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Modelling and Analysis of Photovoltaic Grid Interfaced System using P&O Algorithm based MPPT

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Abstract— Integration of Photovoltaic (PV) systems plays a significant role to reduce the use of fossil fuel consumption in microgrids. In present scenario, fuel reserves are the great challenges which can be met up with plenty of solar irradiance. In this paper, we present modelling of a grid connected PV system. The MATLAB / Simulink is used to establish a model of photovoltaic array. The Simulink model is tested with different temperature and irradiation and resultant I-V and P-V characteristics proved the validation of Simulink model of PV array. Maximum Power Point Tracking (MPPT) Technique using P&O algorithm has been used as control strategy to extract maximum power from PV module. The VSC controlled method along with three level bridge inverter is used to convert the DC voltage to AC. The proper choice of RC bank subsequently reduces the harmonic effects to synchronize the output with the grid voltage. Simulation results are presented to observe the performance and dynamic behaviour of the proposed system.

Keywords—Converter, Grid, Perturb and Observe (P&O) algorithm, Maximum Power Point Tracking, Photovoltaic

I. INTRODUCTION

In present scenario of power industry, fossil fuel resources are becoming insignificant due to their gradual depletion, poor energy efficiency, increasing cost and environmental pollution. Nowadays, 80% of the total energy demand is supplied by fossil fuel. Global energy demand is predicted to increase by around 40% higher in the year 2035. So, penetration of Renewable Energy Sources is a viable solution for the electricity distribution authority which led to a new trend of generating power locally by employing solar Photovoltaic (PV) cells, biogas, wind power, and fuel cells into the utility distribution network [1]. Due to simplicity in construction and absence of fuel cost, PV energy is the third most significant renewable energy source among all RES in terms of globally installed capacity. The generated photovoltaic energy is supported by the country's geographical location, environmental temperature and the amount of solar radiation are received throughout the year.

A Grid-connected PV system brings two issues, firstly it must be operated at maximum power and secondly, it must be synchronized with grid assisting by three power electronic converters to provide an alternating voltage and frequency level that match with the grid [2]. At the same time this alternating voltage should be free from harmonic distortion The grid power quality will be affected if the harmonic is injected from PV system. Various MPPT techniques are available in the literature like Constant Voltage Tracking method, Fraction Open-circuit Voltage method, P&O method, Incremental Conductance method, Variable Step Size method and Artificial Neural Network method to enhanced the efficiency of the PV cell among which Perturb & Observe (P&O) algorithm is widely accepted [3]. In order to synchronize the PV output with the AC grid the maximum tracked power is send through a DC-AC conversion process and fed to a RC bank to reduce the harmonics. Grid-connected PV plants makes good economic sense to maximize the amount of power generated by PV arrays and thus transferred to the grid at all times. The main aim of this paper is to establish a complete modeling and simulation of PV system connected to three phase electrical grid using MATLAB/SIMULINK software. The propose system is highly efficient and free from harmonic distortion. The simulation results are presented to validate the claimed facts.

II. MATHEMATICAL MODELLING OF PHOTOVOLTAIC (PV) ARRAY

The elementary unit of a PV module is the solar cell, which generates electricity by the photovoltaic effect when exposed to solar radiant energy and its equivalent electrical circuit shown in Fig. 1[5].

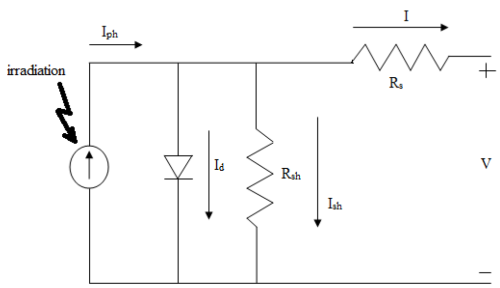

Fig. 1: PV module equivalent electrical circuit

The output current of PV array I is expressed by the equation,

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

Where, the photo-current of the PV array,

$$I_{ph} = [I_{sc} + k_i(T - T_n)]\frac{G}{G_0} \quad (2)$$

The diode current,

$$I_d = I_D\left[\exp\left(\frac{q(V + IR_s)}{nkN_sT}\right) - 1\right] \quad (3)$$

The current through shunt resistor,

$$I_{sh} = \left(\frac{V + IR_s}{R_{sh}}\right) \quad (4)$$

The reverse-saturation current of the PV array,

$$I_{rs} = \frac{I_{sc}}{\exp\left(\frac{q \cdot V_{oc}}{nN_skT}\right) - 1} \quad (5)$$

The saturation current of the PV array,

$$I_0 = I_{rs}\left(\frac{T}{T_n}\right)^3 \cdot \exp\left[\frac{q \cdot E_{g0}\left(\frac{1}{T_n} - \frac{1}{T}\right)}{nk}\right] \quad (6)$$

Where, I_{sc}= short circuit current of PV array, k_i= short circuit current of PV cell at 25℃ and 1000W/m^2 irradiation , T= operating temperature in ℃, T_n= nominal temperature in ℃, G= solar irradiation W/m^2, G_0= reference solar irradiation in W/m^2, q = electrical charge in Coulomb, V_{oc}= open circuit voltage of PV array in V, n= identity factor of diode, k= Boltzmann's constant in J/K, E_{g0}= band-gap energy of the semiconductor in eV, N_s= no. of cells connected in series, Rs= series resistance of PV array in Ω, R_{sh}= shunt resistance of PV array in Ω . Naturally PV system exhibits a non-linear Current – Voltage (I-V) and Power - Voltage (P-V) characteristics which vary with the irradiation and cell temperature. The dependency of power generated by a PV array with changing atmospheric conditions can readily be seen in the I-V and the P-V characteristics of PV arrays shown in Fig. 2.

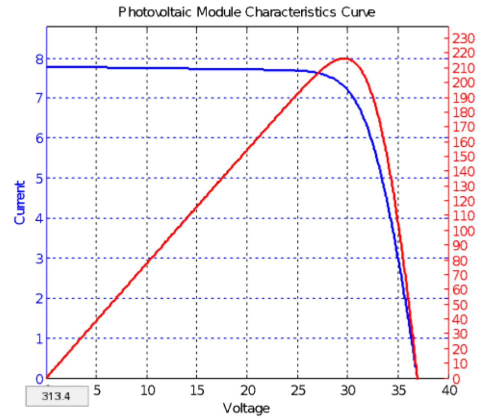

Fig. 2: I -V and P -V characteristics of PV array

In the Fig.2, we can observe that at voltage 'V_m' the power is at the maximum. This is the maximum power point of PV characteristics that we need to track using MPPT algorithm. The block diagram of the grid-connected PV system designed in this work is shown in Fig. 3.

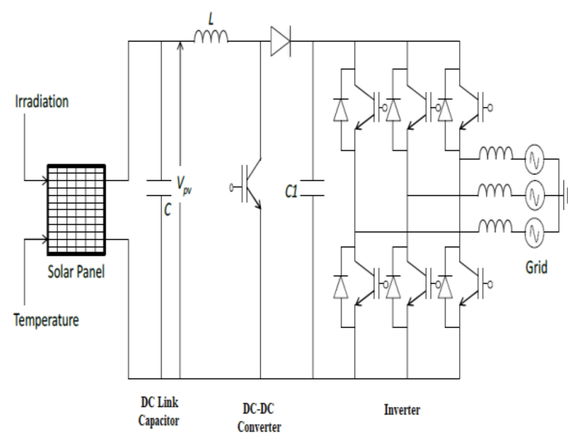

Fig.3: Block diagram of PV system

A. *Dc link capacitor*

The DC link minimizes the ripple of the output PV array current by using a large capacitor. The voltage across the DC link capacitor is controlled by the DC-DC converter.

B. *Modelling of MPPT*

Since the efficiency of the solar PV array is less (around 13%), it is desirable to operate the PV module at the MPP such that maximum power can be delivered even under varying climatic conditions [6]. The MPPT is based on irradiation and temperature which keeps varying with respect to time. Perturb & Observe (P&O) technique is used for this purpose, to obtain accurate results. The flow chart for this algorithm is given in Fig. 4. This algorithm is embedded inside the control of the boost converter to track the required point. The final output of the MPPT block is the voltage at which the PV module has to operate to extract maximum power.

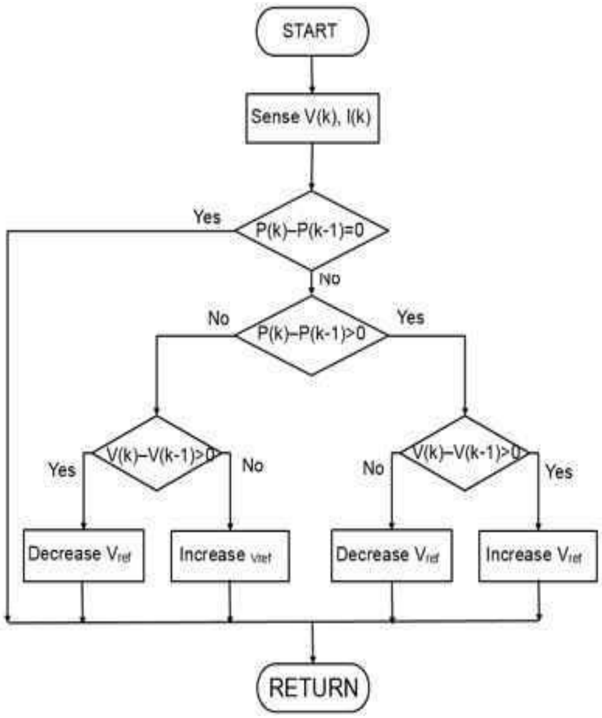

Fig. 4: Flow Chart of P&O based MPPT

C. Power Electronics Converters

Two types of power electronic converters are utilized for the PV system. They are: (i) one boost converter, which permits to extract the maximum power from the PV array by means of an MPPT algorithm, (ii) one three phase inverter, aimed at transforming the DC energy into AC to feed the load. A DC-DC boost converter is used in order to maintain the voltage throughout the circuit. An IGBT is chosen as the switch and the output of the MPPT is used to generate the switching pulses for the boost converter. The three phase voltage source converter (VSC) or inverter is one of the most convenient ways of DC-AC conversion [7]. The three-level bridge inverter consists of 12 IGBT switches which are fed by the output signal of the boost converter and the triggering pulses are controlled by the three phase VSC [8]. It is used to control active power supplied to the grid and inject high quality power.

III. SIMULATION OF A GRID CONNECTED PV SYSTEM

In this work, a 100 kW solar farm is modelled in MATLAB/SIMULINK platform. Here, 5(series) by 66 (parallel) configuration for the PV module is used and a single PV module contains are 96 PV cells connected in series. The actual simulated model is shown in Fig. 5 and Fig. 6.

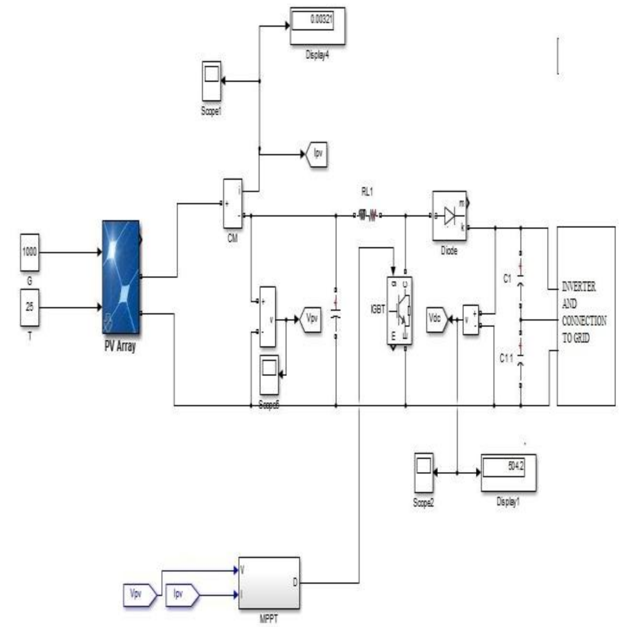

Fig. 5: MATLAB /SIMULINK circuit of PV Generation side of the system

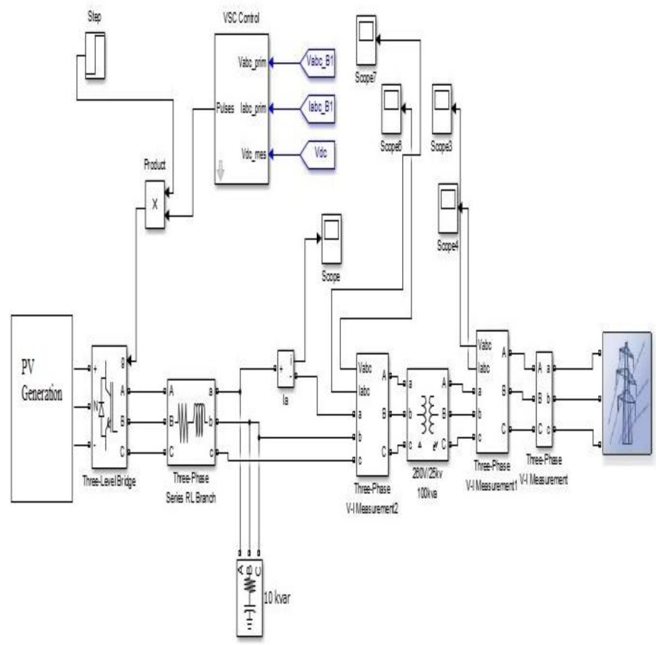

FIG. 6: SIMULINK model of grid connected system

III. RESULTS

The proposed model has been designed for PV module to simulate at 25^0C temperature and 1000 W/m^2 solar irradiance. As it is quite time consuming to simulate the circuit for long duration, the simulation time has been taken as 80ms.

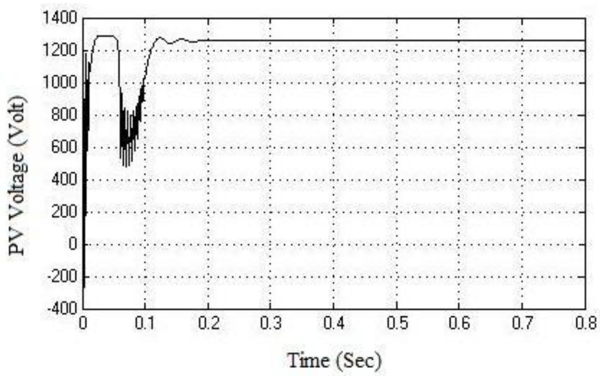

Fig. 7: voltage - time curve of PV array

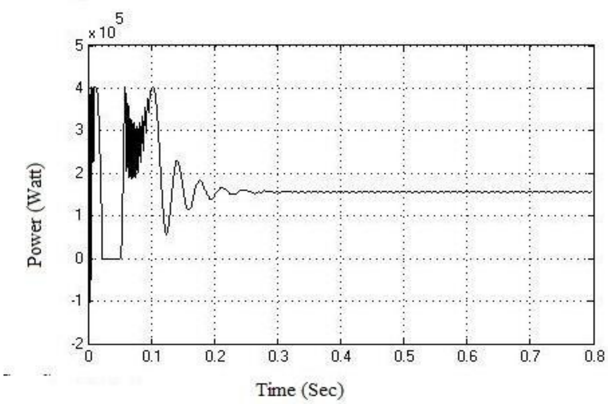

Fig. 8: power- time curve of PV array

Here, the simulation results are given in detail. PV module voltage and power waveforms are presented in Fig. 7 and Fig. 8 respectively. The power generated by PV module is 150kW which is fed to DC link capacitor. Fig. 9 represents that three phase voltage generated by the inverter. Fig. 10 signifies the comparison between the inverter output voltage and the line to line alternating voltage supplying 34kV to the grid. Fig. 11 represents the 100.7kW is power fed to the grid to supply the various active power demands.

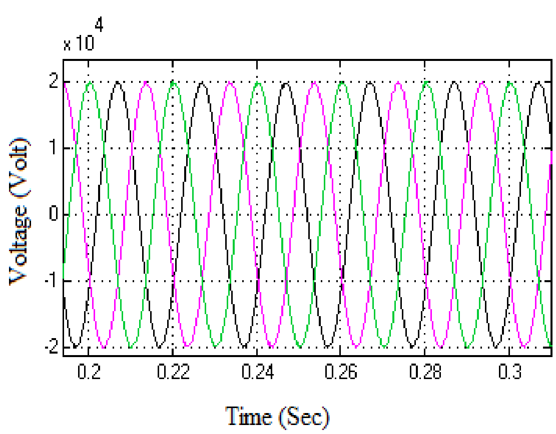

Fig. 9: three-phase output voltage curve of inverter

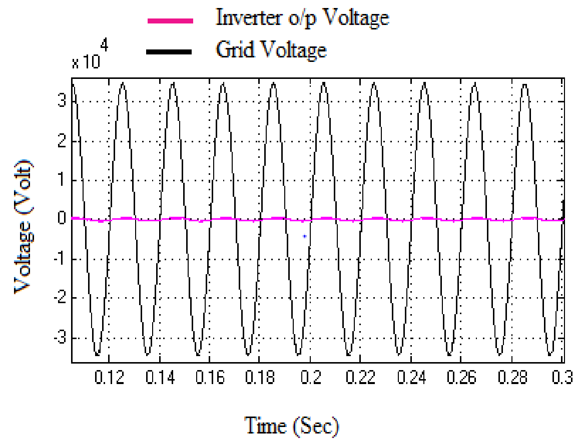

Fig. 10: voltage-time curve of inverter and grid

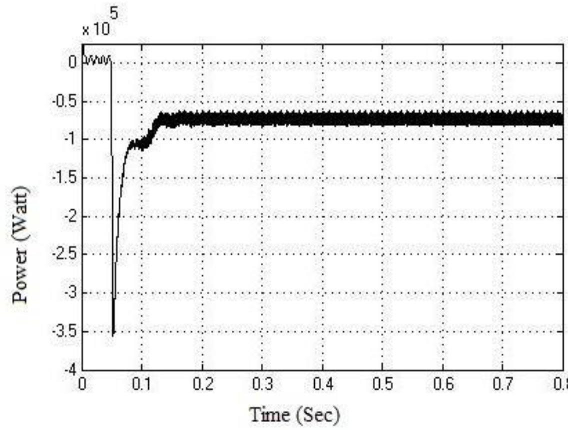

Fig. 11: Output power - time curve

IV. CONCLUSION

This paper conferred a detailed modelling of three phase grid connected PV generation system and control strategy of a VSC controlled three phase inverter based on MATLAB/SIMULINK. The main objective of this work is to construct a system that would work as an active filter, indemnifying power unbalancing and measure total active generated by the system. Perturb and Observe (P&O) algorithm is considered to persuade the maximum power point of the PV module. To reach the theoretical credibility of the designed model and control strategy, some simulation results are shown. The simulation results show the effectiveness of the proposed model of grid connected PV generation system ready to implement in microgrid.

Table 1. Parameter Table

Sl. No.	Name of the parameters	Value
1.	No. of cells connected in series inside module	96
2.	No. of modules connected in series	5
3.	No. of modules connected in parallel	66

4.	Short circuit current of cell at 25ºC and 1000 W/m^2 (I_{sc})	0.0032 A
5.	Voltage at maximum power point of a module	54.7 V
6.	Current at maximum power point of a module	5.58 A
7.	Boltzmann's constant (k)	1.38×10^{-23} J/K
8.	Nominal temperature (T_n)	25 ºC
9.	Reference solar irradiation (G_0)	1000 W/m^2
10.	Diode saturation current at 25ºC (I_D)	5.2622 nA
11.	Electron charge (q)	1.6×10^{-6} C
12.	Identity factor of diode (n)	1.3
13.	Series resistance (R_s)	0.083 Ω
14.	Shunt resistance (R_{sh})	819.13001 Ω
15.	Open circuit voltage of a module (V)	64.2 V
16.	Band gap energy of the semiconductor (E_{g0})	1.1 eV
17.	Capacitor in DC link	100 µF

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