POWER QUALITY ISSUES IN DISTRIBUTION SYSTEM WITH HIGH PENETRATION OF PV GENERATION

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***Abstract*—The Photovoltaic system is an important topic that can be researched and studied in 21st century because fast deploying fossil fuels. The design and simulation of PV system with different types of loads used in regular days. In this paper provides theoretical study of photovoltaic and modeling technique using equivalent electrical circuits. It includes MPPT algorithms and control method to obtained the maximum solar power by using IC method. Simulation of PV system with commercial load (FL, PC and LED) with MPPT algorithm, Boost convert and invert circuit in MATLAB/Simulink. The operation and protection issues on a distribution system with high penetration of PV system. The most noticeable topic for electrical engineer is power quality in recent years.**

***Keywords*—Photovoltaic(PV), Maximum Power Point Tracking(MPPT), Incremental Conductance(IC), Fluorescent Lamp(FL), Personal Computer(PC), Light Emitting Diode (LED).**

I. INTRODUCTION

Solar system is the most important renewable and sustainable energy system. Solar electrical energy system has grown consistently and become a popular resource of energy. The main reasons for this huge attention are 1) increase in efficiency of solar cells; 2) recent technological improvements; 3) green and environment friendship. Typical application of solar energy are supply the residential loads and far off electrical installations[1]. It also has a major role in distributed generation network. Therefore, to preserve this little harvested energy, the whole system such as energy conversion stage has to be designed carefully and efficiently. It enforces system integrator to design very high efficient DC/DC and DC/AC converters. In the present paper, Simulation model for the solar cell is developed using Matlab/Simulink. It is necessary to model the PV module for the design and simulation of Maximum power point tracking for PV system applications because it has non-linear characteristics. Mathematical modeling of the solar array (module) here is done mainly for obtaining the performance characteristics[2]. In this paper to study the impact of high penetration of PV generation on the steady state and dynamic behavior of power systems. The analysis of electrical systems (nonlinear load) has preeminent importance in renewable system due to their nonlinear or time varying behavior of the power devices related with energy injection into the electrical grid. Power system with large penetration of PV generation system are subjected to high harmonic pollution. Due to this voltage and current unbalance produced and harmonics produced which effect the distribution system this pollution is not included by PV system but comes from supply load. These types of issues of PV integration into power system like voltage unbalance, voltage swell, voltage sag, Harmonics, Frequency fluctuation, poor power factor etc. produced.

II. PV CELL MODELLING

Photovoltaic solar energy is a clean, renewable, energy with a long service life and high reliability. But because of its high cost and low efficiency, energy contribution is less than other energy sources. It is therefore essential to have effective and flexible models, to enable you to perform easy manipulation of certain data (for example, irradiance and temperature) investigate how to get its performance as maximum as possible. The use of these simple models provides sufficient accuracy to analyze the behavior of the solar cell and have proven to be effective in most cases. Solar cells convert solar energy into electrical energy. This phenomenon occurs in materials which have the property of capture photon and emit electrons. The main material used in the photovoltaic industry is silicon. But The ideal solar cell, theoretically, can be modeled as a current source in anti-parallel with a diode (Figure 1). The direct current, generated when the cell is exposed to light, varies linearly with solar radiation. An improvement of the model includes the effects of a shunt resistance and another[4].

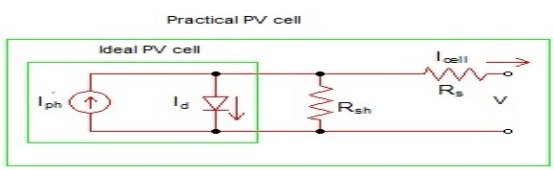

Figure 1 PV cell equivalent circuit

According to Kirchhoff's current law, output current of an ideal cell is given by,

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

This expression describes the electrical behaviour and determines the relationship between voltage and current supplied by a photovoltaic module. It is a non-linear mathematical equation whose parameters are, N_s is number of cells in series, I_{ph} is current produced by the photoelectric effect, I_{rs} is the reverse saturation current, R_s and R_p are inherent resistance in series and parallel associated with the cell, q is the electron charge, k is Boltzmann's constant and a is the ideality factor modified. The equations of I_d, I_{sh}, I_{ph} and thermal voltage (V_t) are given as below.[5],[6] By using the specific parameter of PV cell simulated in MATLAB/Simulink shown in figure 2.

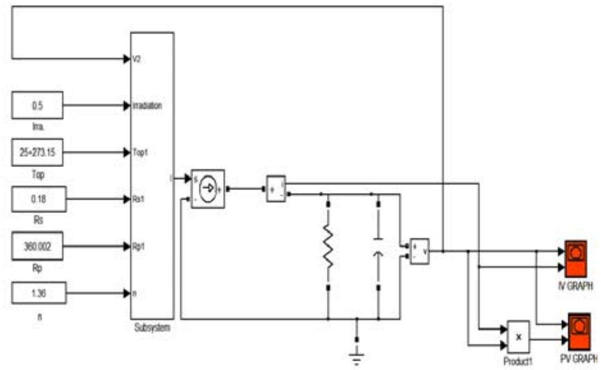

Figure 2 Modeling of PV Module in MATLAB/Simulink

The specific parameter of Solar cell which is used in MATLAB/Simulink to simulate PV model is given below in Table 1.

Table 1 The parameter of a single Solar Module

Short Circuit Current I_{SC} [A]	3.8
Open Circuit Voltage V_{OC} [V]	21.1
Maximum Power [W]	60
Voltage, maximum power Vmpp [V]	17.17
Current, maximum power Impp [A]	3.5
Normal operating cell temperature	25ºC

III. PV MODULE CHARACTERISTICS

The equivalent circuit shown in Figure 1 and described by equation 9 represents a PV cell.There are two characteristics in PV cell (1) I-V Characteristics (2) P-V Characteristics

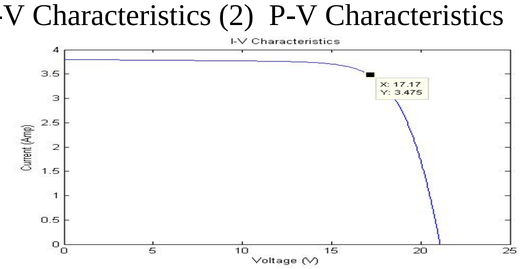

Figure 3 I-V Characteristics of PV Module

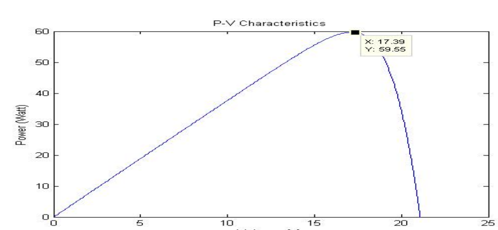

Figure 4 P-V Characteristics of PV Module

Figure 3 and 4 shown the the I-V and P-V characteristics of PV module and figure 3 also shown open circuit voltage (V_{OC}), Short circuit current (I_{SC}), Maximum power point (I_{MPP},V_{MPP}).

A. Impact of solar irradiance on I-V and P-V characteristics

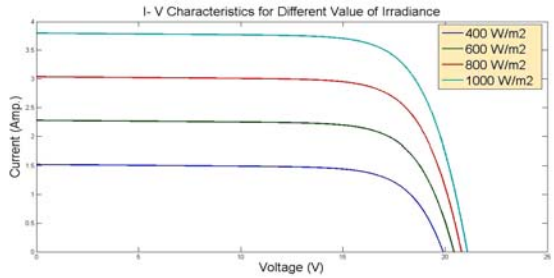

Figure 5 I-V Characteristics of PV Module at 25ºC temp. with different value of irradiance

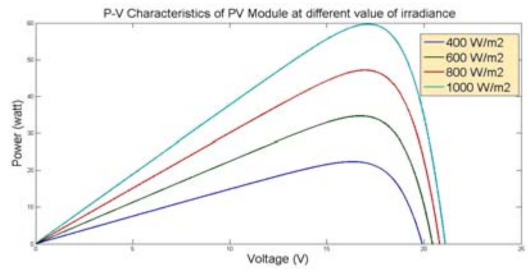

Figure 6 P-V Characteristics of PV Module at 25ºC temp. with different value of irradiance

B. Impact of solar temperture on I-V and P-V characteristics

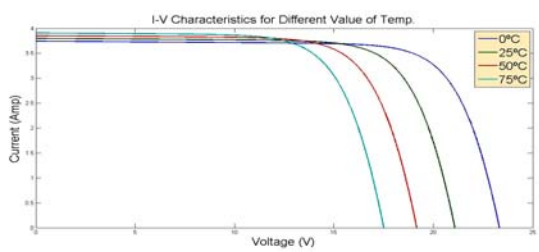

Figure 7 I-V Characteristics of PV Module at 1000W/m^2 irradiance with different value of temp.

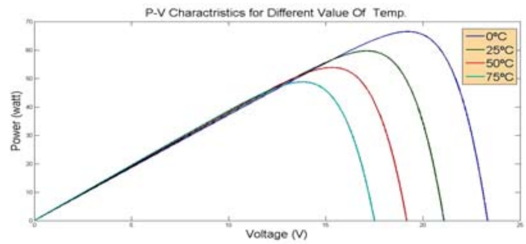

Figure 8 I-V Characteristics of PV Module at 1000W/m^2 irradiance with different value of temp**.**

The effect of irradiance and cell temperature on I-V and P-V characteristic is shown in Figure 5, Figure 6, Figure 7 and Figure 8 respectively. Figure 5 shows that the maximum power output varies almost linearly with the irradiance. Figure 7 shows that the maximum output power from the array decreases as the temperature increases[7].

IV. SIMULATION & RESULTS

Figure 9 shown the simulation of grid connected PV system with linear(resistive) , non linear load(PC & FL)[7][8] and PV array is connected with MPPT (IC method)[9][10], Boost Converter(DC-DC Converter)[11][12], Three Phase Inverter Circuit with filter and Isolation Transformers which are connected with Grid side and PV side. In this simulation PV array generate 5.7 kW power when N_S=16 & N_P=6 of PV module and grid proved 415V at 50 H_Z frequency. In this simulation there are four circuit breakers used with load shown in Figure 9. From the Table 2 grid connected PV system, at starting time 3 phase load, PC and FL taken power from grid but after 2 sec. PV is also connect with these loads. At 2.5 sec. Load 3 is connect with PV and grid.

Table 2 The parameter of a single Solar Module

Load	Power	C.B. closing Time
Load 1(resistive)	2 kW	0.01 Sec.
Load 2(resistive)	3.5 kW	2 Sec.
Load 3(resistive)	5 kW	2.5 Sec.
PC	3 kW	2 Sec.
FL	165 W	
3 Phase Load (resistive)	1 kW	

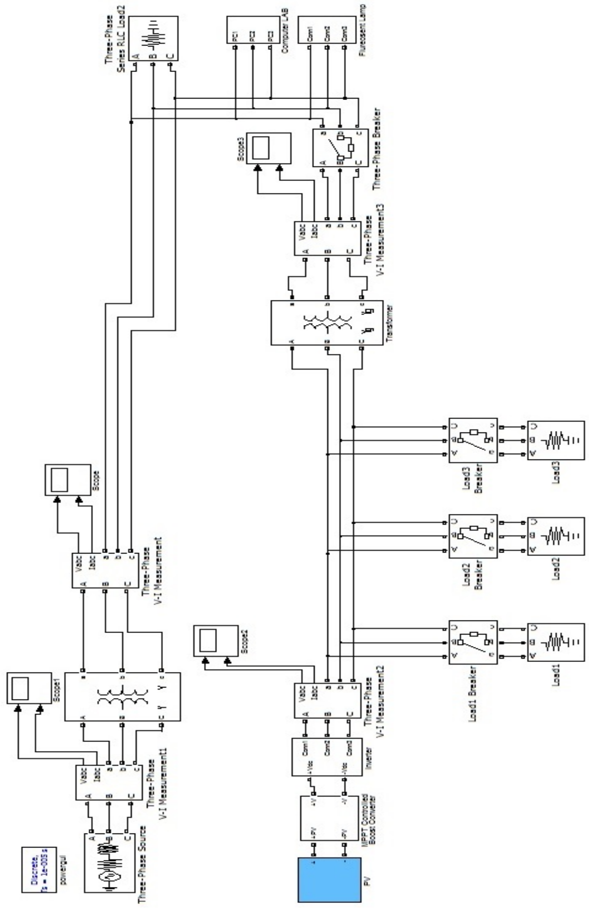

Figure 9 Grid connected PV system with linear & non linear load

A. Wave of Simulation at Grid side and PV side connected Transformer

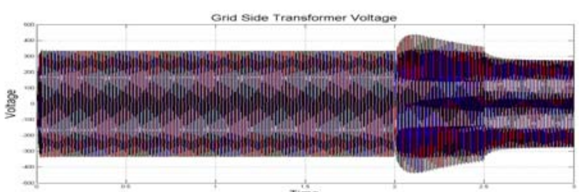

Figure 10 Voltage Waveform of Grid Side Connected Transformer

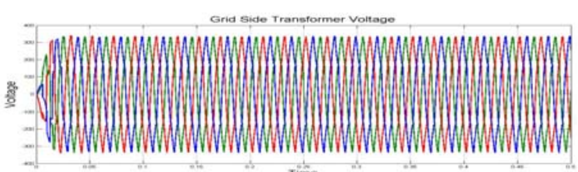

Figure 11 Voltage Waveform of Grid Side Connected Transformer (for 0 to 0.5 sec.)

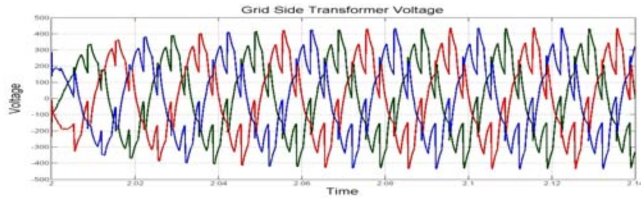

Figure 12 Voltage Waveform of Grid Side Connected Transformer (after 2 sec.)

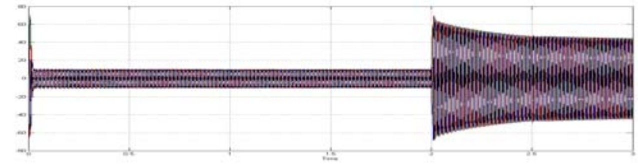

Figure 13 Current Waveform of Grid Side Connected Transformer

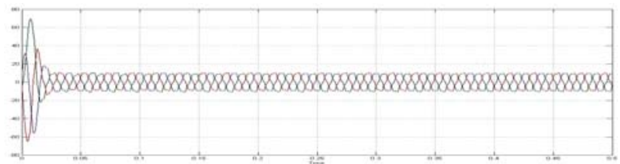

Figure 14 Current Waveform of Grid Side Connected Transformer (for 0 to 0.5 sec.)

Figure 15 Current Waveform of Grid Side Connected Transformer (after 2 sec.)

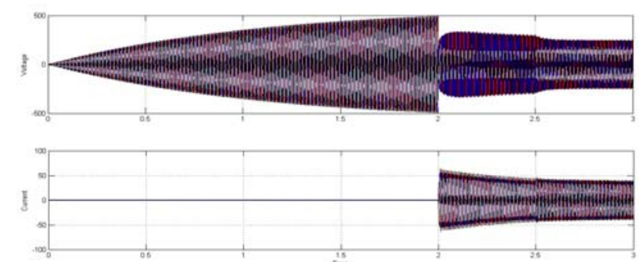

Figure 16 Voltage & Current Waveform of PV Side Connected Transformer

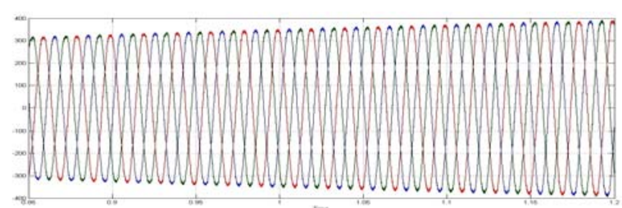

Figure 17 Voltage Waveform of PV Side Connected Transformer (for 0.85 to 1.2 sec.)

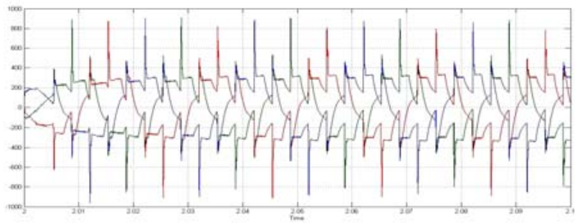

Figure 18 Voltage Waveform of PV Side Connected Transformer (for 2 to 2.1 sec.)

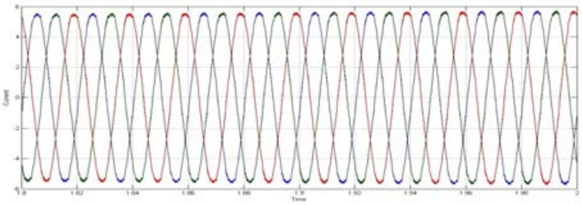

Figure 19 Current Waveform of PV Side Connected Transformer (for 0.2 to 2 sec.)

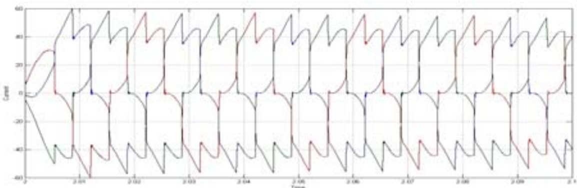

Figure 20 Current Waveform of PV Side Connected Transformer (after 2 sec.)

Figure 10 shown that time period 0 to 2 the voltage magnitude is 315V at that time only 1kw (resistive) and 3kw (nonlinear) load connected after 2 second grid voltage magnitude increased from 315V to 415V because of after 2 the PV side connected load connected with grid. Due to the nonlinear load we can get the distorted voltage and current waveform at grid side connected transformer side shown in Figure 12 and 15. Figure 16 shown the voltage and current waveform of PV side connected transformer. In PV side at 0 to 2 second only resistive load (load1 & load2) connected at that time we can get the sinusoidal voltage and current waveform shown in figure 17 & 19. After 2 second Load 3 and Three phase Circuit Breaker (C.B.) are close so at that time non linear load (PC & FL) and load3 are connected with PV system and also with Grid. So that after 2 second PV side voltage and current waveform are distorted shown in figure 18 & 20.

B. FFT Analysis of Grid side and PV side

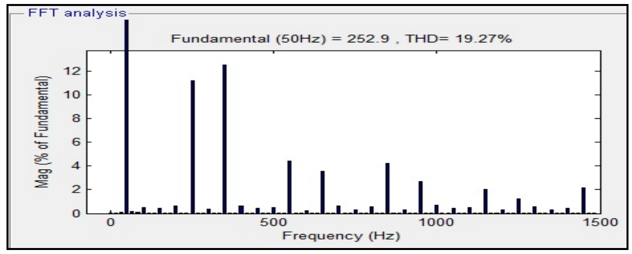

Figure 21 FFT analysis (voltage) of Grid side

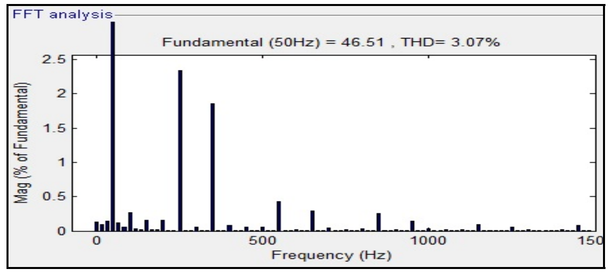

Figure 22 FFT analysis (current) of Grid side

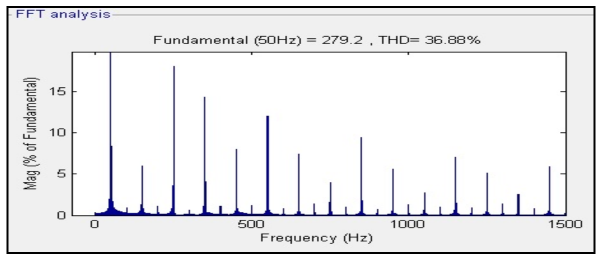

Figure 23 FFT analysis (voltage) of PV side

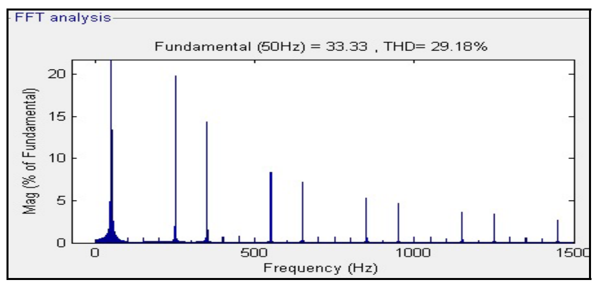

Figure 24 FFT analysis (current) of PV side

Table 3 Harmonics Present at PV side with Non-linear load

PV Side			
Voltage Harmonics		Current Harmonics	
Harmonic Order	THD (%)	Harmonic order	THD (%)
3rd	6.03	3rd	0.53
5th	18.05	5th	19.79
7th	14.32	7th	14.33
9th	7.99	9th	0.75
11th	12.07	11th	8.41

13th	7.45	13th	7.23
15th	3.99	15th	0.66
17th	9.49	17th	5.27
19th	5.62	19th	4.67
21th	2.73	21th	0.63
23th	7.04	23th	3.65
25th	5.11	25th	3.39
27th	2.53	27th	0.6
29th	5.93	29th	2.69

Table 4 Harmonics Present at Grid side with Non-linear load

Grid Side			
Voltage Harmonics		Current Harmonics	
Harmonic order	THD (%)	Harmonic order	THD (%)
3rd	0.63	3rd	0.25
5th	15.05	5th	3.15
7th	17.83	7th	2.66
9th	0.42	9th	0.03
11th	6.67	11th	0.61
13th	4.61	13th	0.35
15th	0.50	15th	0.05
17th	5.52	17th	0.35
19th	4.05	19th	0.23
21th	0.42	21th	0.02
23th	3.27	23th	0.15
25th	1.80	25th	0.07
27th	0.44	27th	0.02
29th	2.87	29th	0.1

Figure 21 & 22 shown the FFT analysis (voltage & current) at Grid side. Figure 23 & 24 shown the FFT analysis (voltage & current) at PV side. Table 3 shown the Harmonics Present in Grid connected PV with Non-linear load. From this table we can shown that higher higher harmonics at PV side.

V. CONCLUTION

The mathematical model of PV model simulate in MATLAB/Simulink by using the equivalent circuit and equations. This model simulate with linear and non linear loads(N_S=16 & N_P=6) for three phase system with grid. In this simulation PV system (generate 5.7kw power when power drawn by load exceed this limit than power taken from the grid. When non linear load connected with grid connected PV system ,current and voltage waveform are distorted due to the non linear load. and from the FFT analysis concluded that THD_V (36.88%) and THD_I (29.18%) more at PV side compare to grid side THD_V (19.27%) and THD_I (3.07%) .

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