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Design and Analysis of Power Quality Enhancement of Grid Connected PV Cells using an MPPT device with LC Filter

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ABSTRACT –

The need for electrical energy is increasing day by day and the surplus electrical energy needed is being supplied from Renewable Energy Sources (RES). The number of grid-connected PV systems is always increasing and this leads to various challenges such as voltage quality, power quality, islands, etc., and these challenges must be increased. The photovoltaic solar system is used as a distributed generator (DG). These DGs help to meet additional electricity demand, improve power quality, reduce distribution losses, etc. The model discussed is built with Simulink block libraries and made in Matlab/Simulink software. The simulation is run and the results are discussed.

Keywords – Solar Cell, MPPT, LC filter, Grid, MATLAB/Simulink

1. Introduction

This article describes developments in power quality monitoring equipment and software tools for analyzing power quality measurement results. Power quality monitoring has evolved from accurate troubleshooting to continuous monitoring of system performance. Increasing the amount of data collected requires more advanced analysis tools. Types of power quality differences are described and characterization methods for each type are presented with measurements. Finally, methods for summarizing and presenting information in useful report formats are described [1-3].

Photovoltaic (PV) solar generation will play an important role in the future structure of electrical energy worldwide. The inverter is an important installation of the photovoltaic system. Ensuring its safety and quality is a necessary link in the development of this technology. The case and prospects for photovoltaic power generation, especially detection and dependence, are presented in this article at the beginning. Second, the detection platform on the grid-connected inverter is designed according to Chinese industry standards, in which the basic structure and working method are analyzed. In addition, the test method, test items and test instruments, including electrical performance, electromagnetic compatibility, protection function and test environment are mainly described [5].

2. Literature Review

With the large number of photovoltaic accesses in the medium and low voltage distribution network, the problem of power quality of the distribution network is becoming more and more important. Therefore, it is necessary to test the power quality of the distribution network by accessing photovoltaic cells and monitoring the power quality periodically. Based on this, this article introduces the current commonly used power quality analyzer and mainly describes the application steps and attention points of the HIOKIPW3198 power quality analyzer [1-2].

In modern electric power systems, dependence on solar energy is increasing. Grid-connected applications are very important with traditional power plants in short supply due to fuel shortages. Designing a control strategy to connect PV systems to the electrical distribution grid is a challenging issue. This article focuses on the design and implementation of controllers in grid-connected photovoltaic systems for power factor correction in power distribution systems [3]. The first step is to model the components of the photovoltaic system, mainly; Photovoltaic source, DC-DC converter and grid interface inverter with a suitable filter. PSCAD is used to simulate this study. Then the proposed controller is designed. The proposed control strategy aims to design a maximum power point tracking algorithm (MPPT) and control the injected active and reactive power. Reactive power control is covered in this article to provide the PV system with power factor correction capability, which improves the overall performance of the PCC. Suggested operational scenarios to test controller feasibility are proposed. The results showed that the model was accepted and that the proposed controller offers the required performance [4- 6].

To harness solar energy, several energy conversion technologies are needed. Photovoltaic (PV) panels, commonly known as solar panels, are devices used to convert sunlight into electricity. The acronym PV stands for the photo (light) and voltage (electricity), photons in sunlight release electrons from atoms on the plates and creates a potential difference. As photovoltaic panels convert sunlight into electricity in the form of direct current (dc), while most electrical appliances for residential applications require alternating current (AC), alternating current (AC) power needs to be converted to direct current [7-10.

Maximum Power Point Tracking (MPPT) is used in photovoltaic systems to maximize the power generated by the photovoltaic panel, regardless of temperature, irradiation conditions and electrical properties of the load. A new MPPT system was developed, consisting of a DC-to-DC converter, which is controlled by a microcontroller-based unit. There are two charging stages for the proposed PV charger. At the beginning of the collection process, a continuous MPPT tariff scheme was adopted [11].

These models provide an estimate of the position of the Sun according to the location studied, determine the solar energy recovered and evaluate the electrical energy generated by the photovoltaic surface. The demand and excessive consumption of energy around the world, worry the environment. Many alternative energy resources are clean, inexhaustible and environmentally friendly, such as solar and wind energy. Therefore, more attention has been devoted to the studies of these renewable energy sources [12]. Among the most used sources, we can mention solar energy. Photovoltaic systems use solar energy to generate electricity to meet the needs of consumers. This article examines harmonic distortion and loss in power distribution systems due to the dramatic increase in non-linear loads. This work attempts to quantify the harmonics caused by non-linear loads in residential, commercial and office loads on distribution feeders and to estimate the power loss due to these harmonics. Norton's Equivalent Modeling Technology was used to model non-linear loads. Norton's equivalent harmonic models for end-user devices are accurately obtained based on experimental data obtained from laboratory measurements. A 20 kV/400V distribution feeder is simulated to analyze the effect of non-linear loads on the harmonic distortion level and feeder losses. The model follows a "bottom-up" approach, starting with Norton's equivalent model for end-user devices and then modeling residential, commercial, and office loads. Two new indicators were introduced [13]

The use of electronic power devices to increase consumption and control power quality is essential. This research work looks at various recently used devices such as remote terminals, digital signal processors, microcontrollers, etc., which monitor power quality issues. These devices monitor different power system parameters and different power quality events using techniques like Wavelet transformation, S transformation, radial neural network, etc. The article also discusses communication technologies such as wireless and wired communication used to transmit data from the electrical system network to the system operator, and control techniques such as dynamic voltage restorer, active shunt filter, etc [14-16].

In this article, a maximum power point tracker battery charger is suggested to extract the maximum power from a PV array to charge the battery. The output power of a photovoltaic system varies continuously with the change in radiation and temperature. It is very important to improve charger efficiency. There are several maximum power point tracking (MPPT) methods available to operate the PV system at the maximum power point. The proposed system used the MPPT Perturb & Observe (P&O) algorithm for design and implementation. When radiation and temperature are constant or slowly changing, the P&O method constantly tracks the MPP and calculates the operating point at which the battery is capable of producing maximum power [17]. This article presents a case study of a power quality audit carried out at S.A College of Engineering, Chennai. The FLUKE 435-ii series is used to analyze power quality behavior. There are many power quality issues such as voltage drop, voltage spike, harmonics, frequency fluctuation, voltage imbalance, bad power factor, etc. Compatibility is one of the main issues.

This issue causes damage to sensitive equipment. In this work, power quality problems are identified from the readings obtained through experiments and suggestions are made [18].

As per the present to maintain the economic growth rate of 8-9%, India needs to generate more and more electricity. Currently, renewable energy (RE) systems and technologies are gaining great importance in the world. There are several types of renewable energy technologies. Renewable energy generates DC or AC power depending on the type and natural behavior. The current scenario leads us to connect more and more renewable energy systems to the grid. The most used renewable energy source is solar energy because it is noise-free and clean due to this reason the photovoltaic system is gaining much more importance in the current situation [19-20]. **2 Photovoltaic modeling**

We can say that the solar cell is a kind of p-n diode that generates charge carriers when the input photon intensity exceeds the bandgap of the semiconductor component. Several photovoltaic cells are connected in series and in parallel to form a photovoltaic module and a photovoltaic array is a series or parallel connection of modules consisting of several photovoltaic cells to achieve the required power. The model is ideal for scientific conditions because it includes series and parallel resistance as well as terminal voltage monitoring. PV is connected to the grid via an inverter, an LC filter and a common coupling (PCC). The inverter converts the DC source into AC and is fed to the LC filter. The main objective of grid-connected PV topology is to give constant power flow parameters for both normal and abnormal conditions. During a network fault condition, PQ issues develop in the grid-connected PV systems. By utilizing the proposed hybrid control technology, the reported problems can be corrected. The proposed hybrid control technology has two cascading loops such as the internal current loop which is responsible for power quality issues and current protection and the external voltage control loop. The proposed control technology is used to generate the inverter control pulses by utilizing network parameters. The LC filter is used as the output filter to limit the higher order harmonics coming from the inverter switching behavior. Hence, ignoring all filter losses, the system on the AC side is explained.

3. Harmonics

In an electrical power system, a harmonic is a voltage or current at a multiple of the fundamental frequency of the system, caused by the action of non-linear loads such as rectifiers, discharge lighting, or saturated magnetic devices. Harmonic frequencies in the power grid are a frequent cause of power quality problems. Harmonics in power systems lead to equipment and conductor overheating, variable speed drive failures, and torque pulsations in motors.

Current Harmonics

In a normal AC power system, the current varies sinusoidally at a certain frequency, usually 50 Hz. When a linear electrical load is connected to the system, it draws a sinusoidal current at the same frequency as the voltage (although it is usually not in phase with the voltage). Current harmonics are due to non-linear loads. When a non-linear load, such as a rectifier, is connected to the system, it draws a current that is not necessarily sinusoidal. Current waveform distortion can be quite complex, depending on the type of load and its interaction with other system components. Regardless of the complexity of the current waveform, Fourier series transformation allows you to decompose the complex waveform into a series of simple quasi-sines, which start at the fundamental frequency of the power system and occur in integer multiples of the frequency.

Other examples of non-linear loads include common office equipment such as computers, printers, fluorescent lighting, battery chargers and also variable-speed drives. In power systems, harmonics are defined as positive integer multiples of the fundamental frequency. Thus, the third harmonic is the third multiple of the fundamental frequency.

Harmonics in power systems are created by non-linear loads. Semiconductor devices like transistors, IGBT, MOSFETs, diodes etc are all non-linear loads. Other examples of non-linear loads include common office equipment such as computers, printers, fluorescent lighting, battery chargers and also variable-speed drives. Normally, electric motors do not contribute much to the generation of harmonics. However, motors and transformers will create harmonics when they are overflowing or saturated.

Nonlinear load currents distort the pure sinusoidal voltage waveform provided by the utility, and this can lead to resonance. Even harmonics generally do not exist in a power system due to the symmetry between the positive and negative halves of the cycle. Also, if the three-phase waveforms are symmetrical, the multiple harmonics of the three are suppressed by the delta (Δ) connection of transformers and motors as shown below.

Voltage harmonics

Voltage harmonics are mainly caused by current harmonics. The voltage supplied by the voltage source will be distorted by current harmonics due to source resistance. If the voltage source resistance is small, current harmonics will cause only small voltage harmonics. Normally, voltage gradients are very small compared to current harmonics. For this reason, the voltage waveform can usually be approximated by the fundamental frequency of the voltage. If this approximation is used, current harmonics will not affect the actual power transferred to the load. An intuitive way to look at this is to plot the voltage waveform at the fundamental frequency and harmonic synthesis of current without phase shift (to observe the following phenomenon more easily). What can be observed is that for each period of voltage, there is an equal area above the horizontal axis and below the harmonic current wave as below the axis and above the current harmonic wave. This means that the average real force contributed by current harmonics is zero. However, if higher voltage harmonics are considered, current harmonics contribute to the actual power transferred to the load.

4. Total harmonic distortion

Total harmonic distortion, or THD, is a common measure of the level of harmonic distortion found in power systems. THD can be related to current harmonics or voltage harmonics and is defined as the ratio of the total harmonics to the value at a fundamental frequency of 100%.

5. Modeling

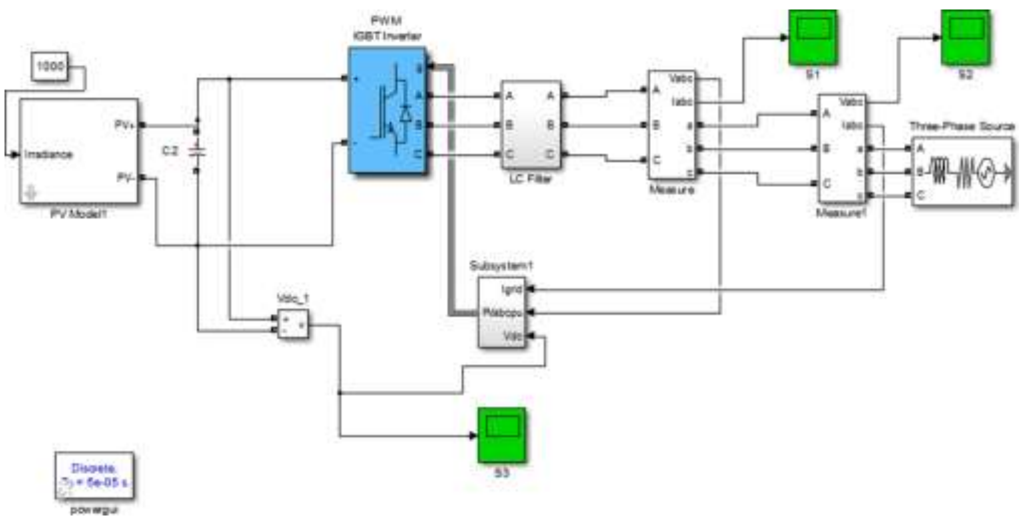

Figure 1 Grid Power Supply and Photovoltaic cells based model

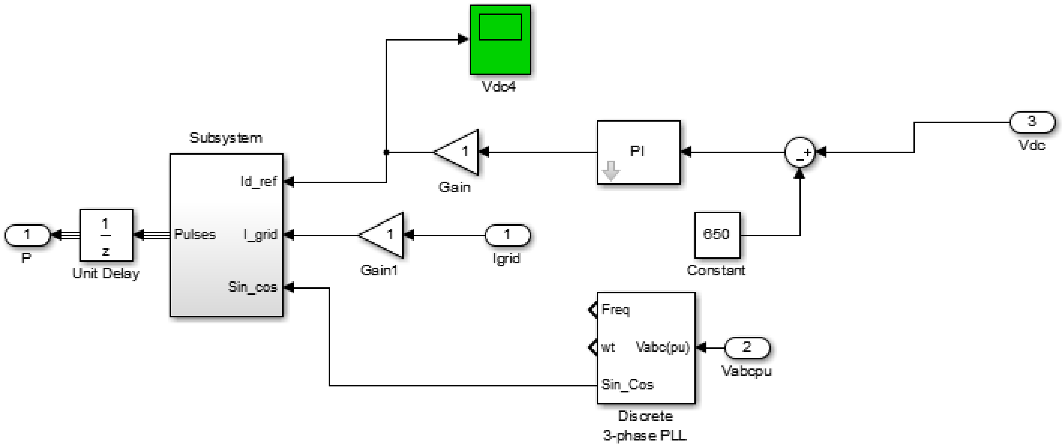

Figure 2 Subsystem of model

6. Results and discussion

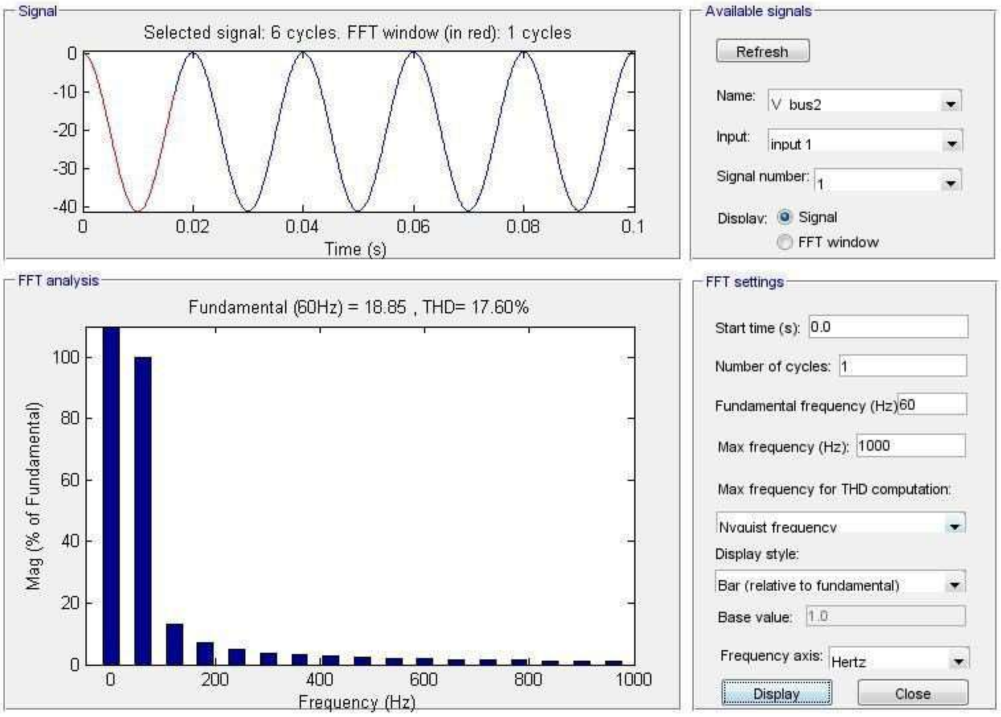

Figure 3 FFT Analysis (Total Harmonic Distortion) of Photovoltaic cells

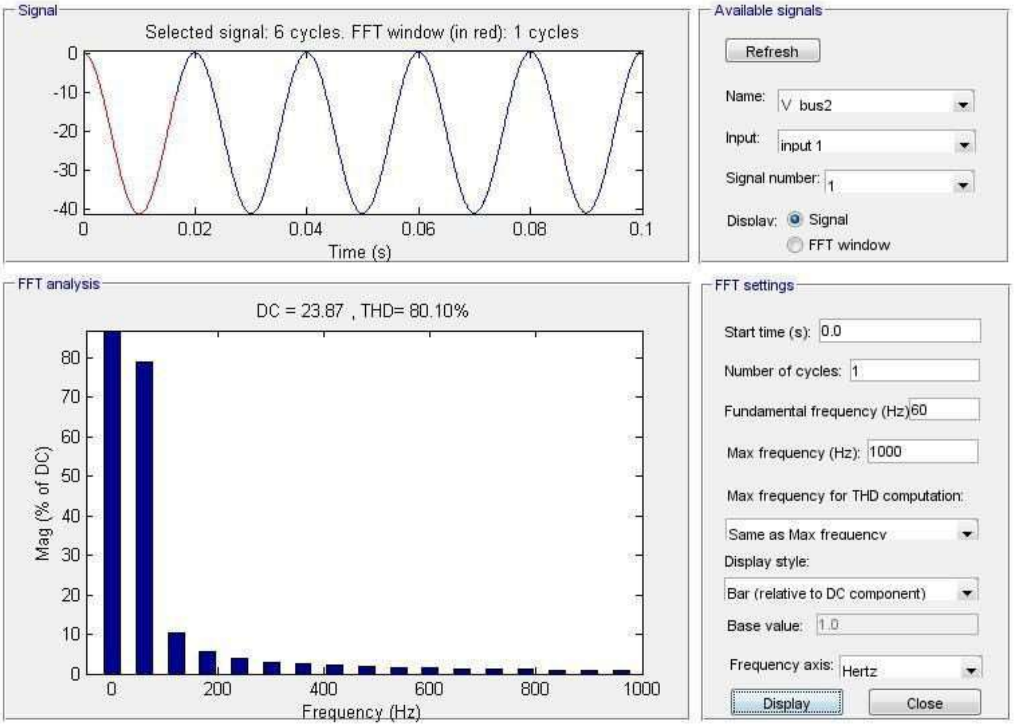

Figure 4 FFT Analysis (Total Harmonic Distortion) of Photovoltaic cells with DC components

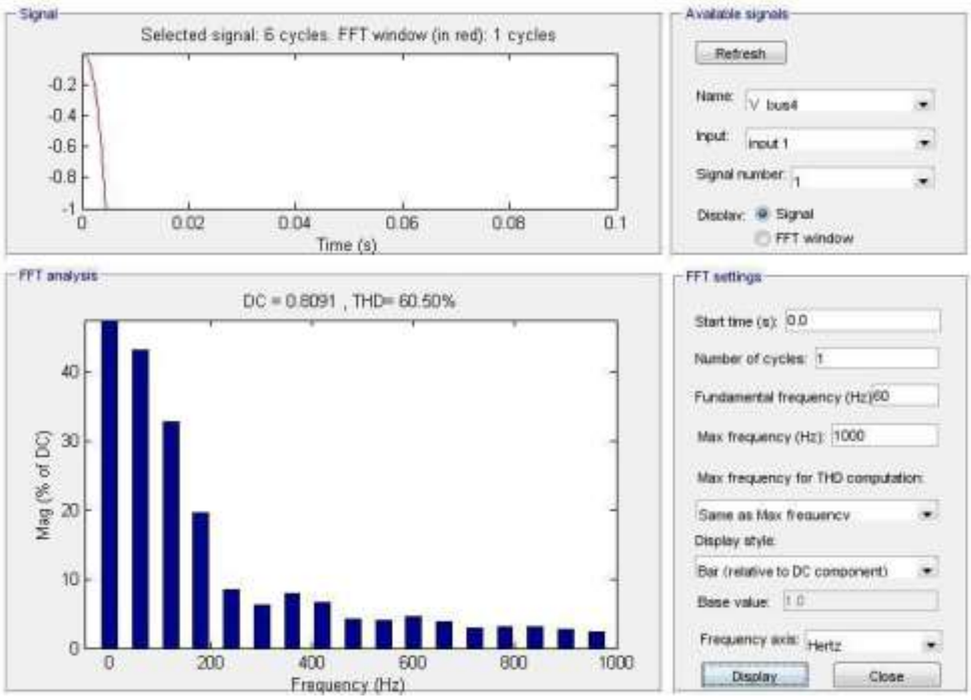

Figure 5 FFT Analysis (Total Harmonic Distortion) of Photovoltaic cells with DC components and PWM IGBT Inverter

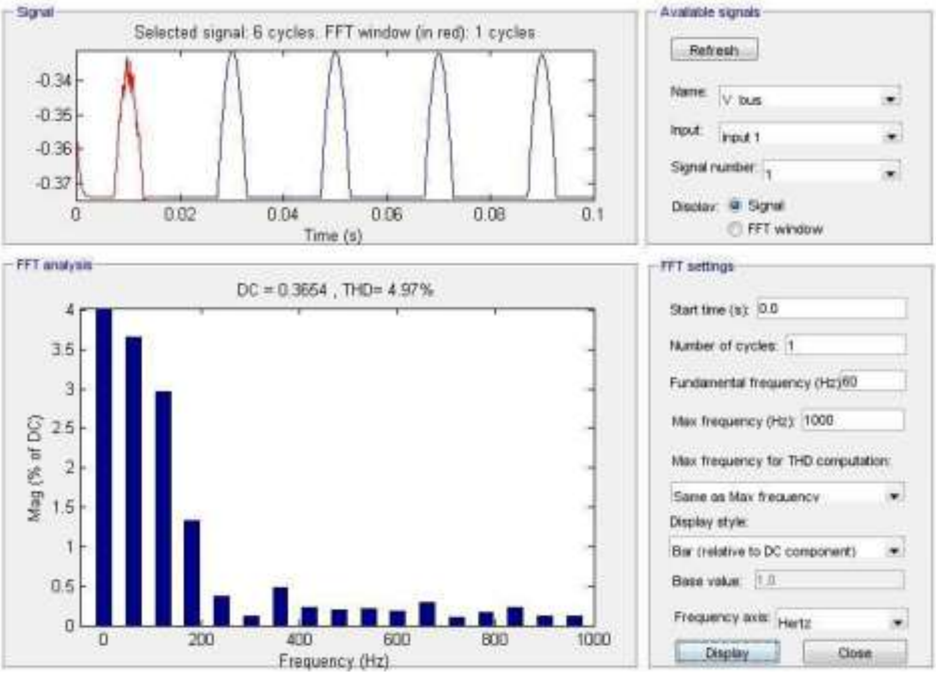

Figure 6 FFT Analysis (Total Harmonic Distortion) of Photovoltaic cells with DC components, PWM IGBT Inverter and filter system

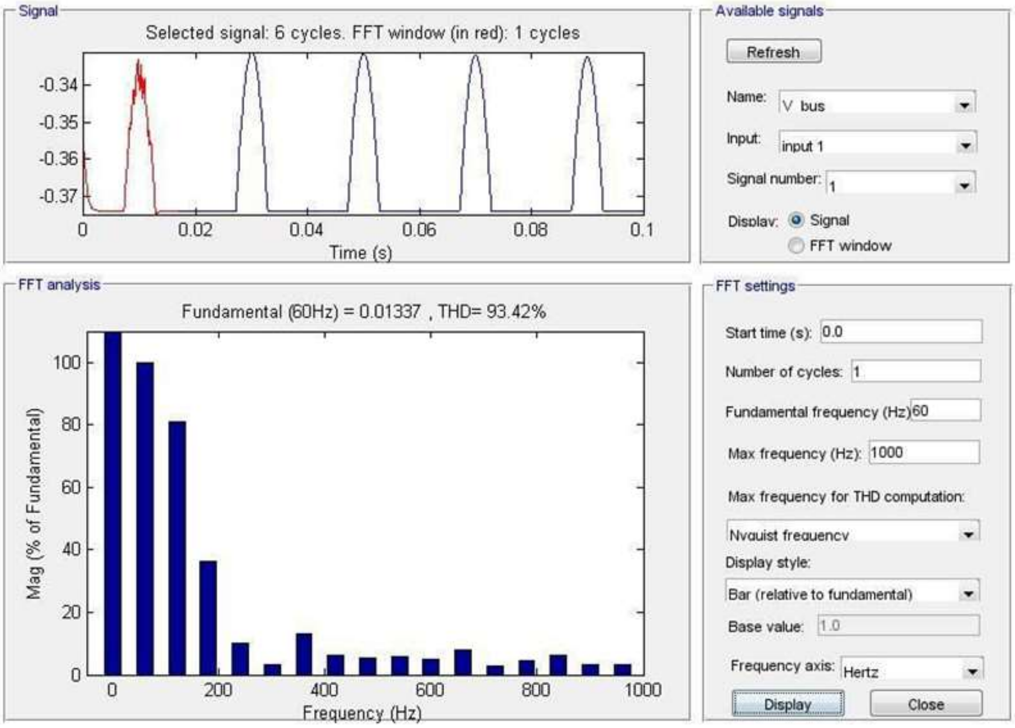

Figure 7 FFT Analysis (Total Harmonic Distortion) of Grid Power Supply

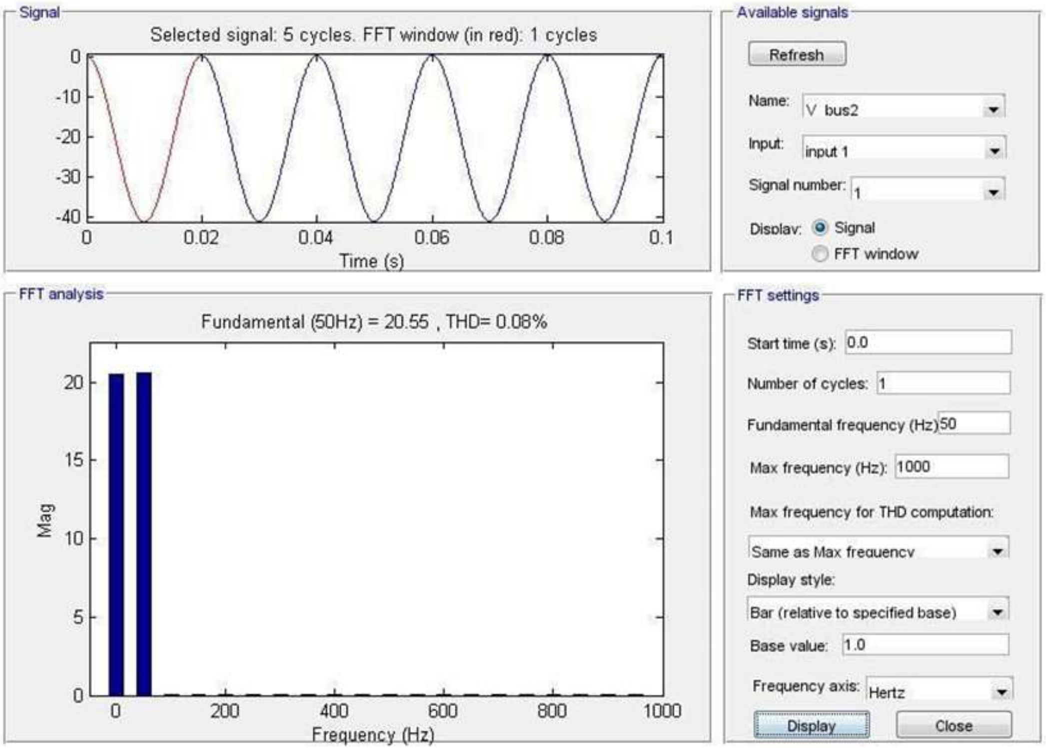

Figure 8 FFT Analysis (Total Harmonic Distortion) of Photovoltaic cells and Grid Power Supply using filter

7. Conclusions

In this article, the photovoltaic system is modeled, all its elements are modeled, and the simulation of the autonomous photovoltaic system and the photovoltaic system connected to the grid is performed. Input parameters are solar insolation of 1000 W/m^2 and operating temperature of 25°C. Current-voltage at this radiation intensity and ambient temperature are plotted for both operating modes. The P&O method of maximum power point tracking strategies is used in this work and is simulated. The boost DC/DC converter, inverter, is part of the photovoltaic system. Figure 3 shows the FFT Analysis (Total Harmonic Distortion) of 17.60% of the photovoltaic cells. Figure 4 shows the FFT Analysis (Total Harmonic Distortion) is 80.10% of the photovoltaic cells with DC components. Figure 5 shows the FFT Analysis (Total Harmonic Distortion) is 60.50% of photovoltaic cells with DC components and PWM IGBT Inverter. Figure 6 shown FFT Analysis (Total Harmonic Distortion) is 4.97% photovoltaic cells with DC components, PWM IGBT Inverter and filter system. The Total Harmonic Distortion (91.84%) was obtained from the Grid Power Supply shown in Figure 7. The Total Harmonic Distortion (0.08%) was also obtained from the photovoltaic cells and Grid Power Supply using the filter shown in Figure 8.

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