PERFORMANCE AND ANALYSIS OF GRID CONNECTED PHOTOVOLTAIC SYSTEM USING MATLAB/SIMULINK

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Abstract

In this Paper Overview of Grid Connected PV system is discussed. The proposed system model is built on MATLAB/Simulink, including the PV array, connected to DC-DC boost converter, the three-phase three level electronic power inverter that is connected to the utility grid (UG) through low pass filter and coupling transformer and synchronizing control system of PV inverter and UG. A Grid-connected inverter used in the PV system outputs a sinusoidal current to inject an active power to the utility. Simulation of PV system is done for different irradiation. Boost Converter is Dc to Dc Converter and it step up the voltage. For Boost Converter Calculation Inductor L and Capacitor C is designed. If we connect the PV system to the Grid, harmonics are generated. Simulation is done for Grid-Connected PV system.

Keywords: Boost Converter, Grid-Connected, MPPT, PV System, PV Array, Power Quality, Solar Irradiation

1.INTRODUCTION

Photovoltaic systems are comprised of photovoltaic cell, devices that convert light energy directly into electricity. The PV system is connected to the utility grid using high quality inverter which converts DC power from the solar array into AC power that confirms to the grid's electrical requirements. Grid connected PV power systems have been commercialized in numerous countries due to their long term benefits, such as pollution-free, low operating costs and sustainable nature [1]–[6], and are supported by generous feeding tariff schemes [7] and other government incentives to promote green energy [8]. However, due to high investment costs, optimal utilization of the available solar energy ha some challenges. To overcome this problem, a maximum power point tracker (MPPT), can be used in conjunction with a power converter to ensure that the system always harvests the maximum power generated by the PV arrays. However, due to varying environmental conditions, namely temperature and solar irradiation, the P–V characteristic curve exhibits a maximum power point (MPP) that varies nonlinearly and presents a challenge for the tracking algorithm [14].

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage; the output current is lower than the source current [2, 3, 13].

2. PV SYSTEM

The word photovoltaic comes from “photo” meaning light and “voltaic” which refers to producing electricity. Therefore, Photovoltaic process is “producing electricity directly from sunlight. Photovoltaic are often referred to PV. PV systems are used in three main fields: 1) satellite applications, where the solar arrays provide power to satellites, 2) off-grid applications, where solar arrays are used to power remote loads that are not connected to the electric grid, and 3) on-grid, or grid-connected applications, in which solar arrays are used to supply energy to local loads as well as to the electric grid [2, 13].

2.1 Grid Connected PV System

These systems are connected to broader electricity network. In grid-connected PV systems, batteries are not needed since all of the power generated by the PV plant is uploaded to the grid for direct transmission, distribution, and consumption. Hence, the generated PV power reduces the use of other energy sources feeding the grid, such as hydro or fossil fuels, whose savings act as energy storage in the system, providing the same function of power regulation and backup as a battery would deliver in a stand-alone system [1, 2, and 12].

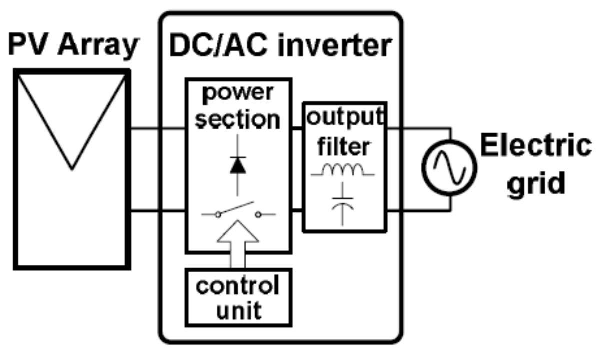


Figure 1. General Structure of Grid Connected PV Systems

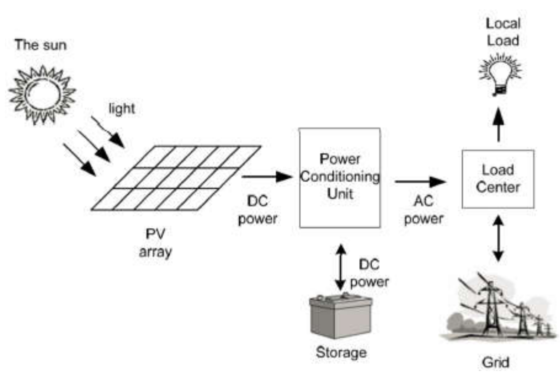


Figure 2. Main components of grid-connected photovoltaic systems

2.2.1 PV arrays

Usually solar cells are connected in series to form a solar module which are then connected in series to form a string. Finally, the strings are connected in parallel to form a PV array (Fig.6). The number of modules in each string is specified according to the required voltage level of the array On the other hand, the number of strings is specified according to the required current rating of the array. Most PV arrays have a power diode, called bypass diode, connected in parallel with each individual module or a number of modules. The function of this diode is to conduct the current when one or more of these modules are damaged or shaded. Another diode, called blocking diode, is usually connected in series with each string to prevent reverse current flow and protect the modules [1,2,3,9].

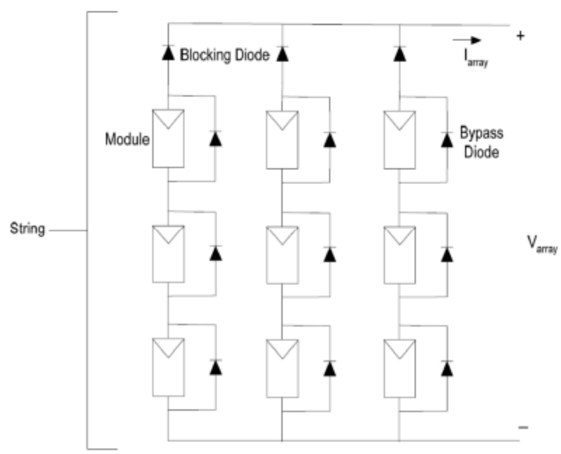


Figure 3. Layout of a PV array

2.2.2 Power Conditioning Units (PCUs)

PCUs are used to control the DC power produced from the PV arrays and to convert this power to high-quality AC power before injecting it into the electric grid. PV systems can be divided, according to the number of power processing stages, into single-stage and two-stage systems. In single-stage systems, an inverter is used to perform all the required control tasks. But, in the two-stage system, a DC-DC converter precedes the inverter and the control tasks are divided among the two converters. Two-stage systems provide higher flexibility in control as compared to single-stage systems, but at the expense of additional cost and reduction in the reliability of the system [2].

(I) MPPT: One of the main tasks of PCUs is to control the output voltage or current of the PV array to generate maximum possible power at a certain irradiance and temperature. There are many techniques that can be used for this purpose where the Perturb and Observe (P&O) and Incremental Conductance (IC) techniques are being the most popular ones.

The MPPT schemes applied are based on the attributes of the PV array current-voltage characteristic. The MPPT process implemented in the control unit of the PV inverter can be performed. Due to high investment costs, optimal utilization of the available solar energy has some challenges. To overcome this problem, a maximum power point tracker (MPPT), can be used in conjunction with a power converter to ensure that the system always harvests the maximum power generated by the PV arrays [3, 7, 10]

(II) Control of the injected current: PCUs should control the sinusoidal current injected into the grid to have the same frequency as the grid and a phase shift with the voltage at the point of connection within the permissible limits. Moreover, the harmonic contents of the current should be within the limits specified in the standards. The research in this field is mainly concerned with applying advanced control techniques to control the quality of injected power and the power factor at the grid interface [2, 4].

(III) Islanding detection and protection: Islanding is defined as a condition in which a portion of the utility system containing both loads and distributed resources remains energized while **isolated** from the rest of the utility system [2].

(IV) Voltage amplification: Usually, the voltage level of PV systems requires boosting to match the grid voltage and to decrease power losses. This task is performed using step-up DC-DC converters or multilevel inverters [3]

(V) Additional functions: The control of PCUs can be designed to perform additional tasks such as power factor correction harmonics filtering, reactive power control and operating with an energy storage device and/or dispatchable energy source such as diesel generator as an uninterruptible power supply [2, 3]

2.3 Simulation Parameters PV System

Table 1. PV Module Parameters

PV Module Parameters	Value
Cells per module	60
Open circuit voltage Voc (V)	37.2
Short-circuit current Isc (A)	9.20
Voltage at maximum power point Vmp (V)	30.3
Current at maximum power point Imp (A)	8.26
Temperature coefficient of Voc (%/deg.C)	-0.35
Temperature coefficient of Isc (%/deg.C)	0.05
Irradiances (W/m2)	1000

Table 2. Boost Converter and Inverter Parameters

Parameters	Value
PV output voltage Vpv	330 V
DC Boost output Voltage Vdc	630 Volt
Input capacitor C	8300 µF
Boost Inductor	139 mH
Output Filter L	55 mH
Grid Phase voltage	415 Volt
Grid Phase Current	15 A

2.4 Calculation of PV System & Boost Converter

Max. Voltage of 1 PV = 30.3 Volt

Series-connected modules per string =10

Parallel-connected modules per string = 2

Therefore, Output voltage of PV V_{out} = No. of modules connected in series*Max. Voltage of 1 PV=10*30.3 V = 303 Volt (1)

From, Table 1

Max. Power of 1 PV = 250.278 W

Therefore PV output power Pout=
No. of total modules*Max. Power of 1 PV20 *250.278 = 5 KW (2)
Load Current Io = P_{out}/V_{out}=16 A (3)

Calculation of Boost Converter:

$V_{dc} = (2*\sqrt{2}\ V_{LL})/\sqrt{3}$
= 653.19 Volt (4)

Where, VLL = Line to Line Voltage
Output of PV = 303 Volt that will be become input of Boost Converter
For Boost Converter
V_{IN}= 303 Volt, V_{OUT}= 653.19 Volt

$$D = 1-(V_{in} * \eta)/V_{OUT} \quad (5)$$

Where, $VIN_{(min)}$ = minimum input voltage
V_{OUT} = desired output voltage
η = efficiency of the converter, e.g. estimated 80%
$V_o/V_{IN} = 1/(1-D)$
Therefore, D = 0.536 (6)
$V_{IN} * I_{IN} = V_O * I_O$ (7)
Therefore, $I_{IN} = I_O/(1-D)$ = 16.55 A
Load Resistance = V/I = 653.19/7.68 = 85 Ω (8)

Inductor Calculation:

Using below equation we can find value of Inductor

$$L = [V_{IN} * (V_{OUT} - V_{IN}] / [\Delta I_L * fs * V_{OUT}] \quad (9)$$

Where, V_{IN} = typical input voltage
V_{OUT} = desired output voltage
fs = Switching Frequency =5 KHZ
ΔIL= estimated inductor ripple current

$$\Delta IL = [(0.2 to 0.4) \times I_{OUT(\max)} \times V_{OUT}] / V_{IN}$$

=7.13 A (10)

Therefore,
L= 303*(653.19-303)/(7.13*5000*653.19)
=139 mH (11)

Capacitor Calculation:

Using below equation we can find value of Capacitor

$$C_{OUT} = (I_{OUT(max)} \times D)/(fs \times \Delta V_{OUT})$$

Therefore, C= (16.55*0.536)/(5000*13.1) = 8300 µF (12)
Where, C_{OUT} = output capacitance
I_{OUT}(max) = maximum output current
D = duty cycle calculated with Equation 1
Δ V_{OUT} = Output Voltage Ripple
f_S = minimum switching frequency of the converter

3. Simulation Model

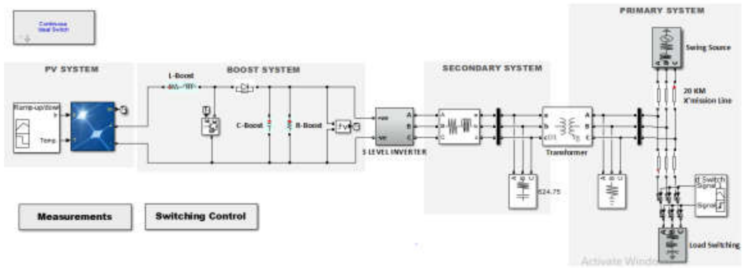


Figure 4. Simulation Model

4. SIMULATION AND EXPERIMENTAL RESULTS

Fig.5 shows Matlab model I-V and P-V curves for various irradiation levels like as 500kw/m^2 and 1000 kw/m^2. Fig. 6 shows output voltage of PV that is 303 Volt.

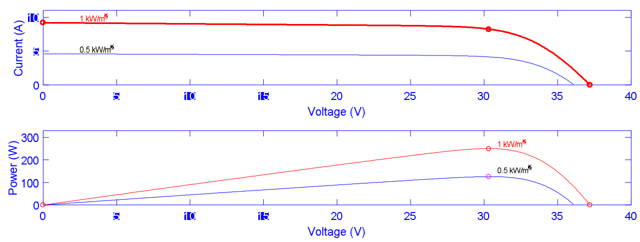


Figure 5. Matlab model I-V and P-V curves for various irradiation levels

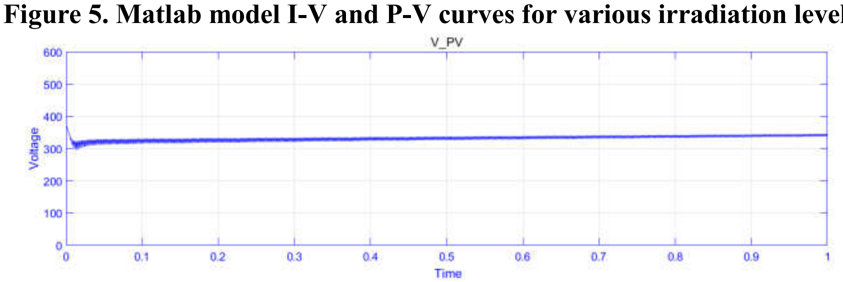


Figure 6. PV Output Voltage

Fig. 7 shows Boost output voltage approximately results found is 630 Volt.

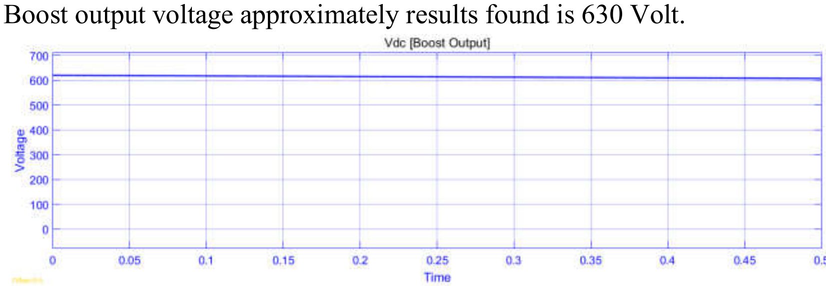


Figure 7. Boost Output Voltage

Fig. 8 shows power of solar and grid system. Solar power is 5 kW and also Grid power is approximately 5 kW as per calculation that is simulated in following figure.

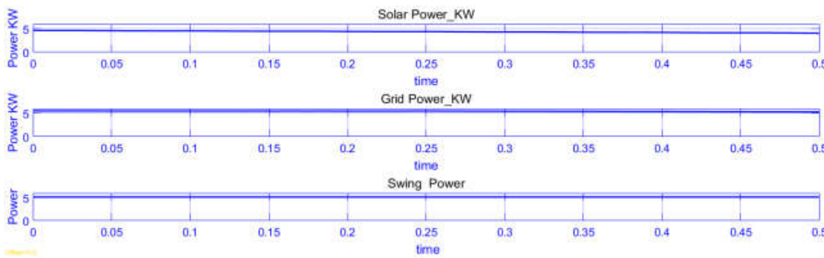


Figure 8. Output Power of Solar and Grid

Fig. 9 shows Primary and Secondary voltage current. Secondary voltage of Inverter is 415 volt and current is appx. 15 A. Fig. 10 shows output voltage and current of Inverter.

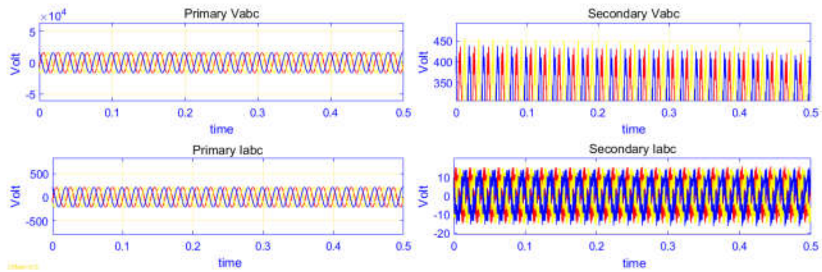
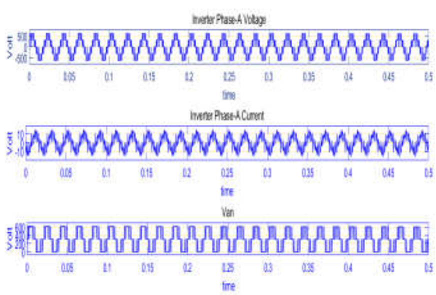


Figure 9. Primary and Secondary Voltage and Current



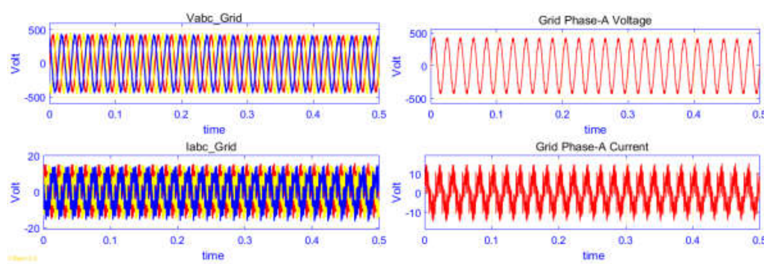


Figure 10. Grid Secondary Output Voltage and Current

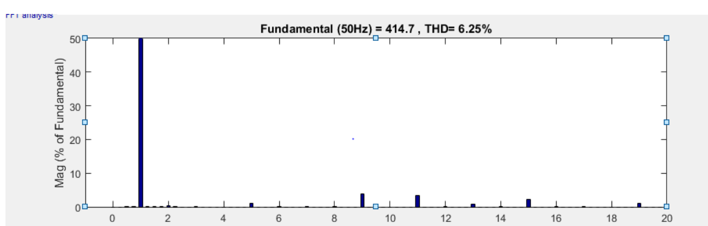


Figure 11. FFT Analysis Secondary Grid System

Conclusion: Grid-connected systems do not need batteries; they are more cost-effective and required 1ess maintenance and reinvestment than stand-alone systems. Simulation is carried out for 5 kW power at different irradiation. From simulation if we connect the pv system to Grid, solar power is generated 5 KW and if changing load parameters there is no change in power it means Grid power is also getting 5 KW as per requirements so we can say that power quality is maintained and THD is reduced to 6. 25 %.

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