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Modelling of Grid Connected DC/AC Converter for Photovoltaic Application

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ABSTRACT

Renewable energy sources are environment friendly. So they are reliable alternatives to fossil fuels. Among all renewable energy resources, solar energy is abundantly available and installation of solar plant is easy compared to others. In photovoltaic (PV) based system DC/AC converter plays important role. In this paper DC/AC converter is designed with its control to deliver quality current into the grid. To extract maximum power from PV cell maximum power point technique (MPPT) is used. Solar radiation data of Aurangabad city is taken to design the rating of photovoltaic system. The grid connected DC/AC inverter is designed and implemented in MATLAB/SIMULINK environment.

Key words : Current Control, Inverter, MPPT, PV Array

1. INTRODUCTION

Nowadays along with food, cloth and shelter, electricity becomes the basic need of humans. Day by day energy demand is increasing but at same time conventional energy source are vanishing. So searching an alternative to conventional energy sources is a need of time. In India solar energy is available in abundance around 5100 kWh of energy is radiated per year. Thus solar is potential source to meet the thirst of energy demand. Photovoltaic cell is used to convert solar radiation energy into electrical energy [1]. To obtain desired power and voltage rating PV modules are connected into series-parallel connection.
The increase in installation of rooftop grid connected solar system is due to support and incentives provided by government. Along with solar plant, wind power plants are also increasing. Hybrid system of solar-wind can be studied [2]. As the connections of PV systems with grid are rising significantly, the impact of PV system on grid cannot be ignored. PV system can affect grid adversely such as by injecting more harmonics or by reducing stability. Hence design of DC/AC converter is important. The shape of output waveform of DC/AC converter is depends on how the conduction intervals of power electronics switches are controlled [3]. By implementing proper PWM technique and

current control strategy, quality of injecting current can be increased. The block diagram (figure 1) of the system is shown below:

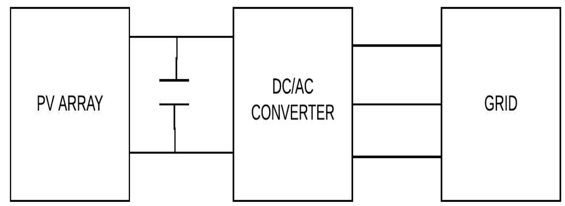
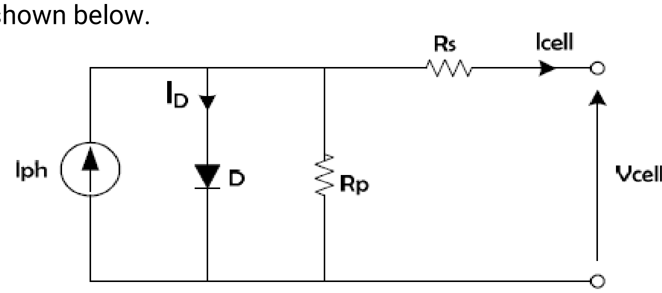


Figure 1: System Block Diagram

2. PV ARRAY MODELLING

A PV cell is PN junction [4]. When solar radiations fall on a PV cell, electron-hole pairs are produced. The equivalent circuit of single diode PV cell (figure 2) is shown below.



2: Equivalent Circuit for PV Cell

Where I_D is diode current which can be calculated using following equation.

$$ID = Isat\left\{\exp\left[\frac{q}{KT}(Vcell + RsIcell)\right] - 1\right\} \quad (1)$$

R_s and R_p are the series and parallel resistances connected across diode. Iph is the short circuit current of PV cell. I_{cell} and V_{cell} are output current and voltage of PV cell respectively. To obtain desired voltage from PV system, PV cells are connected in series parallel manner as shown in figure 3 below:

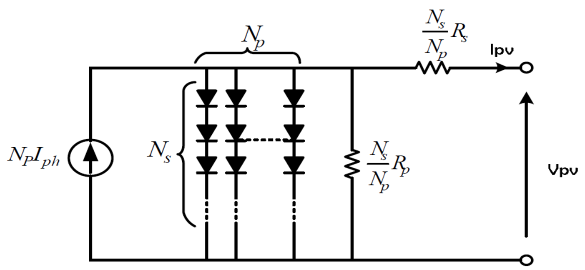


Figure 3: Series-Parallel Connection

In this paper, PV system is designed for load demand of 850 KWh/day and irradiation data of Aurangabad city (19° 53'N 75°19' E) is taken [5].

Table 1: Monthly average insolation (kWh/m2/day)

Month	Jan	Feb	Mar	Apr	May	June
Insolation	7.29	7.24	7.30	6.70	6.36	3.97
Month	July	August	Sep	Oct	Nov	Dec
Insolation	2.88	2.63	4.05	5.68	6.63	6.84

The required energy should be more than demand. To avoid under sizing of system multiply demand by 1.3.

E_{array} = average energy consumption per day * 1.3 (2

E_{array} = 850*1.3 = 1105 kWh

Now power can be calculated by using equation (3)

P = E_{array} / solar isolation (3

P = 1105 / 5.63 = 196.26 KW

PV module of 200 KW is developed in MATLAB using NREL modules. The module used in system is Sunpower SPR-415E WHT-D. The V-I and P-V characteristics of PV array is shown in figure 4 below.

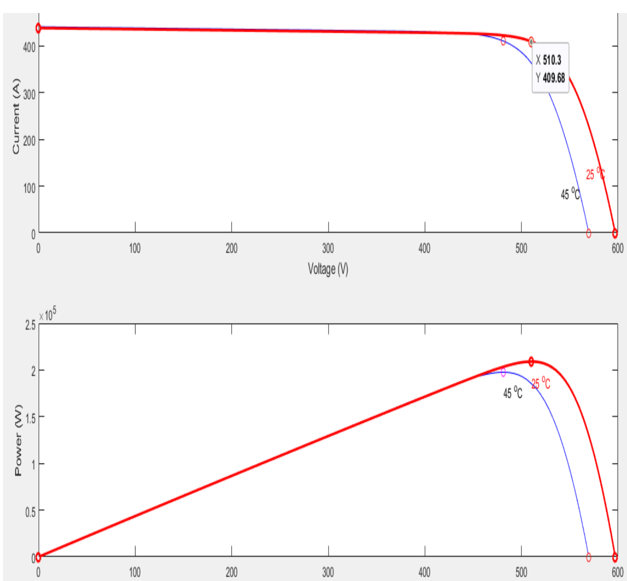
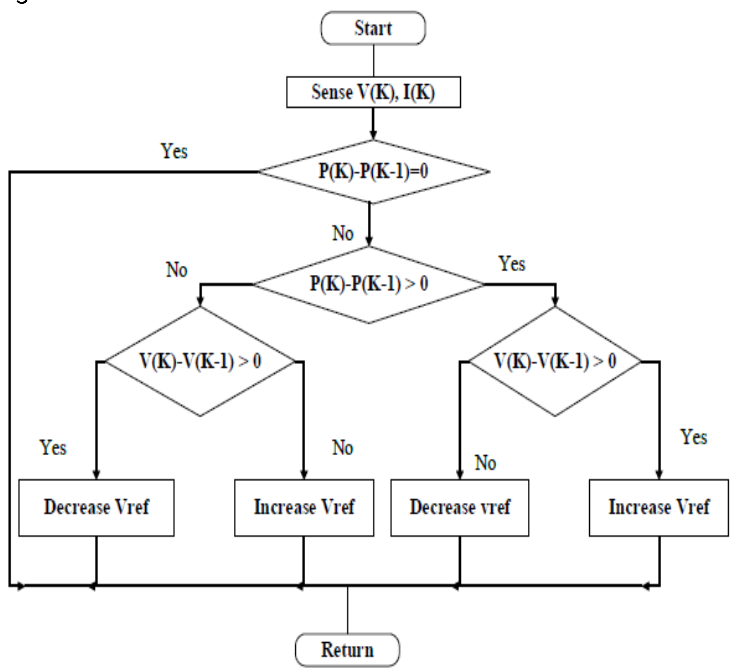


Figure 4 : (a) V-I Characteristics (b) P-V Characteristics

3. MPPT ALGORITHM

Maximum power point tracking (MPPT) is essential in solar power system. It is used to extract maximum amount of power from PV cell. There are different algorithm for MPPT like Perturb and Observe, Incremental conductance, fractional open circuit and short circuit, fuzzy logic control and Neural network MPPT. But among all these technique Perturb and Observe is widely used method because of its simplicity and efficiency [6-7].

The flowchart of P&O MPPT technique is shown in figure 5 below.



5: Flowchart of P&O Technique

In this technique voltage and current of PV cell is taken as input and as per flowchart conditions output capacitor link voltage changes.

4. CONTROL STRATEGY FOR INVERTER

The control is required for DC side as well as AC side. DC side control is done by using MPPT. For AC side, inverter deal with grid. So grid synchronization comes into picture. Thus injecting current with total harmonic distortion with range specified by IEEE standards, grid synchronization and power factor are issues faced during inverter grid connection. In MATLAB for grid synchronization Phase Loop Lock (PLL) block is used. To perform control operation three phase quantities are converted into dq frame.

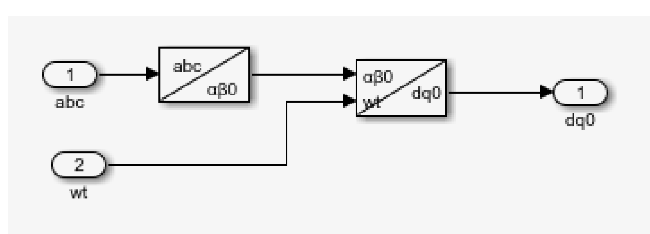


Figure 6: abc to dq0 in MATLAB

In proposed control system, three phase voltages and currents are converted into dq frame. Two loops are used, one is voltage loop and another is current loop. By comparing reference voltage obtained by MPPT and measured voltage, we get current reference. The error obtained by comparing reference current and measured current is passed to PI controller [8-10]. Then obtained Sinusoidal wave is compared with high frequency triangular wave to generate pulses for DC/AC converter.

5. SIMULINK MODEL AND RESULT

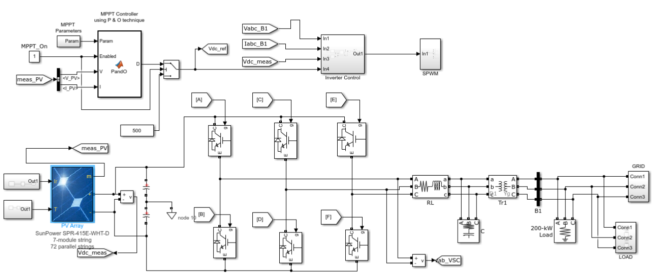


Figure 7: Simulink Model

In system designed, 200 KW capacity solar PV arrays are connected to grid at 66 KV. Output voltage of inverter is increased up to 66 KV by using step up transformer. L filter is used for harmonic reduction. Model is checked at varying solar irradiance with constant temperature of 45^{0}C and it is working smoothly. Current and voltages are in phase.

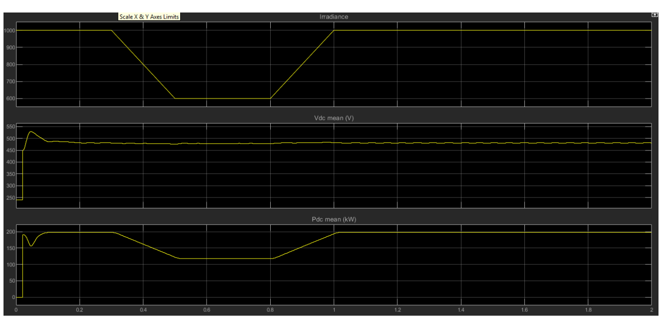


Figure 8: Power Generated at different irradiance

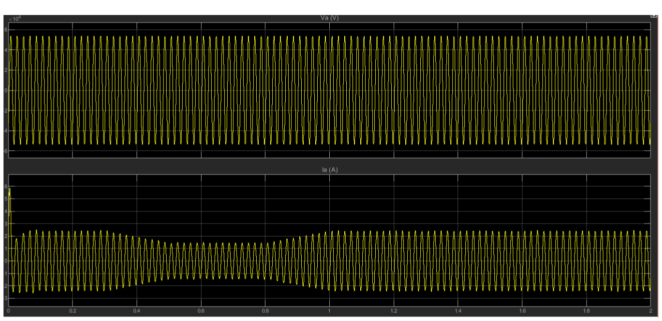


Figure 9: (a) Grid Voltage and Grid Current

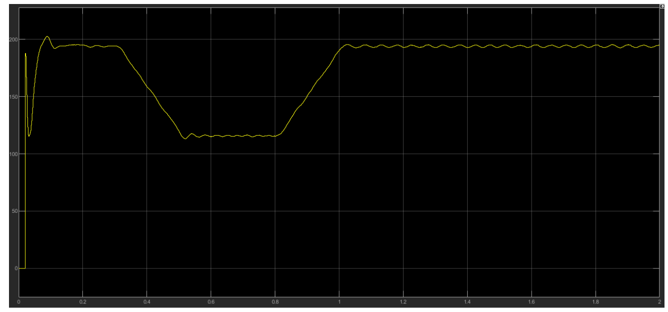


Figure 10: Power Delivering to Grid in KW

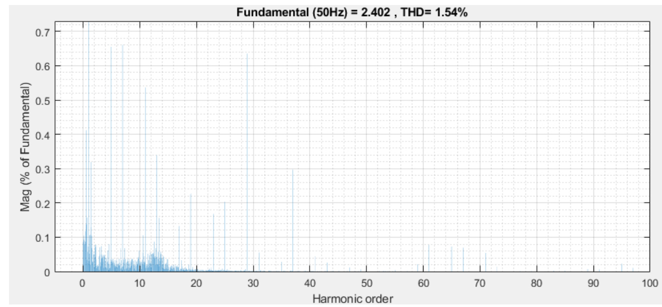


Figure 11: Total Harmonic Distortion

6. CONCLUSION

In this paper, MATLAB modeling of DC/AC converter is done. Solar is not a constant source of energy throughout year, so in simulation, solar irradiance is changed from 1000 w/m^2 to 600 w/m^2 and observed the result. As energy sector is moving towards renewable energy sources, it is important to develop efficient power electronics devices like inverter. The future scope for the project is to reduce the cost of PV panels also develops and implements different PWM techniques on inverter.

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