International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 05 | May - 2023 Impact Factor: 8.176 ISSN: 2582-3930

Design and Simulation of Grid Connected PV Cells using LC filter and MPPT System

Sachin Singh
Research scholar, ME (HVPS) Jabalpur Engineering College, Jabalpur (M.P) 482011, India
Dr. Preeti Jain
Associate Professor, Department of Electrical Engineering, Jabalpur Engineering College, Jabalpur (M.P) 482011, India

Abstract – Grid-connected photovoltaic (PV) system has gained momentum at an exponential rate in recent years. The intermittent nature of the PV system causing mismatches in demand and power generation is one of the major problems. In addition, the quality of the power supplied to the load and the redundant power injected into the grid along with the better dynamic performance are two other major issues of the grid-connected PV system. This paper presents a detailed analysis of a single-phase grid-connected photovoltaic (GCPV) system with a powerful control mechanism and improved power quality. This system uses a DC-DC converter which changes a variable DC voltage to a constant DC voltage. A Voltage Source Inverter (VSI) is used to convert DC voltage to AC voltage. In this paper, the PV array, boost transducer, maximum power point tracking (MPPT) control, bidirectional transducer, three-level NPC inverter, and their associated control system are designed and simulated in MATLAB/Simulink. Simulation results show that the injected current has 0.68% THD, faster system response, and the generated power matches the load demand.

Keywords – PV Cells, MPPT, Grid, MATLAB/Simulink

1 Introduction

As a result of the decrease in non-renewable energy resources in recent years, there is a great need for energy resources that can supply unlimited energy at a low cost. Solar energy resource is one such resource that is available without limits and can be exploited at a relatively lower cost. The energy that is produced from the photovoltaic array is converted by the use of power electronics devices. Various non-linear loads are also connected on the load side which pulls the non-linear current from the supply side. Due to the presence of Power Electronic Transformers (PECs) and non-linear loads such as inductive loads, motor loads and diode rectifier loads, harmonics are produced in the PV system. These harmonics reduce the quality of the real power being pumped into the grid. The harmonics that are created have a serious impact on the solar PV system. Therefore, an efficient filter unit is necessary to filter these

The LCL filter designed in this system improves power quality, increases system stability, and eliminates resonance problems. To address the problem of intermittency and dynamic performance, we use Battery Energy Storage (BES). Similarly, a three-level neutral inverter (NPC) with an LCL filter is used to optimize current and voltage waveforms to ensure a better quality of the injected power.

2 Literature Review

Global energy consumption has increased with rapid industrialization, economic development, and an increase in population. The International Energy Agency estimates that global energy demand will be 17.715 million tons by 2050 which is 21.1% higher than the energy demand of 2017 [1]. Energy giants such as China, the United States, the European Union, India, Russia and Japan still depend on fossil fuels as their primary source of power generation. However, the exploitation of fossil fuels to meet the increasing demand for energy poses a risk of climate change and environmental pollution due to the emission of greenhouse gases. Therefore, renewable energy sources, which are clean, green and sustainable, are getting more attention than in the last few decades. Among the various sources of renewable energy such as photovoltaic, wind, biomass, hydro, biofuels, and geothermal; Photovoltaic generation has gained momentum due to climate policies and the significant drop in solar energy prices during recent years. PV systems are mainly installed in two modes; one is independent and the other is networked. In grid-connected mode, power flows back and forth to and from the grid depending on simultaneous PV generation and load demand [2-3].

The BES system along with the PV grid stores energy during peak sun hours and provides power to the load during peak load and grid outages. A two-way buck converter charges and discharges BES. Inconsistent weather and erratic solar insolation are responsible for the low energy efficiency of the PV array. The MPPT system enables dynamic tuning of the photovoltaic array's output voltage for power optimization [4-6]. The MPPT system controls the output of the boost converter to provide a constant DC link voltage. In this paper, a Sunpower SPR-305-WHT-U PV module is used to generate 7.6 KW power from a 5X5 PV array. The boost transformer is designed to increase the variable photovoltaic voltage to a constant correlation voltage. The MPPT variable step size stepwise conduction method is implemented to track the maximum energy from the PV array. The dc-dc buck-boost bi-directional converter acts as an interface between the dc link and the BES system [7-11]. A three-phase NPC inverter is used with a Class III LCL filter to obtain better waveforms for output current and voltage. The AC grid is designed to be an ideal generator with a frequency of 50Hz and 380V RMS. Either PV systems, battery storage, or grid depending on the state of the system. The proposed architecture of the entire system is designed, controlled and simulated in MATLAB/ SIMULINK software. The simulation results validate and monitor the validity and effectiveness of the design and modeling procedures of the proposed topology [12-15].

Boost Converter and MPPT Boost Converter with MPPT Control are responsible for regulating the photovoltaic output voltage to track the maximum power point to generate the maximum possible power from the photovoltaic system. The circuit configuration of the boost transformer is connected to the PV array. The different structures of the boost converter for the photovoltaic system are discussed. The boost transformer is designed to increase the variable PV output voltage to 700 V. The parameters of the boost converter component were designed based on the equation presented by [16].

3 LC Filter

Due to electronic transducers and non-linear loads connected, the loads pull the non-linear current which generates a lot of harmonics. To suppress these current ripples called harmonics, an effective passive filtering network is required. Compared with other conventional filters such as L and LC filters, the LC filter gives significantly better harmonic attenuation for higher frequency bands by using fewer passive components; Thus, reducing the size of the inductors and capacitors needed. As the size of the LC filter is reduced, the weight and cost of the filter system are also reduced. The LC filter is interconnected between the VSI and the utility grid to reduce harmonics generated by the VSI. The resistor is combined in series with a capacitor to reduce the resonance phenomenon and to ultimately increase the stability of the photovoltaic system [17-18].

4 Maximum Power Point Tracking (MPPT)

Maximum Power Point Tracking (MPPT) is a technique used by charge controllers for wind turbines and solar photovoltaic systems to increase energy production. Photovoltaic solar systems exist in many different configurations. The basic version sends energy from the collector panels directly to the DC inverter and from there directly to the electrical grid. A second version, called a hybrid inverter, can split the power into the inverter, with a percentage of the power going to the grid and the rest going to the battery bank. The third version is not connected to the grid but uses a dedicated PV inverter with MPPT. In this configuration, power flows directly to the battery bank. A variant of these configurations is that instead of just a single inverter, micro transformers are deployed, one for each PV array. All this increases the efficiency of photovoltaic solar energy by up to 20%. There are now new specialized inverters with MPPT that serve three functions: wind connected to the grid, as well as solar PV and power fork to charge the battery [19-20].

The purpose of the MPPT system is to sample the output of photovoltaic cells and apply the appropriate resistance (load) to obtain maximum power for any environmental conditions. MPPT devices are typically integrated into an electrical transducer system that provides voltage or current conversion, filtering, and regulation to drive various loads, including mains, batteries, or motors.

5 Modeling

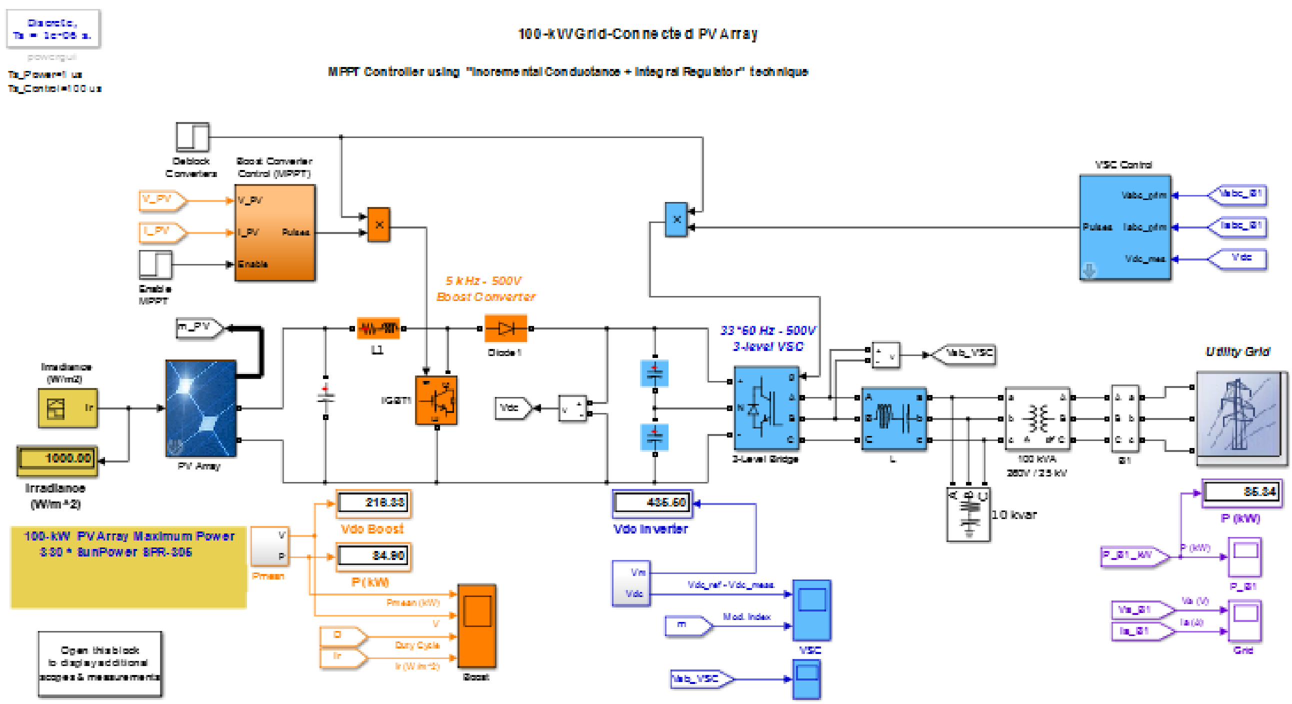

Figure 1 Grid Power Supply and Photovoltaic cells based model

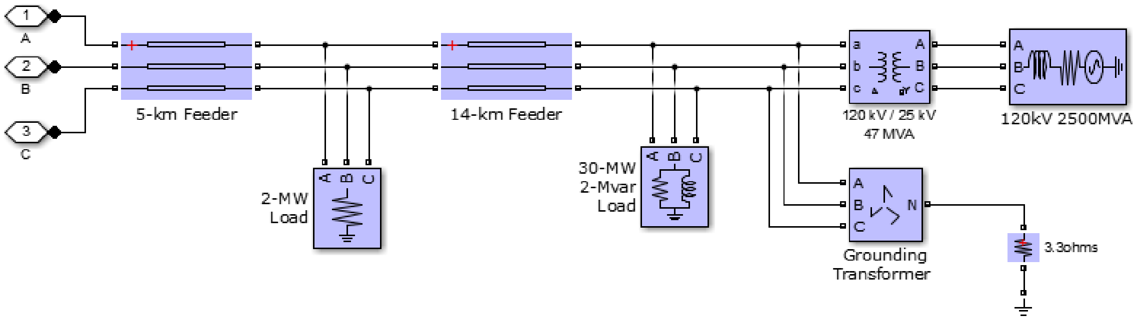

Figure 2 Grid Power Supply

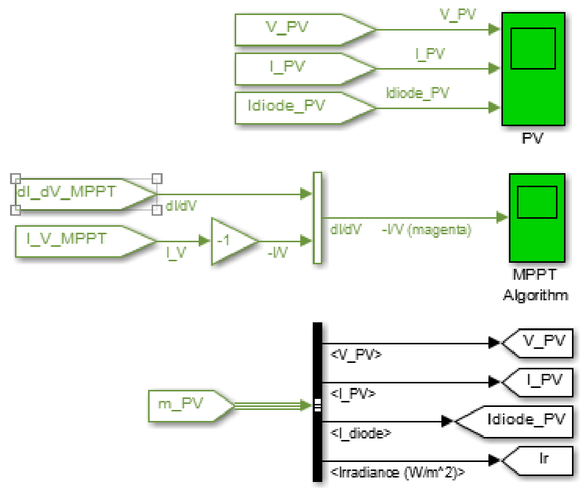

Figure 3 Subsystem of model

6 Results and discussion

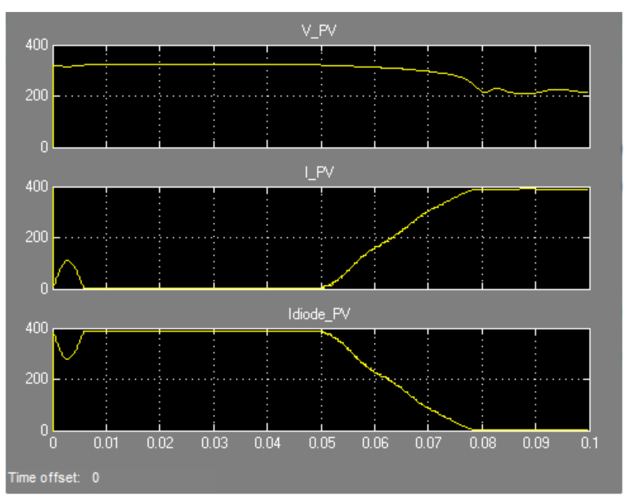

Figure 4 Amplitude of PV Cells

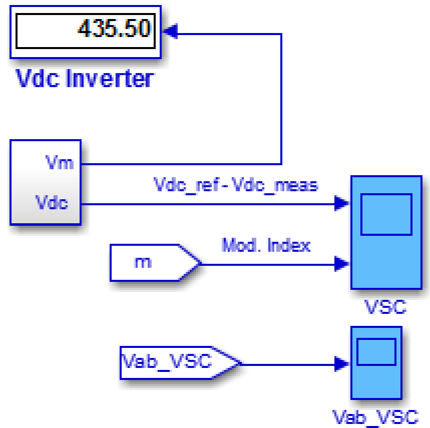

Figure 5 Amplitude of inverter (D.C.)

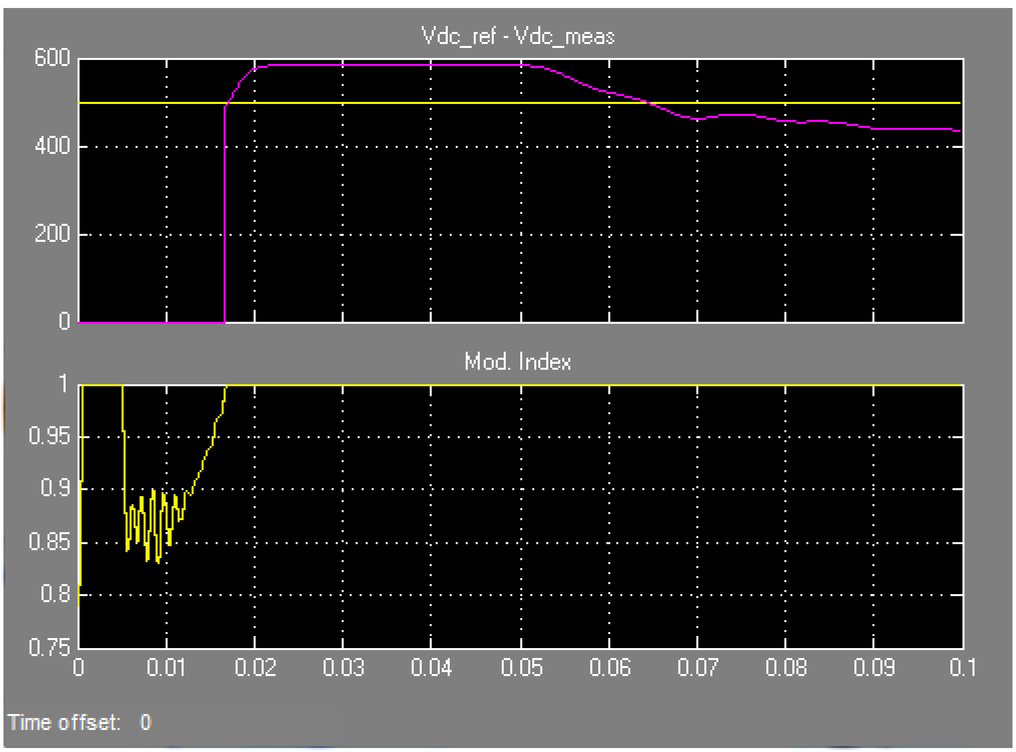

Figure 6 Amplitude of inverter (D.C.) with reference voltages

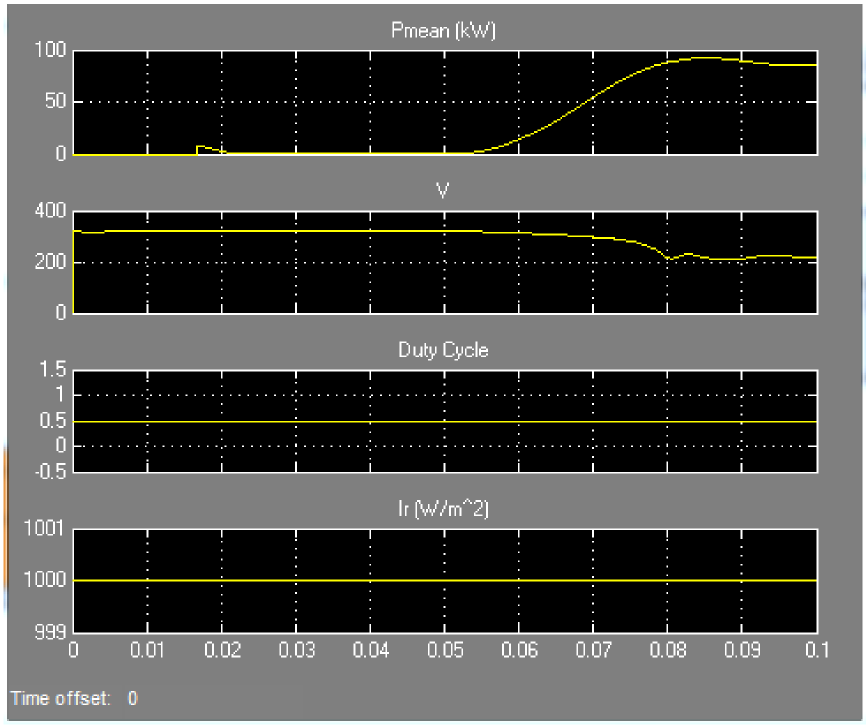

Figure 7 Various amplitudes of Photovoltaic cells and Grid Power Supply system

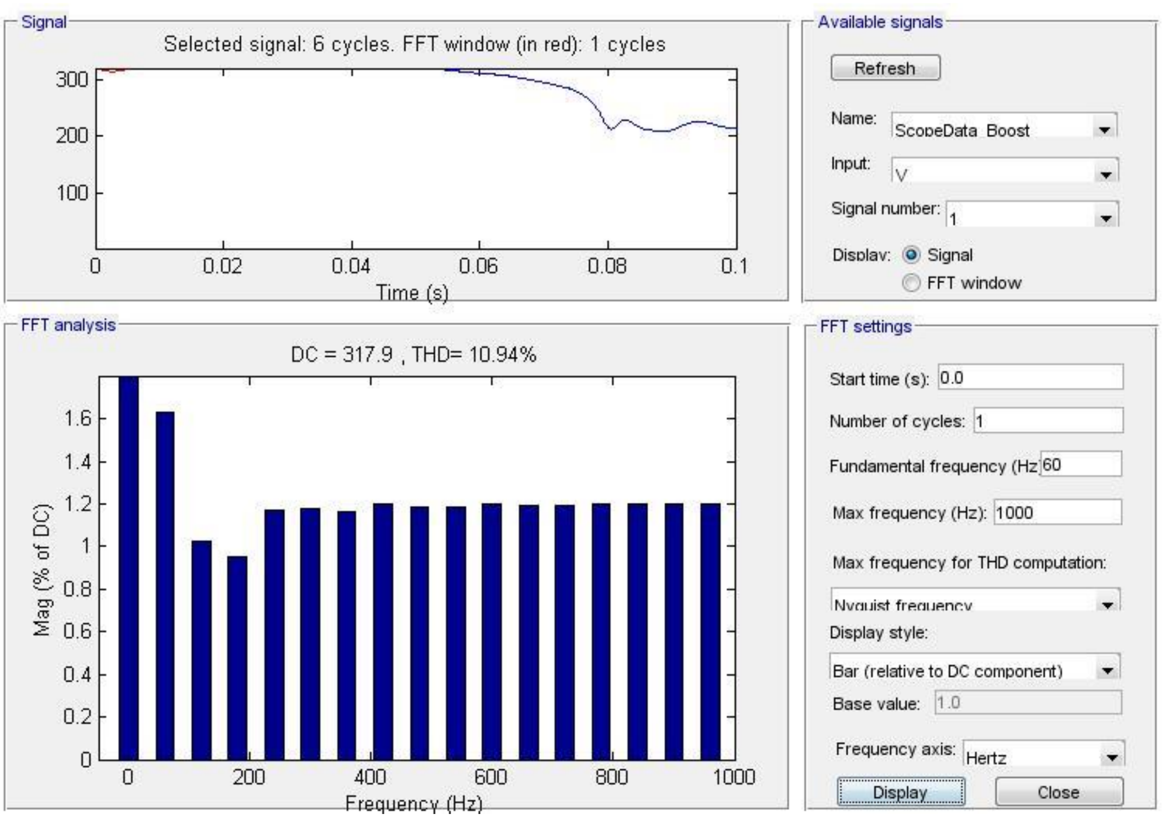

Figure 8 FFT Analysis (Total Harmonic Distortion) of Photovoltaic Cells and Grid Power Supply

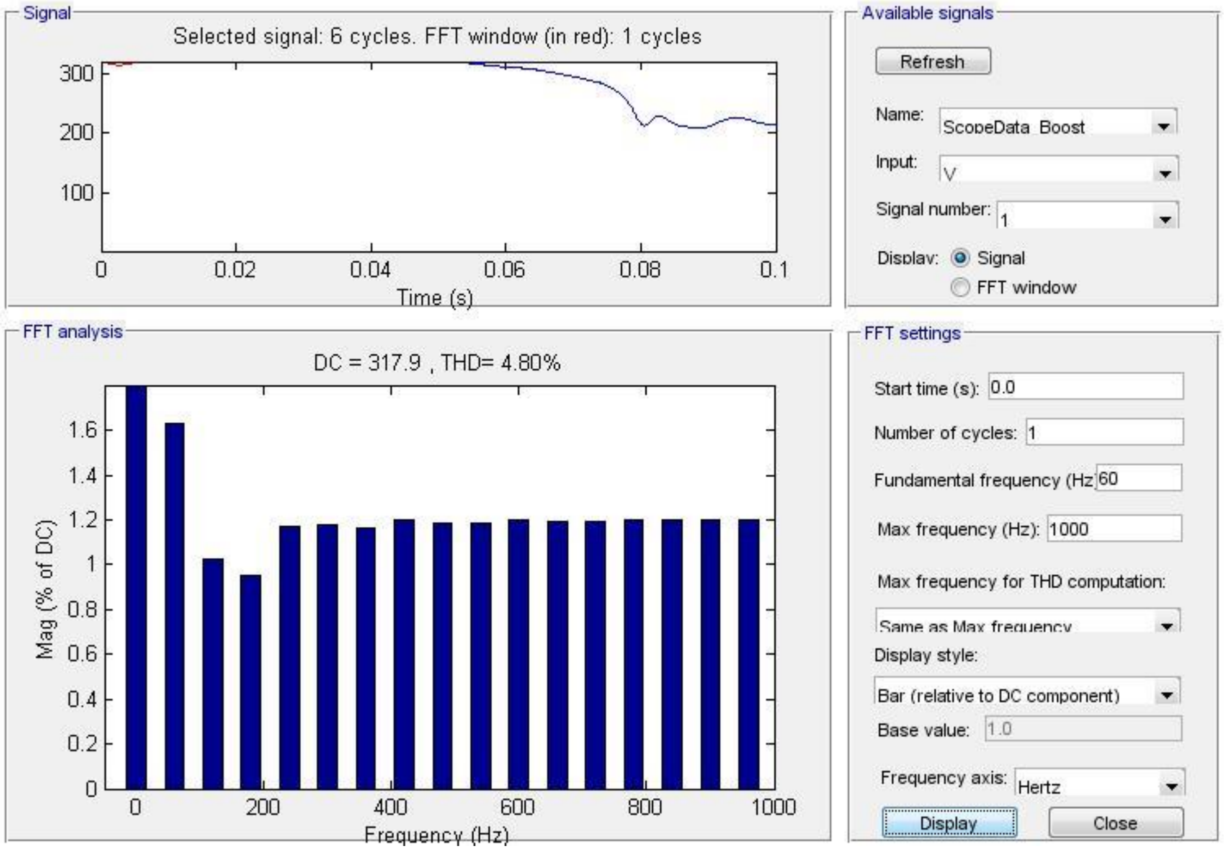

Figure 9 FFT Analysis (Total Harmonic Distortion) of Photovoltaic cells and Grid Power Supply using filter

6 Conclusions

In this paper, an LC-based filter is designed and simulated in a MATLAB/Simulink environment. The variable step IC method used for MPPT tracking proves its accuracy and tracking speed to be highly efficient. The proposed configuration of the LCL filter allows for current to be injected with a very low THD into the network. The grid-connected photovoltaic system enhances the dynamic performance, keeps the DC link voltage stable despite the change in solar radiation, and solves the intermittent problem. The designed LC filter effectively filters out harmonics and improves power quality by nearly tenfold. By using an LC filter, the network output voltage harmonics are reduced from 10.94 to 4.80 percent.

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