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Modeling and Simulation for a 3.5 Kw Grid-Connected Photo-Voltaic Power System

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ABSTRACT

This paper presents the design of small scale three-phase grid connected system for rural location . The proposed hybrid system includes a 3.5 kW PV panel with a DC-DC boost converter with controller for Maximum Power Point Tracking (MPPT), DC-AC inverter with decoupled power controller supplying the load and connected to the grid. The MPPT controller is used to harvest maximum power from the solar panel and decoupled power controller is used for tracking the real and reactive powers and also improves the system stability. MATLAB simulation of the proposed model is carried out to show the effectiveness of grid-connected photovoltaic systems.

KEYWORDS: *PV Panel, DC-DC Converter, Voltage Source Inverter, MPPT, PQ Control Strategy*

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1. INTRODUCTION

Solar energy has the greatest potential than all the renewable energy sources[5]. The increasing popularity of renewable energy over the last few decades has gained momentum owing to the continuing scarcity of fossil fuels[6]. This has also pushed the significance of, and the need for, electrical energy. Against this backdrop, the photovoltaic (PV) industry has been continuously growing at a rapid rate. Photovoltaic (PV) systems can hold the world's electricity production[8]. One hundred giga watts (GW) had been added during 2018; therefore, the total capacity of the installed PV systems reaches up to 505 GW worldwide [10]. Silicon crystalline PV modules are widely used around the world. Nowadays, new PV technologies with cheaper manufacturing costs than traditional silicon crystalline-based modules are available, such as amorphous silicon, copper indium selenide (CIS), and cadmium telluride. In addition, new standards and testing schemes are being developed to be compatible with the new or improved technologies. With the steady increase in electricity prices, domestic PV systems could be implemented and used with a low system cost[11].

Earth received energy from sun nearly 10^{16} watts. The total world-wide power demand of all needs of civilization is 10^{13} watts. Therefore the sun gives us 1000 times more power than we need[12]. If we can use 5% of this energy, it will be 50 times what the world will require. The energy radiated by the sun on the bright sunny day approximately 1 kw/m^2[26]. Many Attempts have been made to make use of this energy in raising steam which may be used in driving the prime movers for the purpose of generation of electrical energy. However on account of large space required uncertainty of availability of energy at constant rate[9]. Due to clouds, winds, haze etc., there is limited application of this source in the generation of electrical power[13].

Indian government has been announced that no any new coal-based capacity addition are required for the 10 years to 2027 beyond more than the 50 GW power different stages of construction and hopefully to come online in the between 2017 and 2022[27]. The ambitious aim will see the India fatly becoming one of the most leading green energy producers in the total world and surpassing many more developed countries. Our government intends to achieve their target 40% cumulative electric power capacity in India from non fossil fuel sources by 2030[27].

The target is given for "bio-power" which includes biomass power and waste to power generation.

Table -1

Source	Total Installed Capacity (MW)	2022 Target (MW)
Biomass power (Biogases) Cogeneration and Biomass & Gasification	9,103	*10,000.00
Small hydropower	4,593	5,000.00
Solar power	28,181	100,000.00
Waste-to-Power	138	*10,000.00
Wind power	36,625	60,000.00
Total	**77,641**	**175,000.00**

2. Environmental Issues

The importance of the sustainable development concept has increased in India as in the whole world. As a result, some new regulations enforce that all development projects should be compatible with the environmental criterions[1]. An environmental impact assessment should be carried out to make sure that projects are compatible with the environmental criterions. Environmental Impact Assessment (EIA) can be defined as a process of environmental management, planning, and decision-making with a purpose of keeping and improving the quality of the environment[2]. The main goal is to develop environmentally friendly industrialization. With this kind of environmentally friendly industrialization, "sustainable development" can be a possibility in the future by keeping the usage/protection balance between economical development and the environmental protection. Solar energy is a lot cleaner when compared with conventional energy sources[23]. Solar energy systems have many significant advantages, like being cheaper and not producing any pollutants during operation, and being almost an infinite energy source when compared with fossil fuels[3]. Nevertheless, solar energy systems have some certain negative impacts on the environment just like any other energy system those are land Use and thermal Pollution , Discharge of Pollutants, Visual Impacts etc.

These Solar energy cells are made with the help of a p-n junction fabricated in a very thin layer of a materials which is called semiconductor materials[15]. Here the solar cell has exponential V-I output characteristics, these characteristics, are similar as of a diode[28]. When photons from the solar energy hit the solar cell , then energy are produce , which is very higher from band gap energy of semiconductor material, then electrons are loose from the atoms in this semiconductor material and they create a electron and whole pairs[16]. The current is being created due to the internal electric field of p-n junction and this current will be directly proportional to the incident radiation.

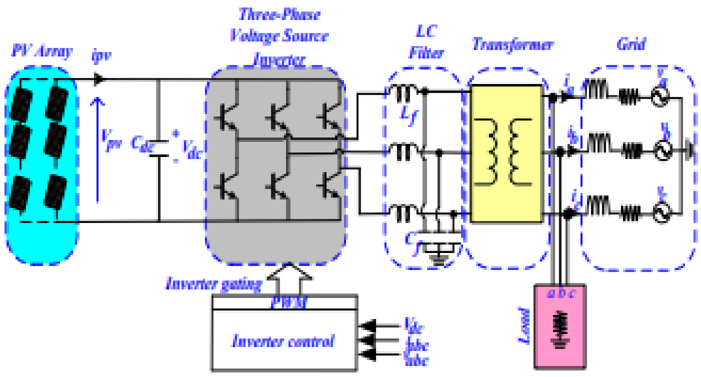

Figure –1 proposed model

3. LC filter:

To limit the voltage harmonics on the load, it is necessary to insert a filter at the output of the inverter. The latter can do away with most harmonic generated by the PWM control. For our study, an LC filter is connected to remove high switching frequency components from output current of inverter. The value of L is design based on current ripple. The ripple of current can be chosen as 10% of rated current and the value of inductor is given by (1).

$$\Delta i_{L\ max} = \frac{Vdc}{8*L*Fc} \qquad (1)$$

The reactive power is design by a capacitor C , it is chosen as 15% of the rated power is given by

$$C = 15\% \frac{P\ rated}{3*2\pi f V_{rated}^{2}} \qquad (2)$$

4. Modeling and Simulation of solar cell:

The One-Diode -Model is the most simple and the most used model for PV cells (figure 2). The simplified equivalent circuit of a solar cell consists of a diode and a current source which are connected in parallel[18]. The current source generates the photo current I_{Ph}, which is directly proportional to the solar irradiance Fs [W/m2], ambient temperature Ta [ºC], and two output parameters: current Is [A] and voltage Vs [V]. The p-n transition area of the solar cell is equivalent to a diode. The characteristic equation of the one diode model could be derived from Kirchhoff's Current law.

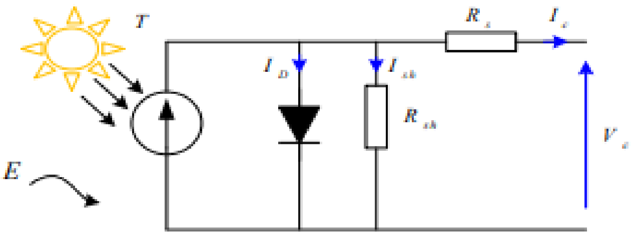

Figure -2 Solar Cell single diode model

To find the desired output voltage and current, assume that PV cells are combined and arranged in series and parallel. The mathematical model that predicts the desired current of the PV generator is defined as.

$$I_{pv} = N_p\left\{I_{ph} - I_0\left[exp\left(\frac{\frac{V_{pv}}{Ns}+\frac{Rs*Ipv}{Np}}{V_T}\right)-1\right]\right\} - \frac{Np}{Ns}*\frac{V_{pv}}{R_{sh}} - \frac{R_{s}I_{pv}}{R_{sh}} \quad (4)$$

Where

$$V_T = \frac{nTK_B}{q}$$

Ipv : Output current of the PV arrays
Np : Numbers of PV arrays connected in parallel
Iph : Light-generated current
I0 : Reverse saturation current
q : Electron charge
Vpv : Output voltage of the solar panel
Ns : Numbers of PV arrays connected in series
Rs : Lumped series resistance of the cell
KB : Boltzmann constant
T : Operating cell temperature
n : Dimensionless junction material factor
Rsh : Lumped shunt resistance of the cell

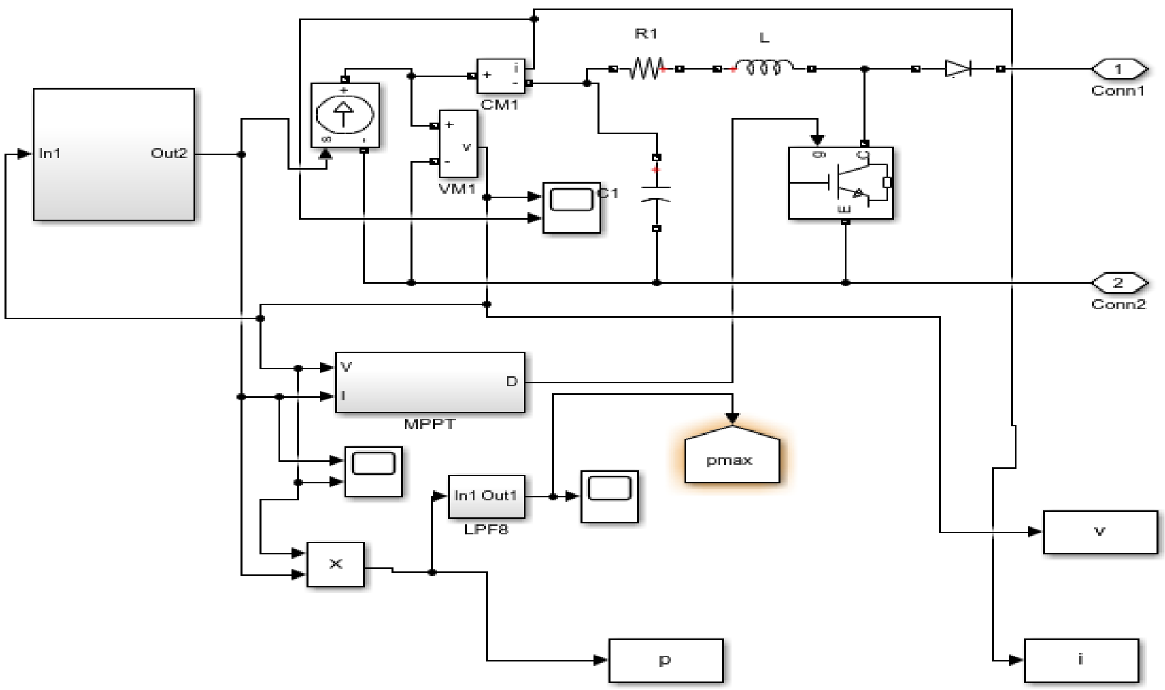

Figure – 3 MATLAB/Simulation of solar cell

5. MPPT algorithm:

According to the operating conditions, the maximum power delivered by the photovoltaic generator is not located in the same operating point[19]. It requires a dynamic adaptation between the PV generator and the load that adapts the operating point of the PV arrays to obtain the maximum power. In this paper, the Perturb and Observe (P&O) method was applied in order to track the MPP[21][28] . The MPPT algorithm generates the amplitude of the voltage at MPP. The flowchart for P&O algorithm is shown in figure -5

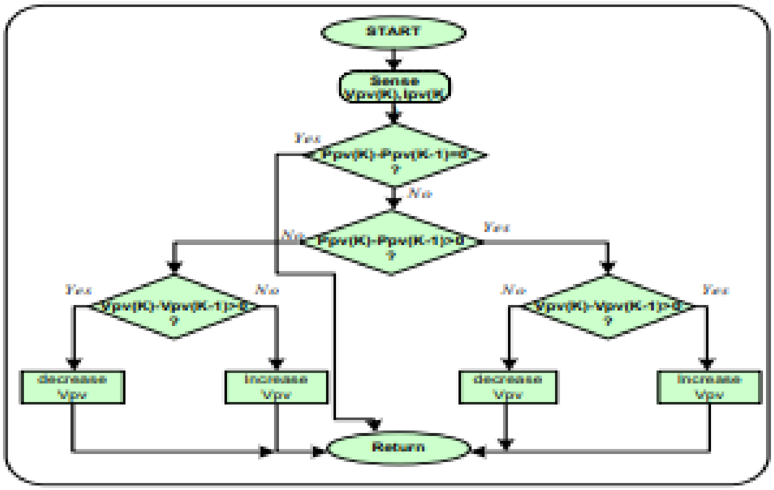

Figure -4 MPPT algorithm flowchart

6. Boost converter:

Boost converter is also know as dc equitant step-up transformer which work on energy conservation principle , which are design from active (MOSFET or SCR) and passive(inductor , capacitor) elements. The circuit diagram of boost converter are shown in Figure -

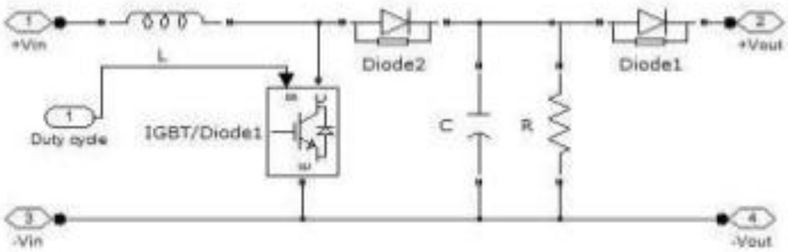

Figure –5 Boost converter

Output voltage of stepup chopper $v_0 = \frac{v_s}{1-\alpha}$ (5)

$v_{0=}$ output voltage of boost converter

$v_s = Input\ voltage\ of\ boost\ converter$

$\alpha = Duty\ cycle = \frac{T_{on}}{T}$

T=$T_{on} + T_{off}$

7. Result:

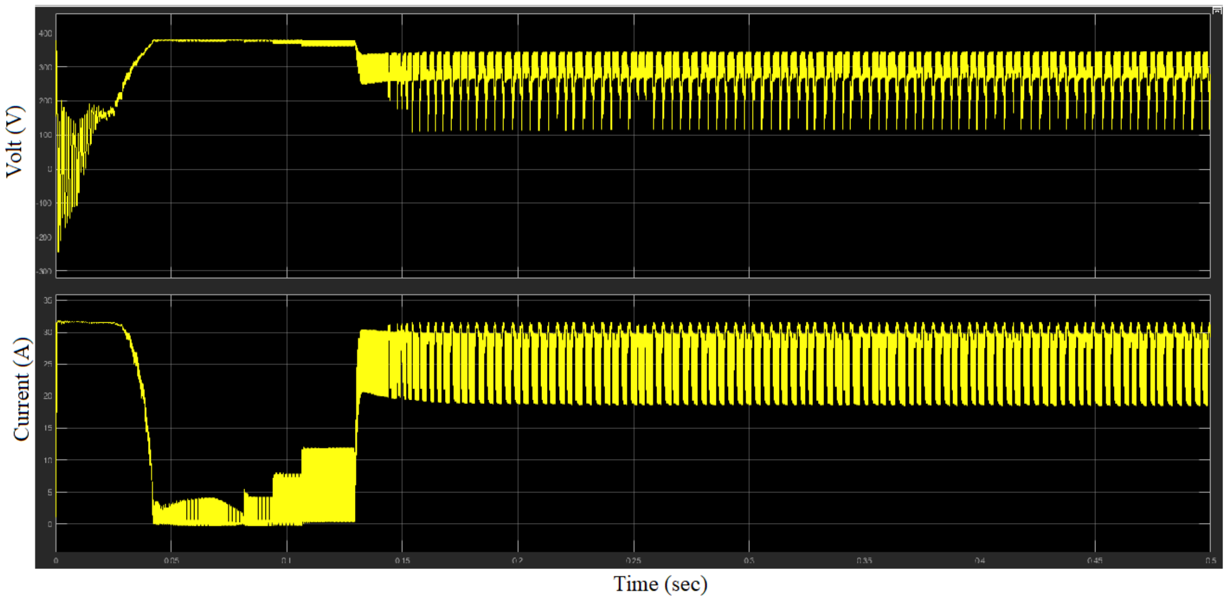

Figure -6 PV generated voltage and current

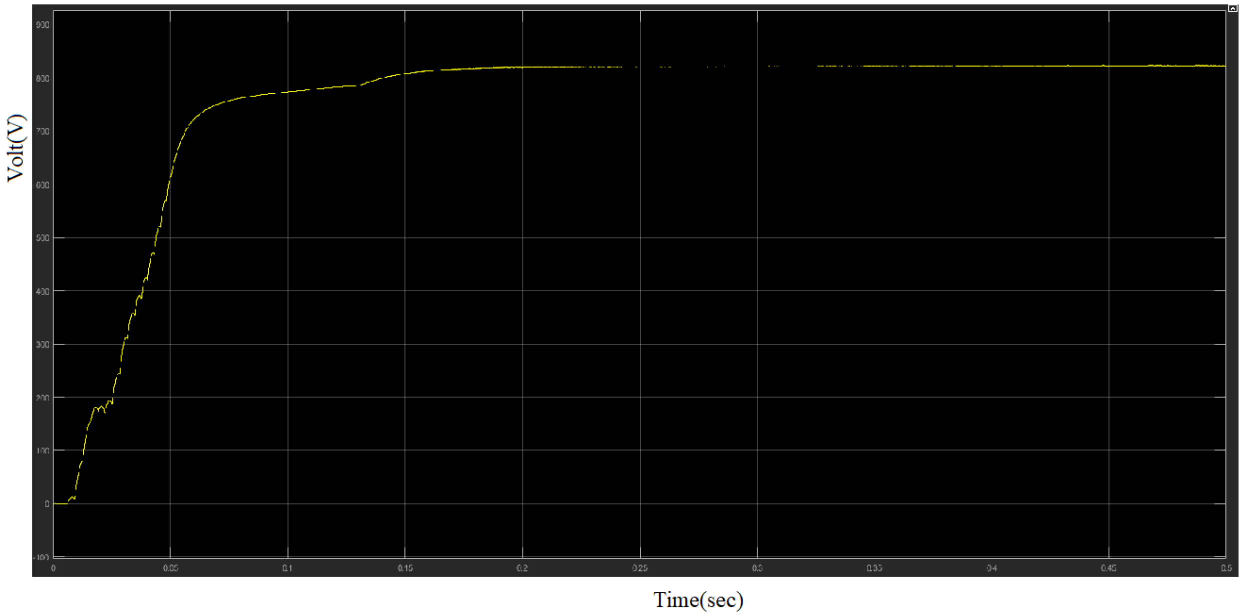

Figure –7 Output of boost converter

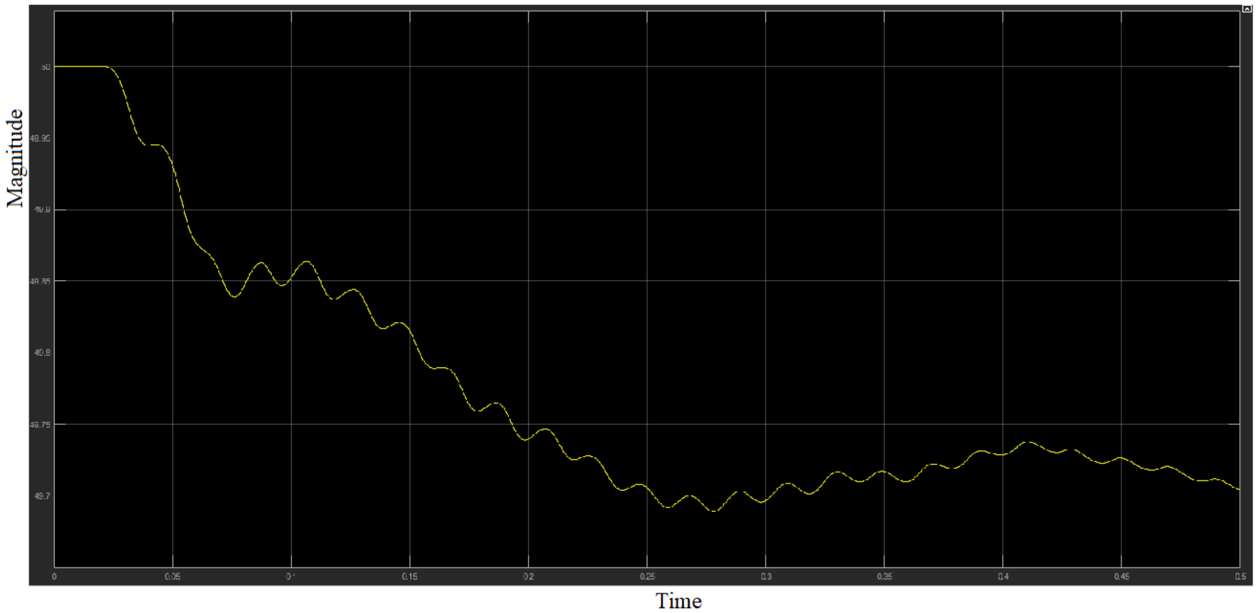

Figure – 8 grid frequency

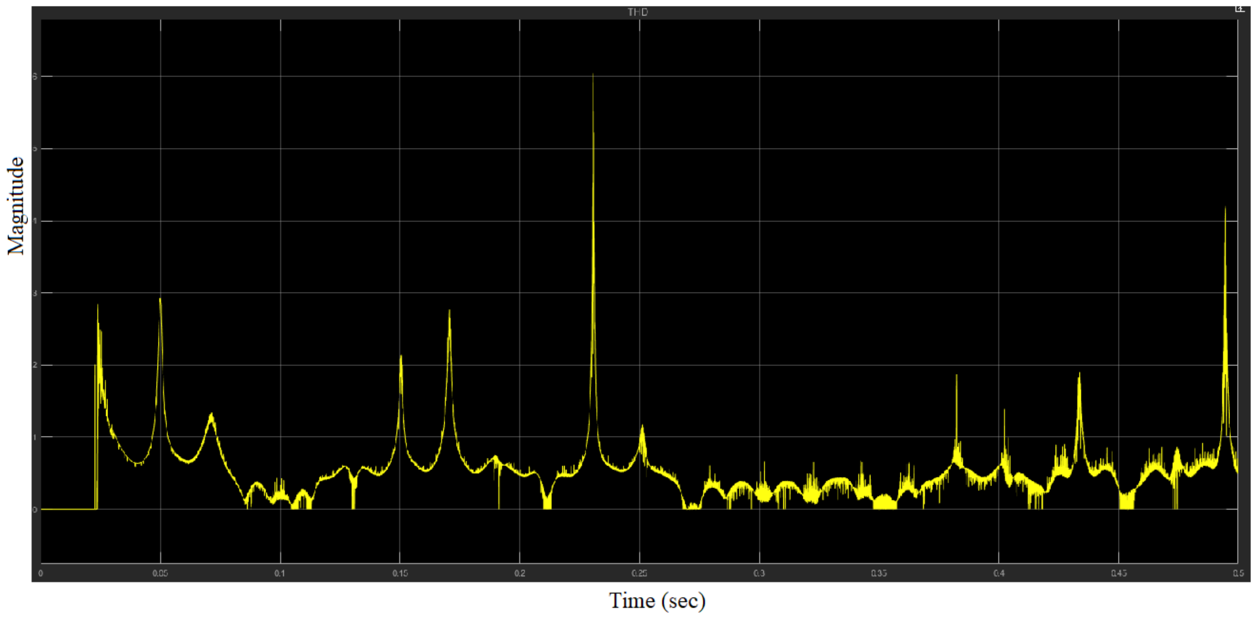

Figure – 9 THD of hybrid system

8. Conclusion:

An accurate PV module electrical model is presented and demonstrated in MATLAB/Simulink for a typical 3.5KW solar panel. The results from the MATLAB™ model show excellent correspondence to manufacturer's published curves. This paper is the first step to develop a complete solar photovoltaic power electronic conversion system in simulation. The final objective is develops a general model to simulate the electrical behavior of the PV systems in a grid connected application. With this study students will be able to simulate the PV system without a laboratory. In this paper 3.5 kW three-phase grid-connected PV power system model is presented, and the power control issues are studied. In this model, main components such as PV panels, a boost converter, inverter and utility grid are physically modeling for high-fidelity simulation. Also, a PQ controller is presented and studied for grid-connection control.

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