Modelling and Analysis of PV-Grid Connected System with Variation of Irradiance and Load

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Abstract - *Increased concern about global warming coupled with the escalating demand of energy has driven the conventional power system to be more reliable one by integrating renewable energy resources in grid. The grid-connected PV system is one of the most promising renewable energy solutions which could offer many benefits to both the end user and the utility network. Such systems may cover the consumer's own power demand and reduce electricity bills, while feeding any surplus power into the grid or use the grid as a backup system in times of less PV generation. This paper assesses the effect of high penetration levels of PV grid connected systems on the power quality of electricity distribution network. Different scenarios for both solar irradiation level and load level are considered to investigate the power level of system. The MATLAB/SIMULINK software package was used to carry out this assessment.*

Key Words: Photovoltaic System, MPPT Technique, Utility Grid, Boost Converter.

1. INTRODUCTION

The Earth, because of the colour of the oceans that cover two thirds of its surface is known as the blue planet. This planet, the third planet from the Sun, is the only one where the sufficient conditions exist to sustain life, something that makes the Earth special. It has liquid water in abundance, a mild temperature, and an atmosphere that protects it from objects that fall from outer space. The atmosphere also filters solar radiation thanks to its ozone layer. Slightly flattened at its poles and wider at its equator, the Earth takes 24 hours to revolve once on its axis. This plant is so rich by many things which made the man thought how to use them as sort of energy. Nowadays, the world changes to become more developed, therefore the demand of the energy has known increasing recently. The massy usage of the fossil fuels, such as the oil, the coal and the gas, result in serious greenhouse effect and pollute the atmosphere, which has drastic effect on the world. Meanwhile, there is a big contradiction between the fossil fuels supply and the global energy demand, which leads to a high oil price in the international market recently. The energy shortage and the atmosphere pollution have been the major limitations for the human development. How to find renewable energy is becoming more and more exigent. All of these reasons urge the scientists to look for new power source [1].

Among the RE sources, solar PV has an unpredicted growth in power generation due to its reliability in power conversion and cost effectiveness [2]. This unpredicted growth in PV market mostly has been driven by the residential Grid connected PV systems- 'A source of emission free power generation'[3]. Grid-connected photovoltaic (PV) power systems are energized by PV panels which are connected to the utility grid via an inverter can upload the excess energy to the grid during average or low peak demands. Grid connected PV systems reduces the line losses as the consumer power is generated close to the load demand. In addition, grid connected system benefits the utilities economically in delaying the line upgrades by means of peak load reduction [4]. However, integration of solar PV into grid has several impacts resulting to operational problems due to its intermittent nature. Integrating solar PV effects the functional operation of the power system network like load/frequency control, unbalancing of voltage and current levels in the network and power quality issues including voltage disturbance, poor power factor, reactive power compensation flicker and harmonic distortions. Though integration issues/effects are not the major focus of this paper it is essential to study some of the effects of the Grid connected PV system that has to be analyzed for efficient power generation and distribution for sustainable energy flow [3, 5-7]. Keeping this in view, this paper explains the effects of Grid connected PV systems on the distribution network with variation of irradiance and load.

2. SOLAR CELL MODELLING

Solar cell is basically a p-n junction fabricate in a thin wafer or layer of semiconductors. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect [8]. When exposed to sunlight, photons with energy greater than the band-gap energy of the semiconductor are absorbed and create some electron-hole pair proportional to the incident irradiation. Under the influence of the internal electric fields of the p-n junction, these carriers are swept apart and create a photocurrent which is directly proportional to solar irradiation [9]. Naturally, PV system exhibits a nonlinear current-voltage (I-V) and power-voltage (P-V) characteristics which vary with the radiant intensity and cell temperature. The PV module is the interface which converts light into electricity. Modelling this device necessarily requires taking weather data (irradiance and temperature) as input variables. The output can be current, voltage, power or other. However, trace the characteristics I(V) or P(V) needs of these three variables. Any change in the entries immediately implies changes in outputs. That is why, it is important to use an accurate model for the PV module. This paper discusses the effect of irradiance on the parameters of the PV module.

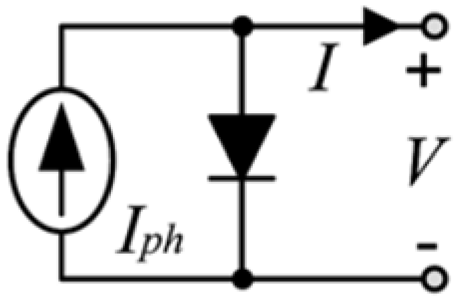

Figure 1. Equivalent circuit of Ideal PV Cell

To develop an accurate equivalent circuit for a PV cell, it++++ is necessary to understand the physical configuration of the elements of the cell as well as the electrical characteristics of each element. The ideal equivalent circuit of a PV cell is a current source in parallel with a single-diode. The configuration of the simulated ideal solar cell with single-diode is shown in figure 1 [9]. The equation for the output current is given by:

$$I = I_{PV} - I_D$$

Where, $$I_D = I_0 \left[e^{\left(\frac{V}{AV_T}\right)} - 1 \right] \qquad (1)$$

Then equation (1) becomes:

$$I = I_{PV} - I_0 \left[e^{\left(\frac{V}{AV_T}\right)} - 1 \right]$$

I_{PV} is the current generated by the incidence of light; I_0 is the diode reverse bias saturation current; $V_T = \frac{N_s * K * T}{q}$ is the thermal voltage of a PV module having Ns cells connected in series; q is the electron charge; k is the Boltzmann constant; T is the temperature of the p-n junction and A the diode ideality factor.

MPPT Technique

In general, solar panel converts only 30 to 40 % of the incident solar radiation into the electrical energy. In order to achieve the maximal efficiency of such MPPT technique to get maximum power from solar system. From the Maximum Power Transfer Theorem (MPTT), we know that the output power of a circuit is maximum only when the Thevnin impedance of the circuit matches with that of its load impedance. In similar way, the objective of the solar irradiance tracking is to meet the point of power maximality in MPPT technique, which must need to be done in such a way that it also matches the impedance of corresponding as stated in MPPT technique [10]. Thus, one can say that for the purpose of impedance matching in PV grid the element which must need to be introduce is the boost converter at the input side. This may regard as step-up type transformer for the tracking of optimal one, so that the voltage at the output side get enhanced which can be employed for the application of different types like to drive the motor as load, for lightning etc. By changing the duty cycle of such converter appropriately we can able to match the intrinsic (or Thevenin) impedance with that of the load impedance. If we have variable input, for instance, solar irradiance, the current and voltage will be found to vary correspondingly. Where, the output power (i.e. simply the product of V & I) is zero at Voc (because I=0) and zero again at Isc (because I=0) [11]. In between these two crispy points it rises and then falls, so that there is one point at which the cell delivers maximum power.

3. MODELLING OF PV GRID CONNECTED SYSTEM

Figure 2 shows the PV Grid connected system model developed in MATLAB to analyze the power variations for the consideration. To investigate the various impacts of the proposed grid connected PV system model a rigorous study has to be done on the model considering level of solar irradiance and load demand. This section describes the proposed distribution network model developed in MATLAB, the typical solar profile used in analyzing the model. The maximum voltage (Vmp), and maximum current (Imp) of each solar PV module is considered as 54.7 V and 5.58 A respectively [12].

Grid Source

A three phase source block available in MATLAB is used as a grid source in this network model. The power source block specifications used in this analysis are base voltage 22kV, frequency 50 Hz, three phase short circuit level 10 MVA.

PV System

A PV system with a combination of three different groups of solar PV is used as a unique solar PV power system in analyzing the proposed model. The rated capacity of each group of solar PV system at Standard Test Condition (STC) is 33.1 kW. Each PV system consists of around 240 numbers of solar PV modules with configuration of 60 solar PV modules connected in series per string and 4 strings connected in parallel.

Load Group

Three load groups are considered in this model and the maximum capacity of load in each group is assumed to be around 25.95 kW which is equivalent to residential load of 30 houses.

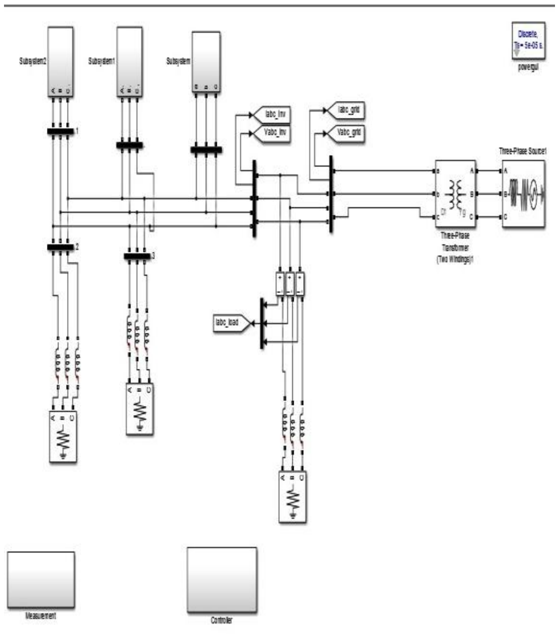

Figure 2. Proposed PV-Grid connected system

4. SIMULATION RESULTS AND DISCUSSION

The grid connected PV system in figure 2 is simulated by using MATLAB/SIMULINK software environment in order to analyze the power values with the variation of irradiance level of PV and load. Two different cases are used in analyzing the power scenario with respective to the PV integration into the grid.

Case A. Power analysis at minimum PV generation with peak load

The power analysis has been carried out at minimum solar irradiance (600 W/m2) and peak load (25.94 KW) conditions

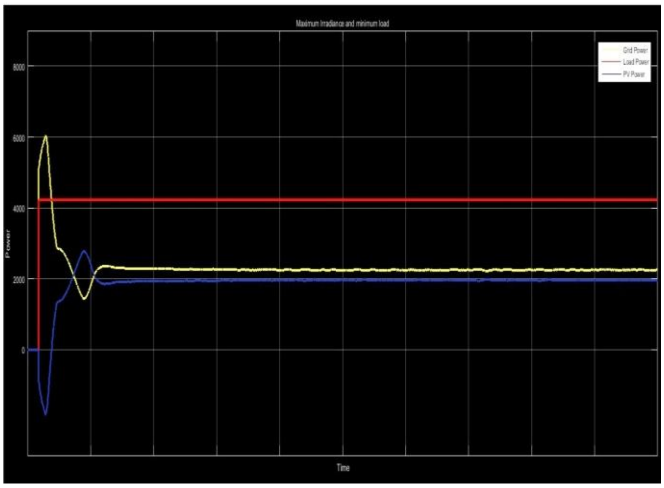

Figure 3. Simulation results with minimum PV generation and peak load

Case B. Power analysis at maximum solar irradiance with minimum load

The power analysis has been carried out at minimum solar irradiance (1000 W/m2) and peak load (14.64 KW) conditions

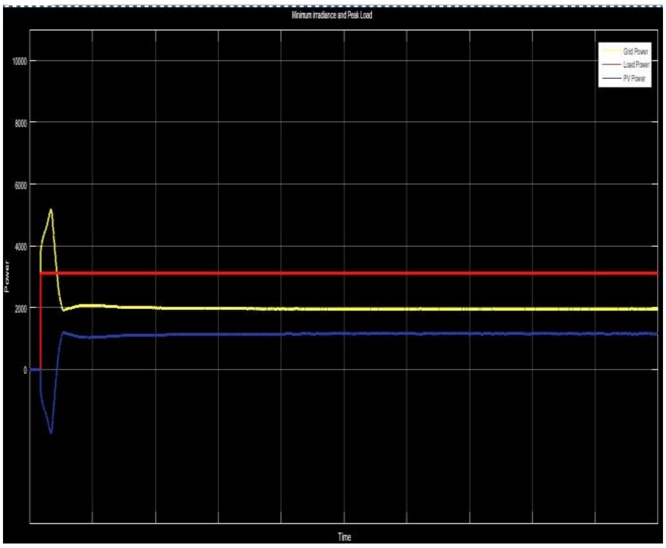

Figure 4. Simulation results with maximum irradiance and minimum load

5. CONCLUSION

In this paper, a dynamic model of grid connected PV systems with different irradiance and different load conditions has been developed using MATLAB/Simulink. This model is being used to investigate the impact of irradiance levels of grid connected PV systems on the power quality of distribution network. With the simulation results we can say that when maximum irradiance is given to system, then power from grid is less in value and required power is given to load from PV system. In another case, when minimum irradiance is given to system and then required power is given to load is from grid source. In this context, future work will extend the analysis to investigate the power of the network with the integration of electric vehicles (EV) as storage system to optimize the provision of power from PV systems and support the grid.

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