Simulation Study & Modeling of Grid Connected Single Phase PV System

Vikash Kala[1], Raj Kiran B[2]

[1, 2]Mewar University, Department of Electrical Engineering, Chittorgarh, Rajasthan, India

Abstract: ***In this paper we are study of simulation of grid connected PV MATLAB software . In this work we present a new method for the modeling and simulation study of a photovoltaic grid connected system and its experimental validation. When the PV system is connected to the grid, it can transfer the extra energy to the grid after fulfilling the local demand. But when the system generates less than what is required to support the local demand, than extra energy is extracted from the grid. Thus PV solar energy acts as an alternative resource of electricity. The PV system, The validation of model is through Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE). Results showed that inverter output power from simulation is acceptable with small deviation from the actual data. This is due to inaccuracies of predicting de-rating factors listed in this work. The simulation results have been performed through Matlab/Simulink environment. Results has shown good agreement with experimental. The significant error indicators are reported in order to show the effectiveness of the simulation model to predict energy generation for such PV system.***

Keywords: Parameter extraction, Modeling Simulation, Photovoltaic, MPPT, Pulse width modulation, Perturbation and Observation, Active and Reactive power, Boost Converter

1. Introduction

A Grid Connect solar PV system is a type of electrical inverter that convert direct current electricity from PV module into alternating current(AC). When the PV system is connected to the grid, it can transfer the extra energy to the grid after fulfilling the local demand. But when the system generates less than what is required to support the local demand, than extra energy is extracted from the grid. Thus PV solar energy acts as an alternative resource of electricity. The PV system, designed in this work, aims to transfer electrical power from PV panels to the grid. First, a dc-dc Converter is used to boost up PV voltage to a level higher than the peak of grid voltage. The converter also tracks the maximum power point of PV module. There are many algorithm for tracking maximum power point . In this system I used perturb and observe method. PV module‘s voltage and power need to sense for tracking maximum power point in this method. Then, a pulse width modulation (PWM) based dc-ac inverter (voltage source inverter) is used for enforcing sinusoidal voltage waveform with matching phase frequency with grid voltage. The output voltage wave shape of PWM inverter is square PWM wave. Therefore, I used an LCL filter for coupling the inverter to the grid. It is one kind of low pass filter that converts PWM square wave to pure sine wave .Finally I incorporated a control mechanism in order to supply the desired amount of real and reactive power to the grid from the PV system. Active power is controlled by varying the angle between grid and inverter voltage. The supply of reactive power is controlled by varying the amplitude of inverter voltage.

2. Model of Photovoltaic Cell

2.1 PV cell

The basic structure of PV cell is given below:

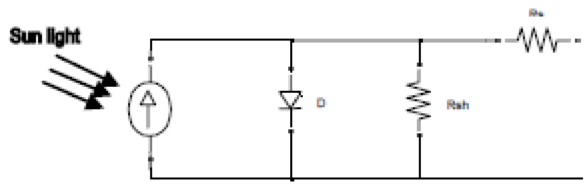

Figure 2.1: Basic model of PV cell

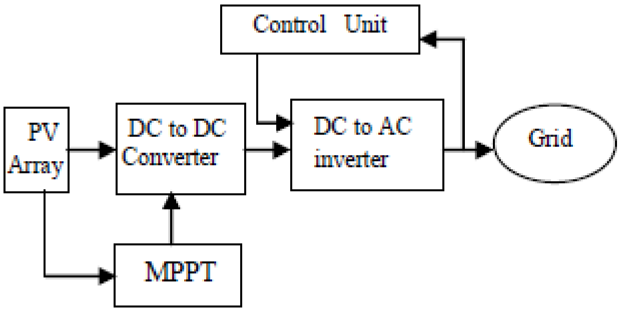

Figure 2.2: Basic structure of Grid connected PV system

Battery model can usually be divided into experimental model, electrochemical model and equivalent circuit model. The equivalent circuit model is most suitable for dynamic simulation. reference [7] presents a generic battery model for dynamic simulation, which assumes that the battery is composed of a controlled-voltage source and a series resistance, shown as figure. This generic battery model considers the state of charge (SOC) as the only state variable.

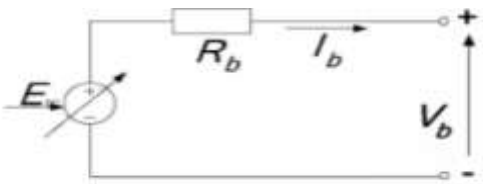

Figure 2.2: A generic battery model

A single-phase full-bridge inverter is modeled in this study. The semiconductor switches used is IGBT as it can handle very large power, which is suitable for this PV system. Fig. 2 shows the schematic diagram of the developed grid inverter model in GCPV system. Using bipolar switching scheme, the full-bridge inverter has two switching states as outlined in Table. The PWM inverter output waveform is then filtered to produce a sinusoidal AC waveform.

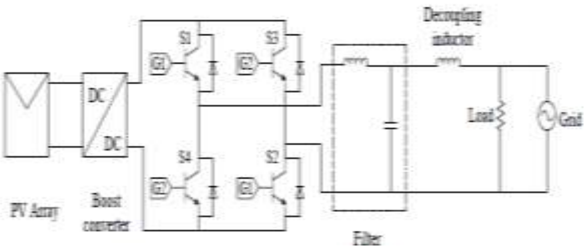

Figure 2.3: Inverter schematic diagram in GCPV system

A PV module has been modeled in MATLAB circuit. Open circuit voltage is 200V and short circuit current is 5A [In practical case, one PV module's rating is not so high. So that PV modules are connected in parallel or series for getting high power]. The PV module is given below:-

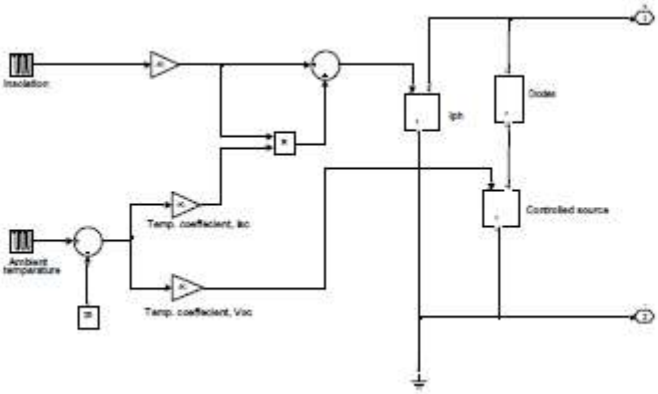

Figure 2.4: Model of PV module in MATLAB

3. DC-DC Boost Converter

In this section I used Boost converter. It is one of the DC to DC converter. Boost converter is used to _stepup' a source voltage to a higher level. The gain from boost converter is directly proportional to the duty cycle (D). The equation is given below:-

$$\frac{Vo}{Vin} = \frac{1}{1-D}$$

When boost converter is in PV applications, the input voltage coming from PV panel is changed with atmospheric conditions. Therefore if the duty cycle vary than we get maximum power point of PV module.

The design law of Boost converter is given below:-

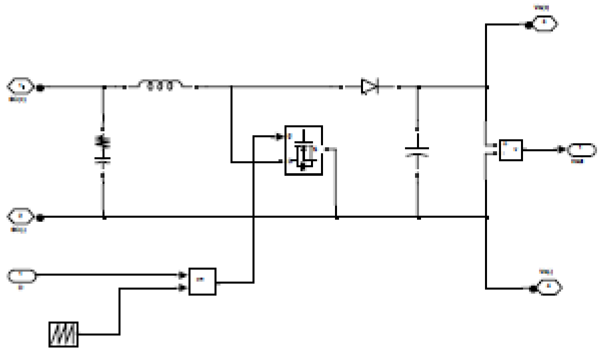

Figure 3.1: Boost converter

A boost converter is a dc to dc voltage converter with an output dc voltage greater than input dc voltage. This is an SMPS containing at least two semiconductor switches (a diode which act as freewheeling diode two ensure a path of the current during the off state of other switch and a transistor connecting in series of the source voltage). Filters made of capacitor and inductor is used to reduce the ripple in voltage and current respectively, is used at the output stage of the converter. The basic operating principle of the converter consists of the two distinct states.

- In on state, switch is closed, resulting in an increase in the inductor current.
- In off state, switch is open, resulting in decrease in the inductor current.

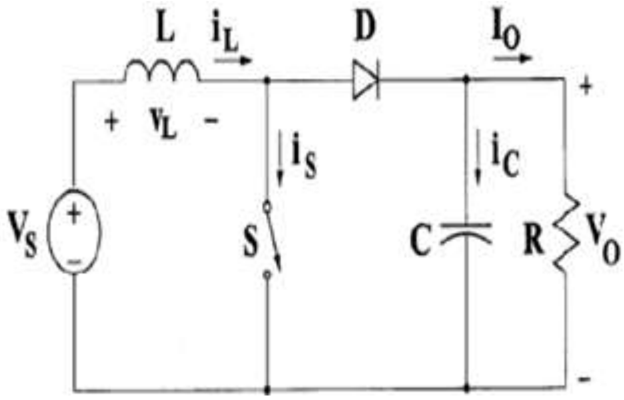

Figure 3.2: Dc-Dc Boost Converter

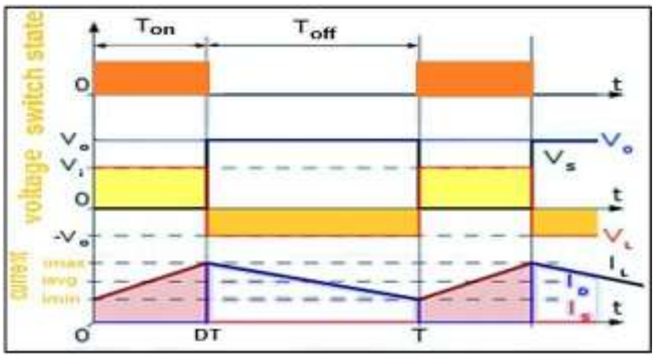

Figure 3.3: Voltage Waveform in Continuous mode

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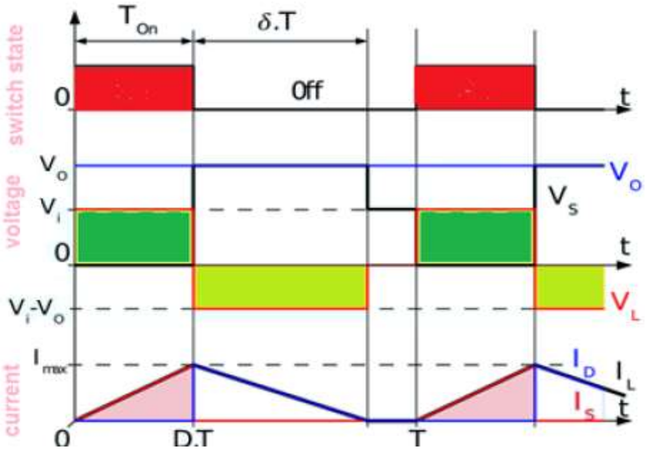

Figure 3.4: Voltage Waveform in Discontinuous mode

4. DC-AC Inverter

Inverters that take DC and produce a constant amplitude sinusoidal output have been studied and designed for many years. Initially, most inverter technology used silicon controlled rectifier (SCR) devices and a transformer coupling to approximate a sine wave via line commutation . As power transistors became More feasible, most low to medium power inverter systems replaced the SCR with the MOSFET or the IGBT. These new transistors lead the way for force commutated inverters that can be classified in terms of their output waveform. A summary of the basic types of line commutated inverters. Significant research and development in the area of pulse width modulation (PWM) has been done in attempt to reduce the passive filter size and create a better sinusoidal output, thus reducing harmonics.

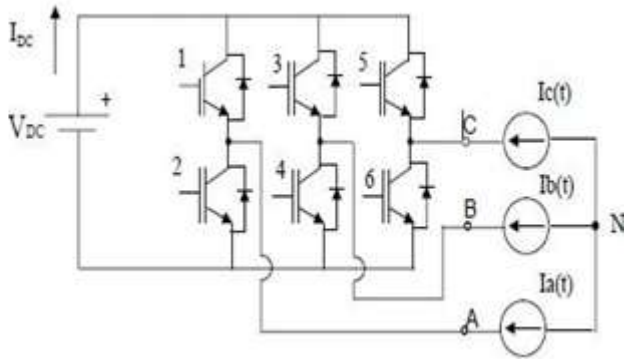

Figure 4.1: Dc-Ac inverter

I used Unipolar based Voltage source PWM(pulse width modulation) dc to ac inverter. So that the shape of the output is Square PWM wave. I used this because if we pass this type of signal in a low pass filter than we get pure sine wave which matches to the grid.

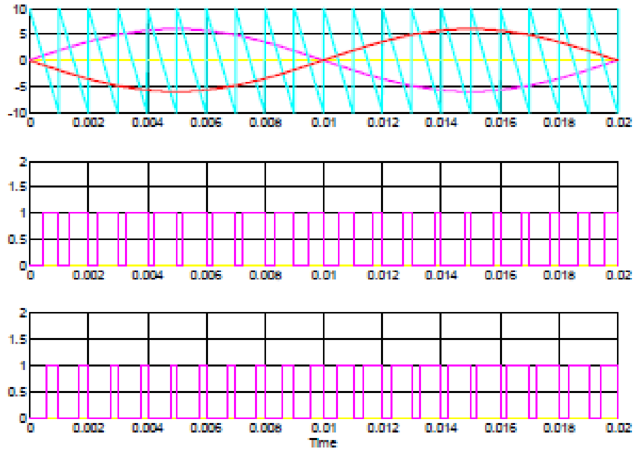

Figure 4.2: Waveforms of the Unipolar PWM

5. Simulation Results of Single Phase Grid Connected PV System

5.1 Current Controller

The current controller mainly used for getting triggering pulse as per the reference value. Here we take the inverter output current and using by MATLAB software converts the current into direct axis and quadrature axis current. This two currents and current given by power controller outputs compared and using PI controller we get the pulse.

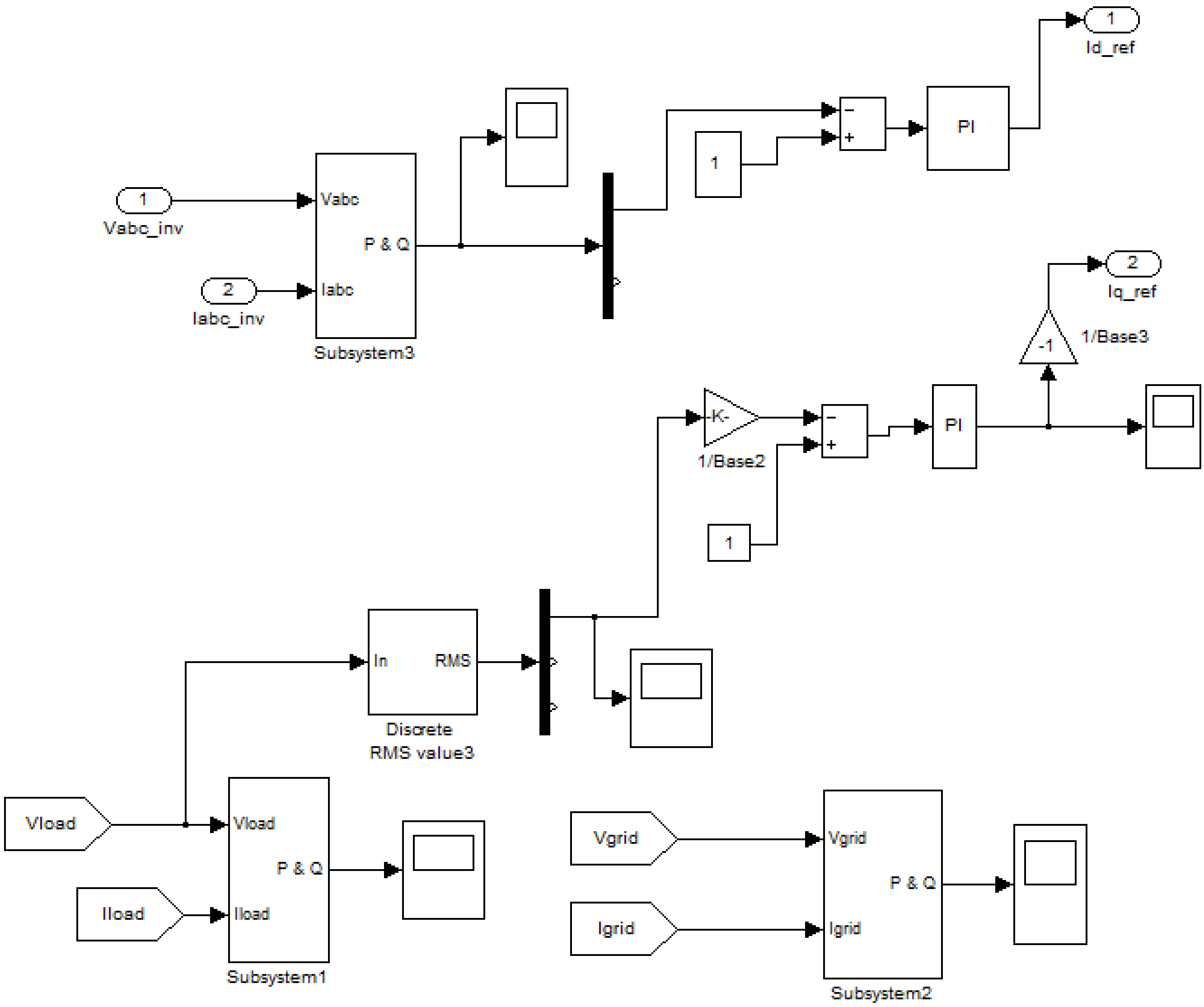

Figure 5.1: Current controller

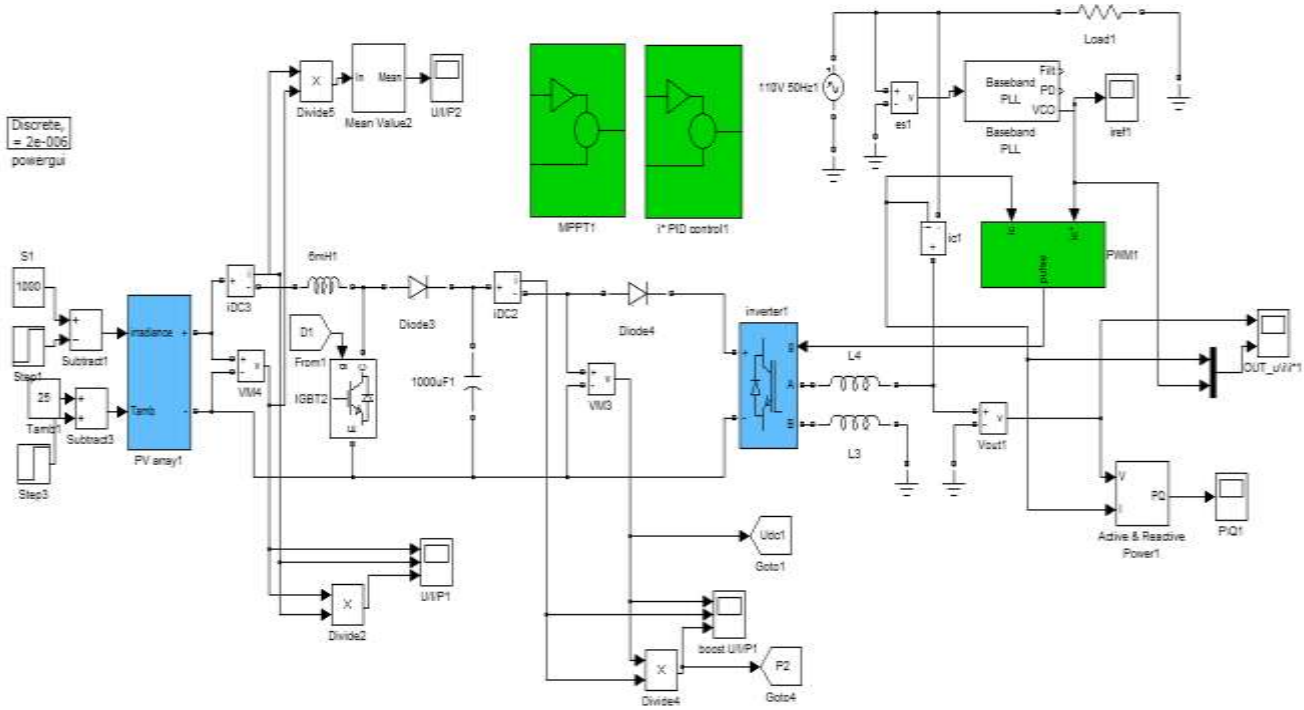

Figure 5.2: Single phase grid connected PV System

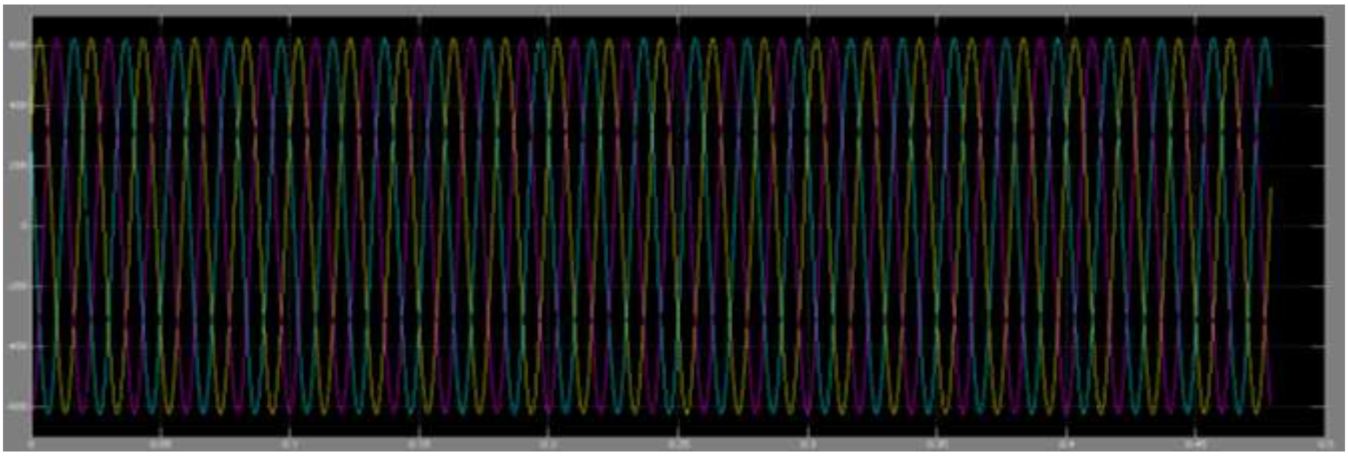

Figure 5.3: Grid voltage waveform

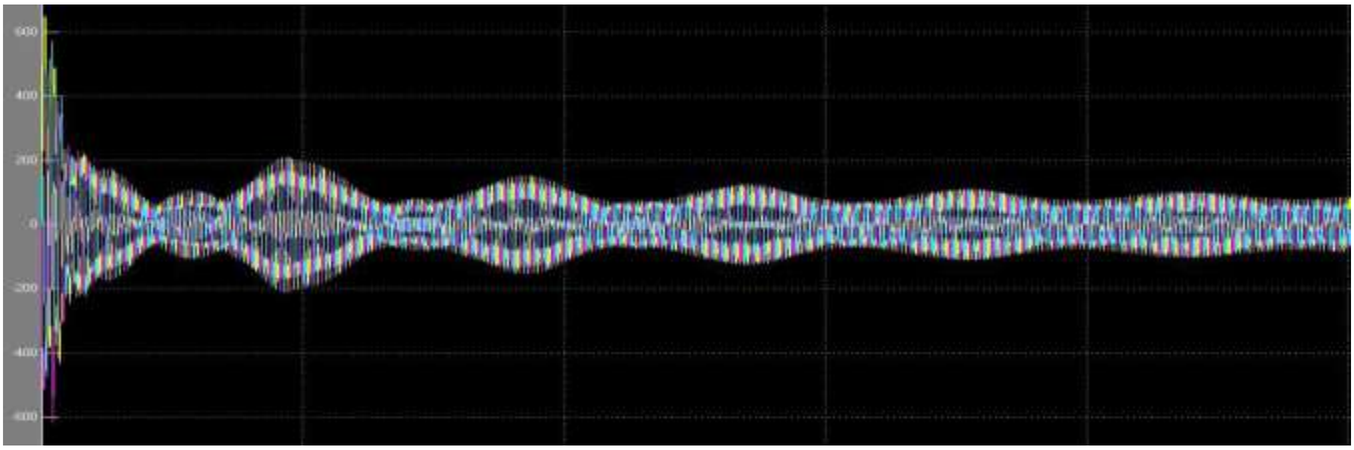

Figure 5.4: Grid current waveform

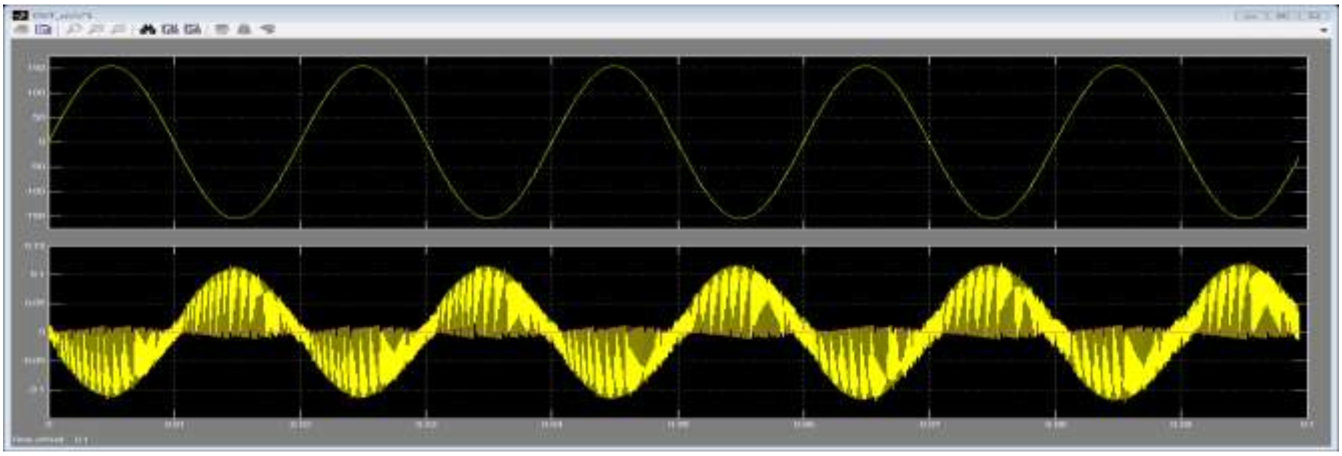

Figure 5.5: Active & Reactive Power waveform

6. Protection Unit

Grid-tie inverters are designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during utility outages. So that, protection unit observe the islanding situation, when the utility supply fails. In case of islanding, the PV generators should be disconnected from mains. PV generators can continue to meet only the local load, if the PV output matches the load. If the grid is reconnected during islanding, transient over currents can flow through the PV system inverters and protective equipment such as circuit breakers may be damaged. Now for anti-islanding protection, grid voltage and frequency should be measured because the voltage or the frequency is changed during the grid failure. Now in the Protection Unit, frequency measurement process is

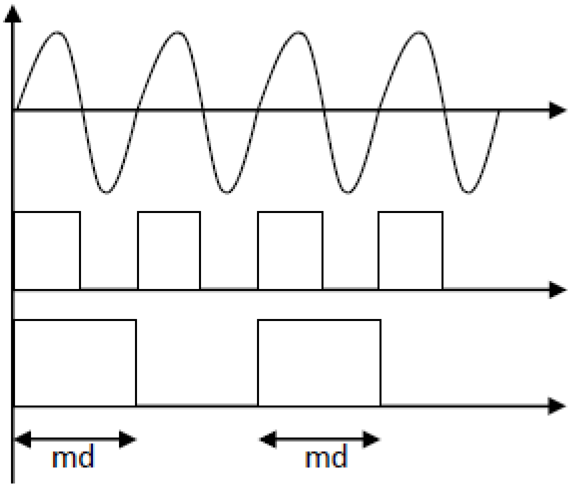

Figure 6.1: Frequency measurement process

Now, to find out the peak value of voltage by MATLAB the procedure diagram is given below :-

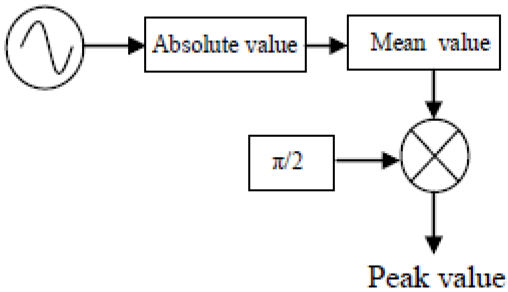

Figure 6.2: Voltage measurement process

7. Conclusion

In this paper we are successfully study of simulation of grid connected PV system using MATLAB software . Three main tasks of the proposed power conditioning system (PCS) are DC link voltage regulation, power flow control and power quality improvement. Correspondingly, PCS is composed of DC/DC converters, DC/AC inverter. The modeling process and stability analysis of each part are presented in this thesis. This dissertation focuses on a practical case developed in MATLAB [simulink] simulation platform has been presented and the results confirm the adequate performance of whole designed control. Control laws are provided active & reactive power control and guarantees the maximum power point of PV module. Besides control laws can be easily implemented by means of microcontroller, operational amplifiers,

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