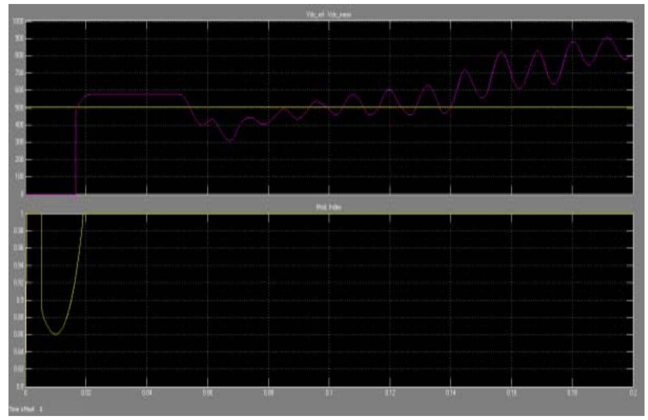


Fig. 12: Modulation index and Vdc of VSC converter

13. HARMONICS ORDER OF GRID CONNECTED LOAD CH'S

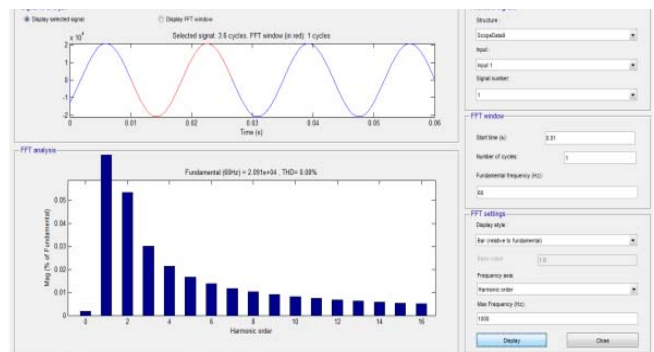


Fig. 13: Harmonic waves

14. GRID POWER CURVE

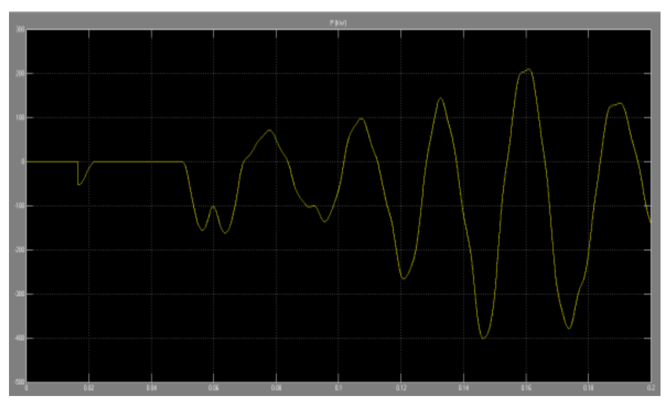


Fig. 14: Grid power curve

15. CONCLUSION

In this paper, a general approach on modelling Photovoltaic modules are presented with P&O technique. The points chosen for the parameter determination are the maximum power point, Grid connected load and data's are shown with help of V-I characteristics and Wave forms. Solar module were modelled and evaluated. The model accuracy for isolated system and grid connected load is also described with the parameters. Designed system proves the effectiveness of this modelling method based on a simplified one-diode model. This allows efficient use of Simulink to model photovoltaic power systems.

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