International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

Design and Simulation of Grid tied 200kW PV System

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Abstract: In this paper, a MATLAB based simulation of Grid tied Photovoltaic system is explained. The key components of this simulation are photovoltaicarray, Boost converter; Maximum Power Point Tracking System (MPPT) and Grid tied photovoltaic three phase inverter with closed loop control system are designed and simulated. A simulation investigate is done in different solar radiation level.

Keywords: PV Array, Boost Converter, MPPT, PWM Inverter.

I. Introduction

The continuous use of fossil fuels has significantly affected the environment and caused of pollution and global warming. To fulfill the increasing demand of energy in daily life, renewable based energy resources widely used in the last several years. Among them, Solar Energy is widely useful because it is pollution, maintenance free, and abounded in nature [1]. In PV Solar System, PV Solar cell converts the sunlight into the electricity by the photovoltaic effect. PV Solar Panels are used in many applications, such as, battery chargers, solar powered water pumping systems, grid connected PV systems, solar hybrid vehicles and satellites. PV array system and storage battery sources produce low voltages, so dc-dc boost converter is generally provided to adapt voltage level for grid-tied inverter. Boost converter, in addition to boosting, also controls inverter input voltage and sometimes isolates low- and high-voltage in circuit [2].

A Block Diagram of grid -tied PV System is depicted in Fig.1. PV solar cells are made from crystalline silicon which is interlinked together in series and parallel combination to form PV module and PV module is connected in series and parallel combination to form solar PV array [3]. PV solar array develops DC Power which relies with solar radiation intensity level , In morning hours and twilight durations , solar radiation level is low , as a result of that output power of PV solar panel is lower than rated level and during noon , output power is maximum due to presence of higher solar radiation level . To extract maximum power, Maximum Power Point Tracking (MPPT) System is essential to use in system [4, 5].

The output DC power is converted into the AC form, PWM based Inverter is used in practice. The design and Simulation of each component are presented in next section [5].

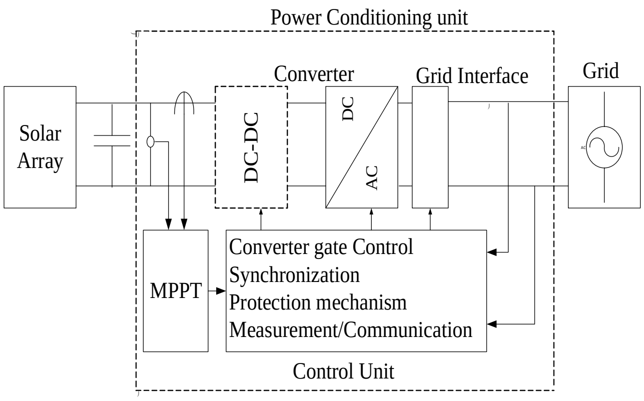

Fig.1. block diagram of grid connected PV array system

II. MATHEMATICAL MODELING OF GRID TIEDPV INVERTER SYSTEM

A. *Solar cell*

A photovoltaic module contains a considerable number of photovoltaic cells connected in series configuration. It is essential to understand performance of a single solar photovoltaic cell, and then performance of module under distinctive conditions is easier to understand. An ideal photovoltaic cell contains a current source and a diode. A practical model of a photovoltaic cell has

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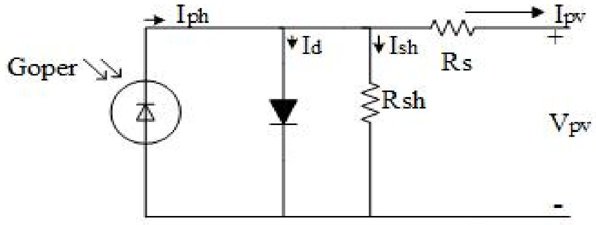
an additional shunt resistance connected parallel to the diode and a series resistance is shown in Fig. 2



.Fig.2. Equivalent circuit of PV Solar Cell

Basic equation from theory of photovoltaic cell and array [6] that mathematically explained I-V characteristic of practical PV array is:

$$I_{pv} \text{ X } I_{ph} \text{ Z } I_d \text{ Z } I_{sh} \quad (1)$$

$$I_{ph} \text{ X} \frac{G_{oper}}{G_{ref}} \quad I_{sc} \,\Gamma\, k_i \, f T_{oper} \text{ Z} T_{ref} \text{ A } N_{para} \quad (2)$$

$$I_{pv} \text{ X} N_{para} I_{ph} \text{Z} N_{para} I_{sat} \ \exp \ \frac{q}{Q_d k T_{ref}} \ \frac{V_t}{N_{ser}} \Gamma \frac{I_d R_s}{N_{para}} \quad \text{Z1 Z}$$

$$\frac{1}{R_{sh}} \ \frac{V_t}{N_{ser}} \Gamma \frac{I_d R_s}{N_{para}} \quad (3)$$

Where:

I_{ph}= Light-generated photo-current of PV model, A, Goper =Operating irradiance, W/m2 Gref= Reference irradiance= 1000 W/m2,Id=Diode Current, A,Ish=Shunt Current, A, Toper=Operational Temperature, °C or K, Tref= Reference Temperature = 25 °C or 298 K, Npara=No. of modules in an array connected in parallel, Nser= No. of modules in an array connected in series,Vt=threshold voltage, k=Boltzmann Constant = 1.3806 e-23 $J.K^{-1}$.

B. Boost Converter

DC-DC power converter whose output voltage is greater than its input voltage is known as step-up or boost converter. Boost converter shown in Fig. 3. To reduce output voltage ripple, a capacitor filter is added at output of converter. DC sources like batteries, solar panels, rectifiers or DC generators can be used to power boost converter. DC- DC conversion is process of changing one voltage to other voltage. A converter with an output DC voltage greater than source DC voltage is known as boost or step-up converter. Since power must be conserved, output current is lower than source current.[7].

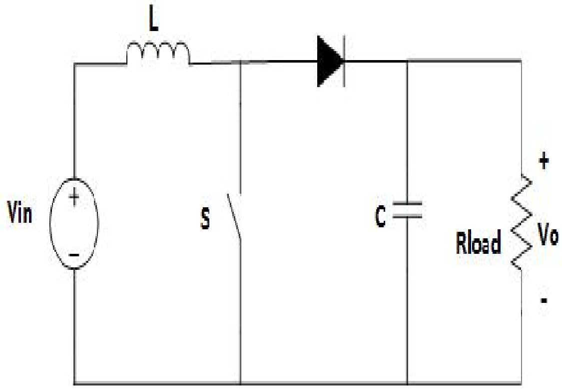


Fig.3. Design Parameters of Boost Converter:

The parameters involved in the design of boost converters are shown follows:

$$V_o \text{ X} \frac{V_{in}}{1 \text{ Z } D} \quad (4)$$

$$D \text{ X} \frac{T_{on}}{T_{totle}} \quad (5)$$

Where,

V0 = output voltage, Vs = input voltage, D= duty cycle = Ton/Ttotal, *f* = switching frequency (Hz).

C. Maximum Power Point Tracking System (MPPT)

Maximum Power Point Tracking frequently labeled as MPPT, controls Solar PV modules in a manner that enables the modules to generate all the power they may be capable of generating. MPPT is not a mechanical tracking system but it operates on a specified tracking algorithm and is based upon a control system. The voltage at which PV module can produce maximum power is termed „maximum power point? Maximum power relies with solar radiation, ambient temperature, and solar cell temperature. In MPPT model Vpv voltage as well as Ipv current taken by PV panel. This voltage and current connect a filter block after filtering voltage will change Vn and Vb, after filtering current will change in and Ib. The power Pn=Vn*In and Pb=Vb*Ib will obtain, a difference of this power is ΔP =Pn-Pb and difference between Vn-Vb is ΔV. This signal is compared to threshold switch. In this signal gained duty cycle of the converter. This duty cycle is compared to 10 KHz frequency carrier wave and acquired PWM based duty cycle[8].

$$P = V*I \quad (6)$$

Differencing the eq. 7 gives:

$$dP/dV = dVI \quad (7)$$

In condition of zero slope of PV curve where:

$$dP/dV = 0 \quad (8)$$

We have

$$dI/dV = -I/V \quad (9)$$

When, dI/dV< -I/V the voltage must be reduced in order to achieve MPP operation. When dI/dV> -I/V voltage must be raised in order to achieve the maximum power point of the PV generation. In the case of grid-connected PV system, different inverter topologies and controllers are usually used for interfacing the PV modules and the utility grid. The IGBT based three phase full bridge inverter topology is the most widely used configuration in three phase systems [9].

Parameters of Boost Converter	
Input Voltage (V_{in})	296V
Output Voltage (V_{out})	500V
Duty Cycle (D)	0.5
Lin	13mH
Cin	120µF
Parameters of PV Inverter	
DC Link Voltage	500V
Switching Frequency	10kHz
Filter Inductance	125mH
DC Link Capacitor	0.5mF

III. SIMULATION AND RESULTS

This section explains MATLAB based simulation of Grid tied PV array system. A parameters used for this simulation is shown in Table 1.

TABLE.I

No.	**NREL: 2007(E) Sunpower SPR-305-WHT**	
Crt.	**Parameter**	**Value**
1	Number of cells in series per module, n_{Cells}	96
2	Maximum power, P_{mp}	305.2 W
3	Open circuit voltage, V_{oc}	64.2 V
4	Short circuit current, I_{sc}	5.96 A
5	Voltage at maximum power point, V_{mp}	54.7 V
6	Current at maximum power point, I_{mp}	5.58 A
7	Temperature coefficient of P_{mp}, TempC_P_{mp}	−1.154 W/°C
8	Temperature coefficient of V_{oc}, TempC_V_{oc}	−0.177 V/°C
9	Temperature coefficient of I_{sc}, TempC_I_{sc}	0.003516 A/°C
10	Temperature coefficient of V_{mp}, TempC_V_{mp}	−0.186 V/°C
11	Temperature coefficient of I_{mp}, TempC_I_{mp}	−0.00212 A/°C
12	Series resistance of PV model, R_s	0.038 Ω
13	Parallel resistance of PV model, R_p	993.5 Ω
14	Diode saturation current of PV model, I_{sat}	0.0319 µA
15	Light-generated photo-current of PV model, I_{ph}	5.9602 A
16	Diode quality factor of PV model, Q_d	1.3

The Grid connected PV system of the rating of 200kW is connected with 25kV Grid is simulated in MATLAB shown in Figure 4.

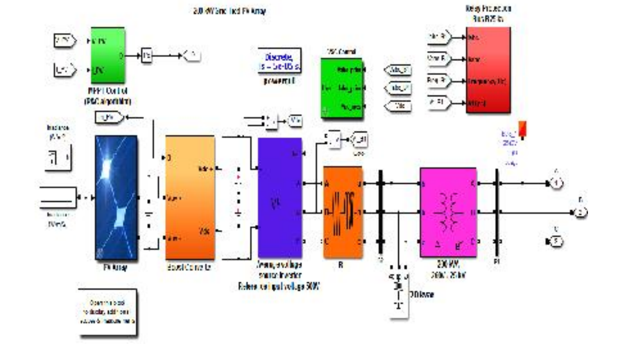


Fig.4. Simulation of Grid Connected PV System

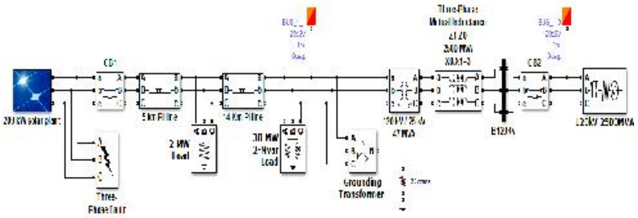


Fig.5. Simulink model of the 25kV line with 120kV Utility Power grid.

I-V and P-V characteristics of Simulated PV panel in different solar radiation level are depicted in Fig. 6 and Fig. 7, respectively. From this characteristic it can be notice that Output of PV solar farm is varies with the different solar radiation level.

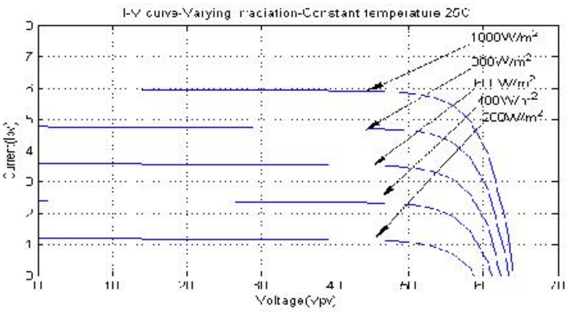


Fig.6. I-V Characteristic of Simulated PV Panel in Different Solar radiation.

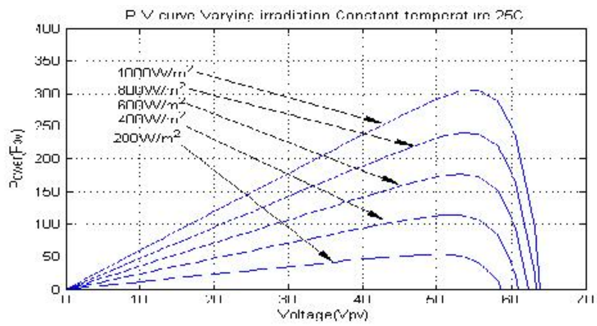


Fig.7. P-V Characteristic of Simulated PV Panel in Different Solar radiation.

For instance, periods of (0.15–0.4 s), (0.7–1.0 s), and (1.5–1.75 s) are probably characterized by sunny periods, where period of (0.4–0.7 s) is characterized by thin low stratus clouds. Period of (1.0–1.5 s) shows the development oflarger clouds resulting in mostly overcast skies. It is worth noting that the temperature usually changes quite slowly, so that the temperature value is often considered constant with respect to the irradiance level variation.Temperature value is often considered constant with respect to the irradiance level variation, from fig.8 can be show it [10].

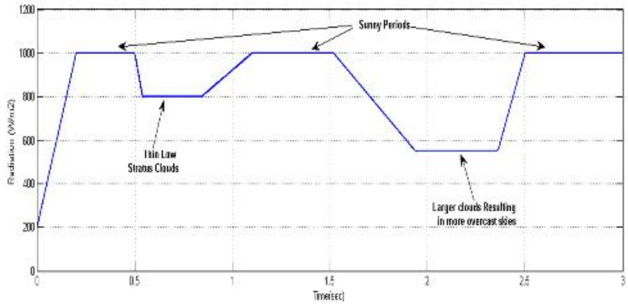


Fig.8.The hypothetical solar radiation distribution

The simulated output DC current from PV array before DC–DC boost converter is expressed in Fig. 9 when having hypothetical solar radiation distribution discussed in Fig. 8. Although Fig. 10 describes the duty cycle variation at the exact time frame. From this figure, it can be noticed that the duty cycle become constant during constant radiation. Fig .11 provides maximum output power, according to IC MPPT algorithm, from PV array during radiation variation. From this figure, it can also be noticed that output power improves with solar radiation step up. Fig .12 displays simulated three-phase line voltage waveforms form three phase inverter before and after LC filter. It can be noticed that the voltage includes more steps; therefore it is more similar to a sinusoidal waveform than the output voltage of a traditional inverter

Fig .13 displays the simulated three-phase line voltage waveforms from three phase inverter at B2. It can also be noticed that the three phase inverter yields balanced sinusoidal three-phase voltage waveforms. Fig .14 describes the simulated three-phase current waveforms at B2. It absolutely was found out that the inverter output current has the similar kind as the hypothetical solar radiation distribution over an allocated time frame. Fig .15

displays the simulated voltage and current profiles of phase "A" at bus B2 before the coupling transformer. From this figure, it can be seen that the voltage and current injected into the UG with THD 1 .90 % and 1 .57 %.

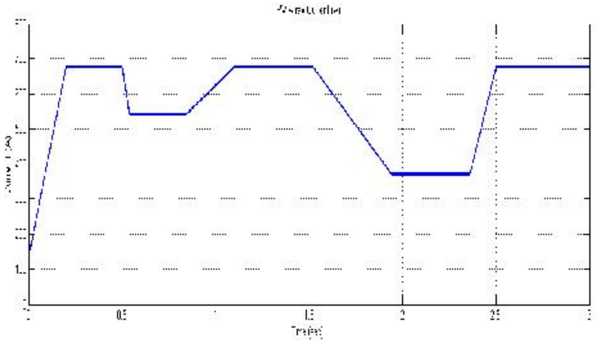


Fig.9. Simulated PV array current during a specified period of time

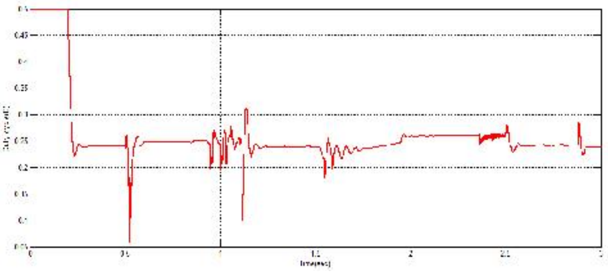


Fig.10. Duty cycle variation

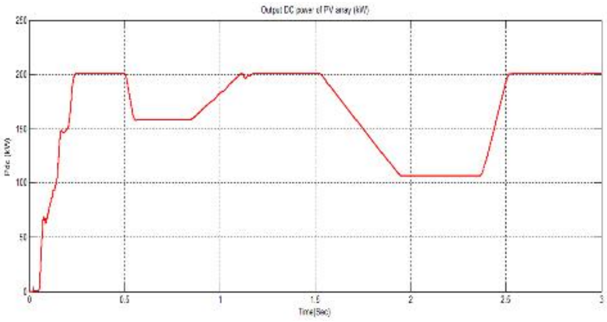


Fig.11. Simulated output power from PV array

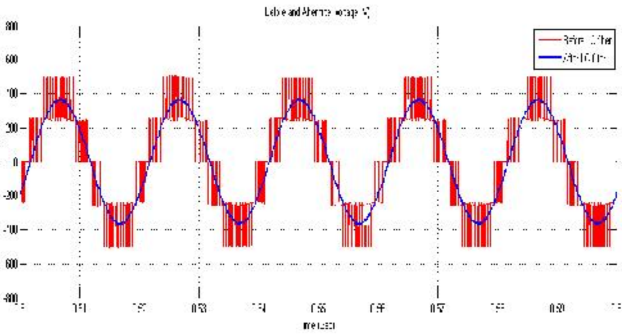


Fig.12. output voltage of 3L-VSI before and after LC filter

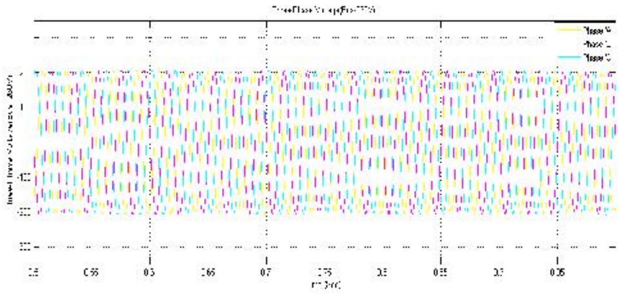


Fig.13 three-phase line voltage waveforms at bus B2

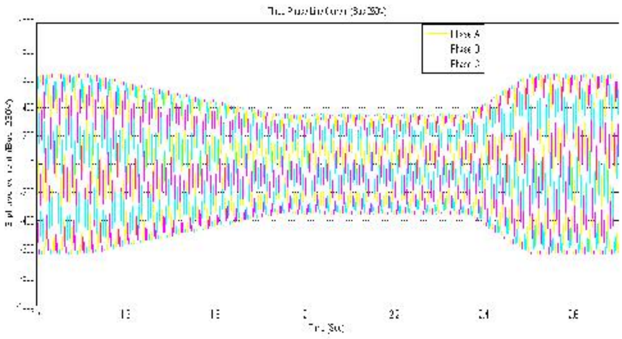


Fig.14. Simulated three-phase-to-ground voltage waveforms at bus B2

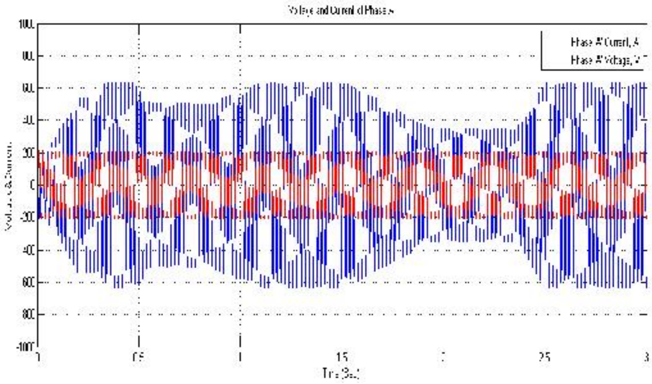


Fig.15.Simulated voltage and current waveforms of phase "A" at bus B2

CONCLUSION

In this Paper,the Grid tied Photovoltaic PV is simulated in MATLAB software package. The model of the system is worked for providing 200KW power to the grid The Inverter is regulated to help you to supply active power to the grid. The performance of PV Solar arrays is dependent upon the amount of solarradiation. In higher solar radiation level, the output of Photovoltaic Array is Optimum.

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