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Modelling and Simulation of Boost Converter for DC Nano-grid Integrated with Solar PV Generation for harmonic distortion analysis

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Abstract-

This paper deals with boost converter based DC Nano-grid system in which the analysis of harmonic distortion in AC load is analyzed. A battery is also interfaced with the grid such that in absence of source, the battery will be used to supply the load. This system can supply DC and AC load simultaneously which makes it suitable for DC Nano-grid system. The wide use of DC characterized loads and more distributed power generation sources (DERs), the DC Nano grid becomes more and more popular and seen as an alternative to the AC grid system in future. Therefore for connection or island mode which connects local distributed energy sources and local distributed system.safety considerations, DC Nano grid provides reliable grounding for residential loads like low voltage AC power system. The proposed paper is based on the FFT analysis of output waveforms for analysis of Total Harmonic Distortion.

Keywords- DC Nano grid, Boost converters, DER (Distributed Energy Sources), Battery, FFT Analysis, Total Harmonic Distortion.

Abbreviation- FFT Fast Fourier Transform

Introduction

The development of renewable energy has been anincreasingly critical topic in the 21st century because of the growth in global warming and other environmental issues. Today most ofthe equipment's are working on DC voltage supply. Normally, the supply coming from power station to the homes, offices, industries etc. in form of AC supply. So it is needed to convert AC supply into DC supply to make useful for the equipment's which works on DC supply. Nowadays, energy generate in form of clean, efficient, and environmentally friendly sources has become one of the major challenges for engineers and scientists[1]. Out of all the available renewable energy resources, solar source attract more attention because they provide awesome opportunity to generate electricity and free source [1] [2]. However, despite all the aforementioned advantages of solarpower system, they do not present desirable efficient [3]. The efficiency of solar cells depends on many factors such as temperature, insolation, spectral characteristics of sunlight, dirt, shadow, and so on.The distributed power generation is becoming more and more attractive due to long term lack of energy and environmental problems caused by burning the fossil energy[4]. Large number of DERs are connected to AC power system through different kinds of power converters, which may cause problems like current distortion, voltage fluctuation and also issues related to protection[5][6][7]. Nowadays, the major challenge for engineers and scientists is to generate energy in form of clean, efficient and environmental friendly sources. Renewable energy is a preferred solution to fossil fuels and their deployment in off-grid systems is growing steadily in both developed and developing countries[8]-[13]. DC Nano-grids employing hybrid energy

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systems are increasingly considered as a viable option to electrify remote and sparsely populated areas[14]-[16]. They can provide reliable electricity supply with improved power quality to households and small-scale commercial users, thereby boosting commercial activities in the rural areas[17][18][19]. In this paper, the boost converter is used for DC Nano-grid integrated with solar PV array. The solar PV system generates solar power and is converted to step up level of the generated voltage through boost converter and is fed to DC bus. The bus directly feeds DC load while an full-wave bridge inverter is used to convert DC to AC for feeding AC loads. In this , the FFT analysis of the output voltage and current in AC load side is performed.

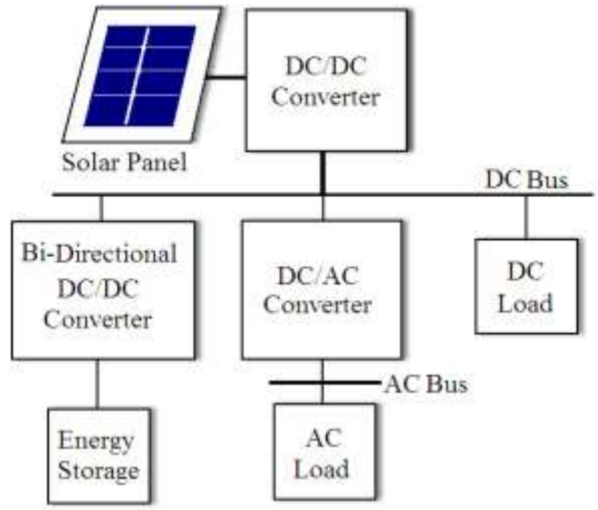

Figure 1: Basic Structure of DC Nano-grid System

Nano-grid

Nanogrid is meant for supplying domestic load of the order of few hundred watts to 5 kW generated from renewable sources like roof-top solar photovoltaic, fuel cell, wind farm, etc. The generators are primarily based on clean forms of energy such as fuel cells, solar arrays and wind turbines. A Nanogrid consists of power electronic converters which interface the generators and the loads to the nanogrid. These converters also link the nanogrid to the power system grid. Each nanogrid should be efficient, reliable, self-sufficient and fault tolerant. The nanogrid distribution system can be based on AC or DC depending on design. DC nanogrid possesses the following advantages over AC nanogrid.

• DC based distribution provides higher system efficiency than AC based distribution as losses due to skin effect, no-load equipment losses are absent.

• Unlike AC distribution systems, frequency stability is not a concern for DC distribution systems.

• DC distribution systems do not have any reactive power issues

Figure. 1 shows the schematic diagram of a DC Nano-grid. The DC Nano-grid constitutes of solar PV panels as energy source, power electronic converters, storage elements and local AC and DC loads. The power demanded by the local loads is met by the solar panels, with the storage elements maintaining power balance in the system. From Figure. 1 it can be seen that the sources, energy storing elements and different loads are connected to the DC bus through different power electronic converters. These converters regulate the DC bus and AC bus voltages at their rated values as well as transfers power from the storage elements to the load or from the source to the storage elements as required.

BOOST CONVERTER

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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). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converterwith 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. Since power (P=VI) must be conserved, the output current is lower than the source current. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure. 2.

- When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.
- When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed andthe right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

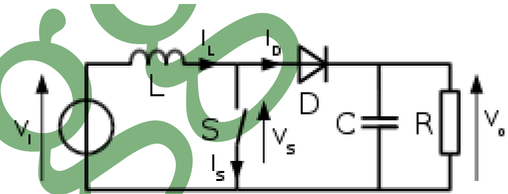

Figure 2: Boost Converter schematic diagram

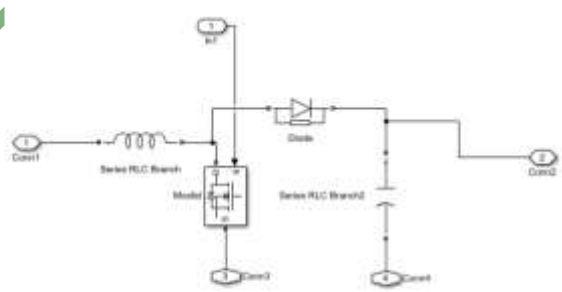

Figure 3: Simulink diagram of Boost Converter

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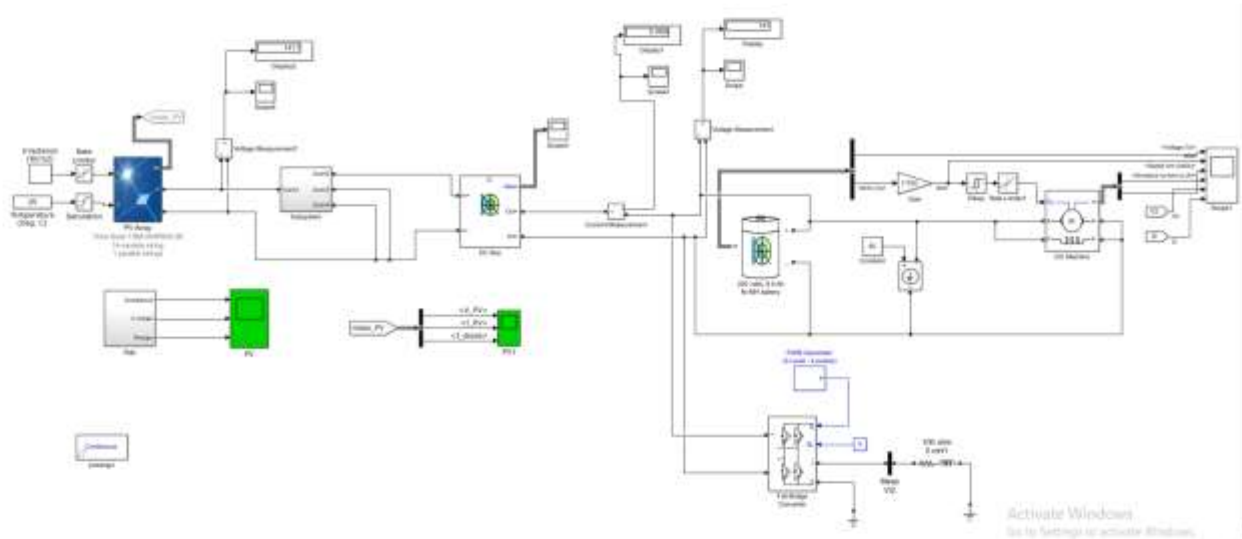

Figure 4: Simulink diagram of DC Nano-grid system using Boost Converter

SIMULATION AND RESULT

The DC Nano-grid integrated with solar PV array gives output of 140V DC and is fed to DC bus which feeds the load according to load demand and the nature of the load i.e. whether the load is DC or AC. For AC load a full bridge inverter is used as shown in Figure 6. The inverter converts the DC voltage to AC voltage and feed the AC load. In this RL load is taken into consideration.

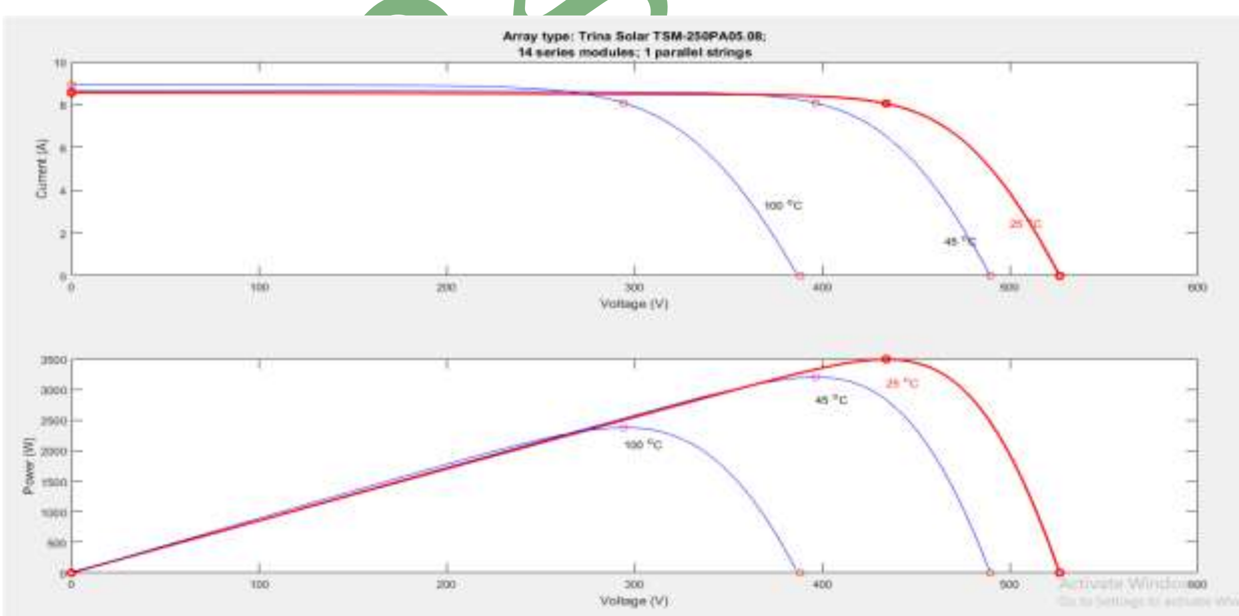

Figure 5: Plot for Solar PV Array

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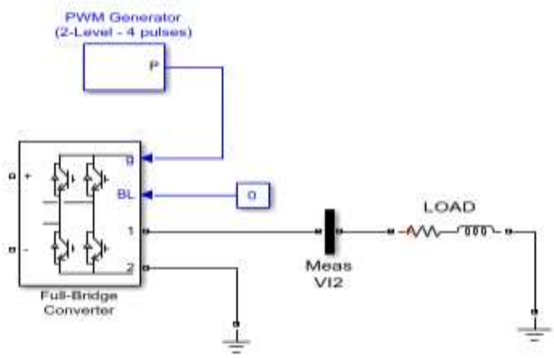

Figure 6: Full Bridge Inverter

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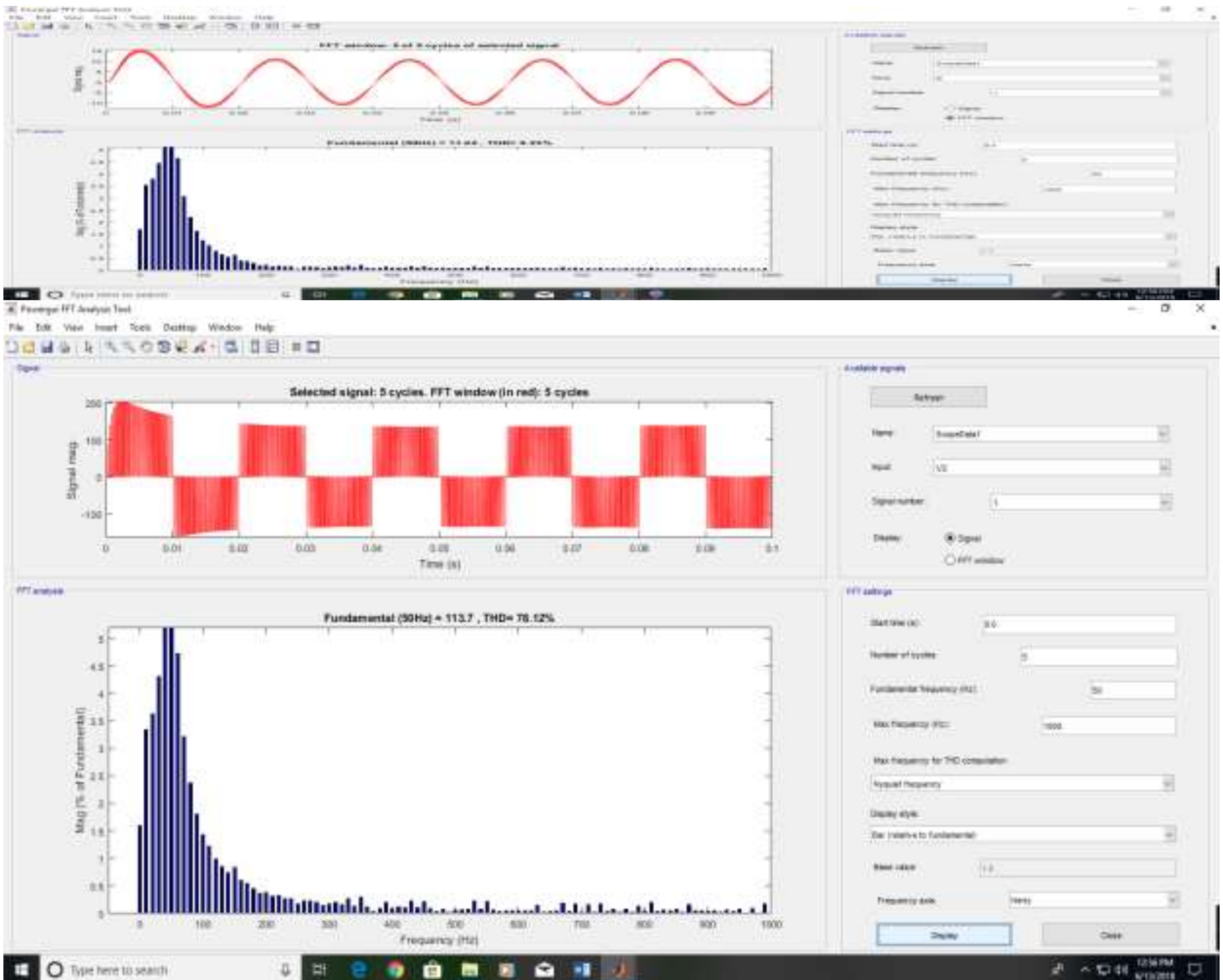

Figure 7: Current and Voltage FFT at load 10ohm and 0.5H

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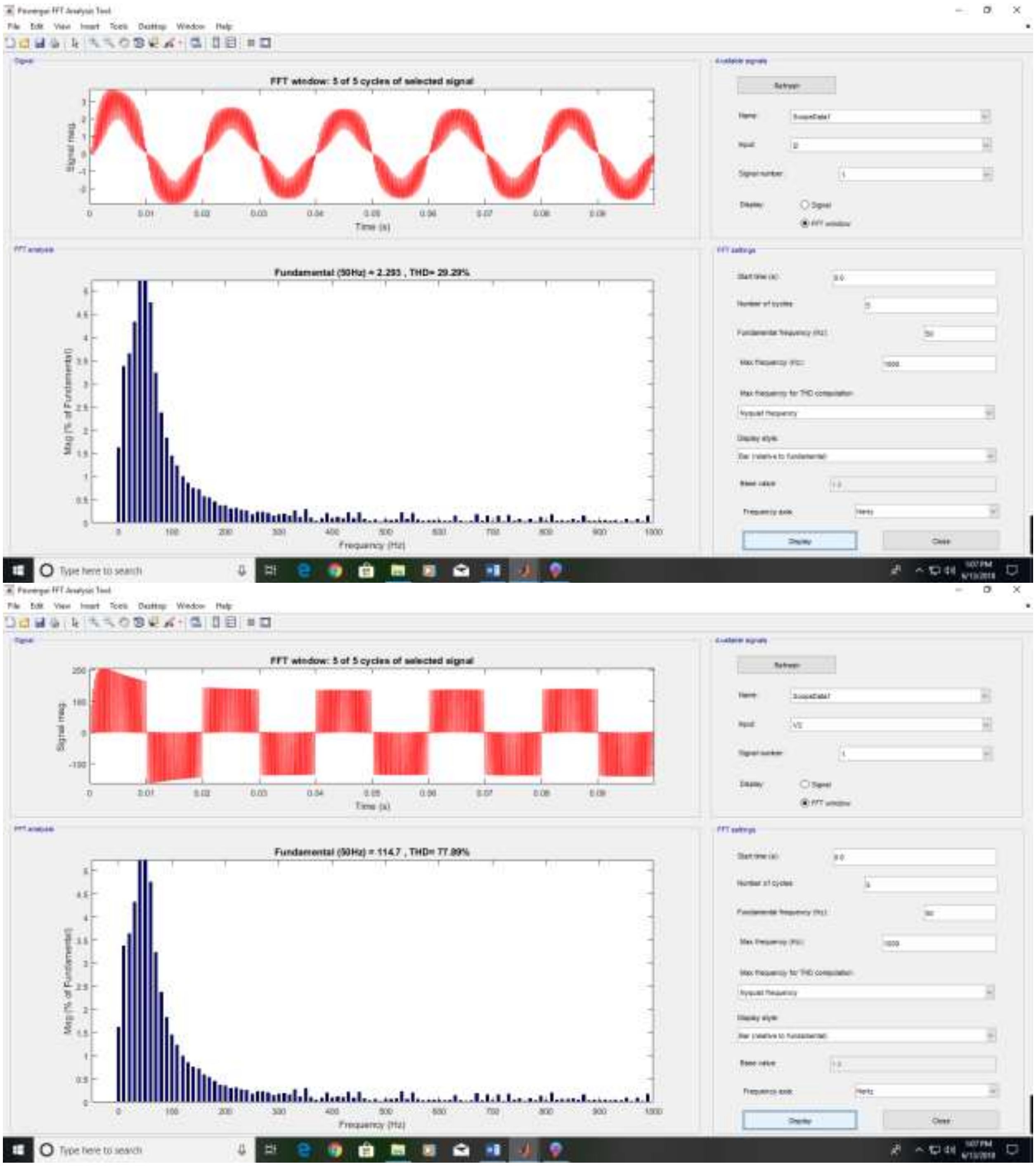

Figure 8: Current and Voltage FFT at load 50ohm and 0.5H

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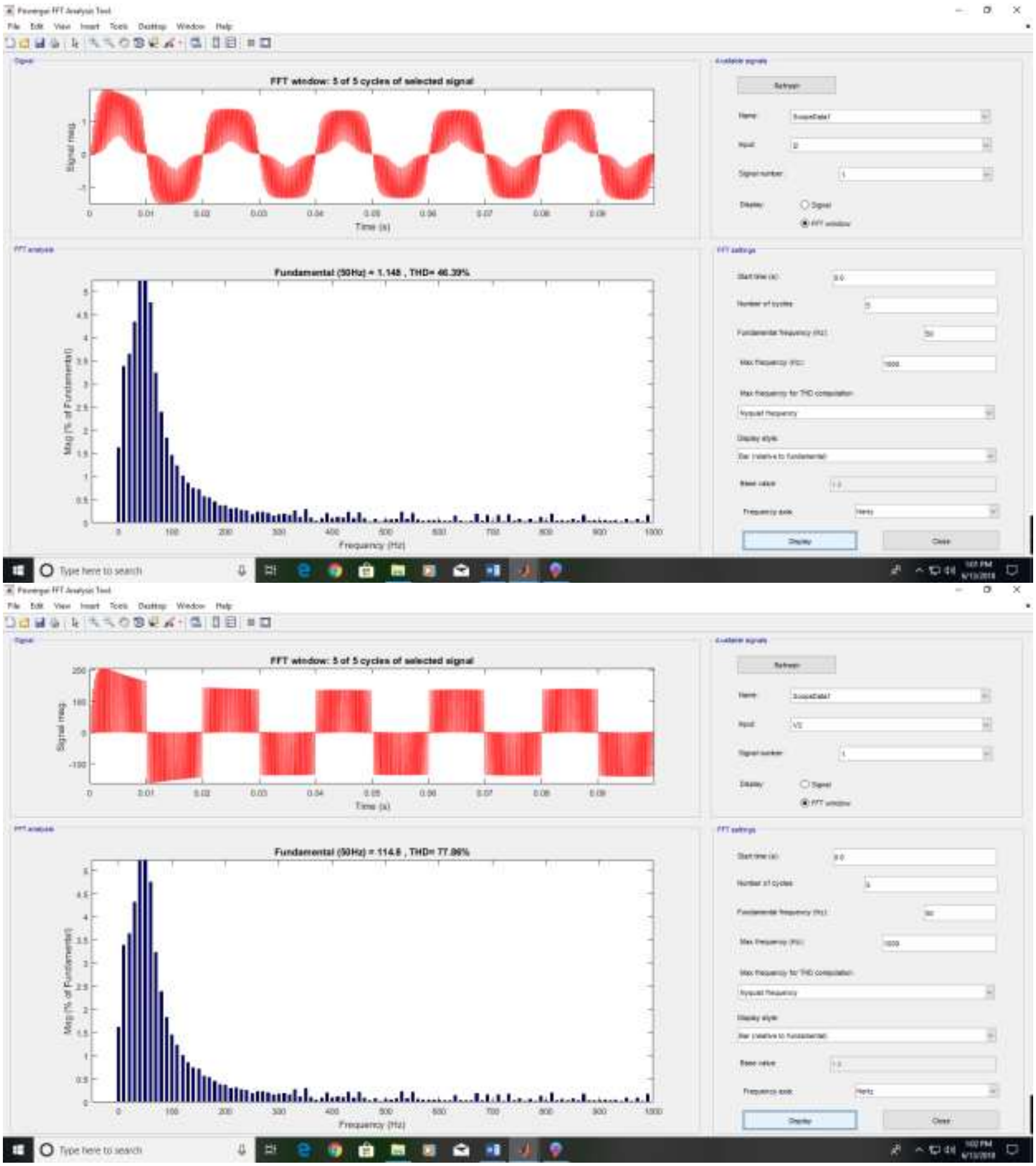

Figure 9: Current and Voltage FFT at load 100ohm and 0.5H

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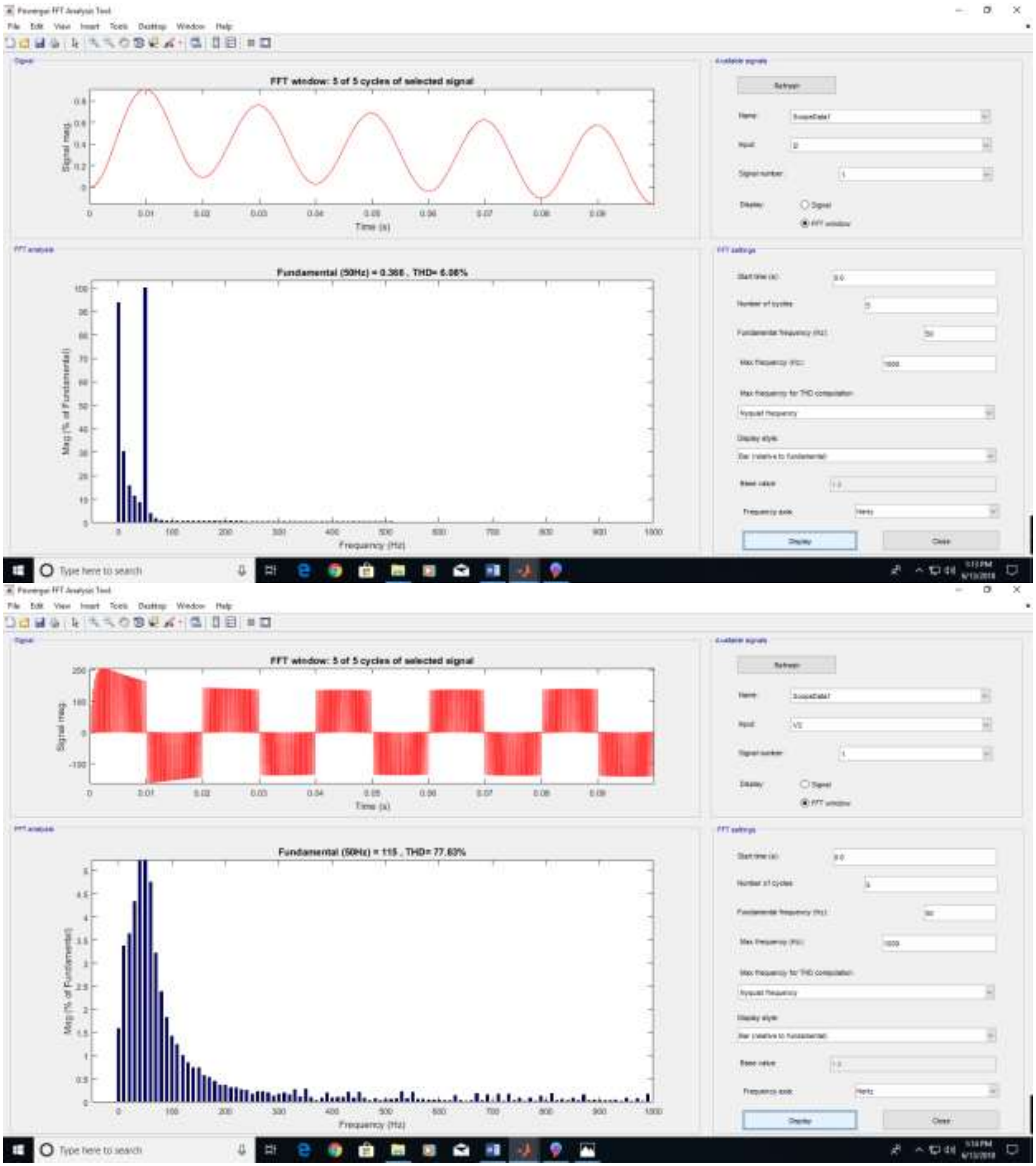

Figure 10: Current and Voltage FFT at load 10ohm and 1H

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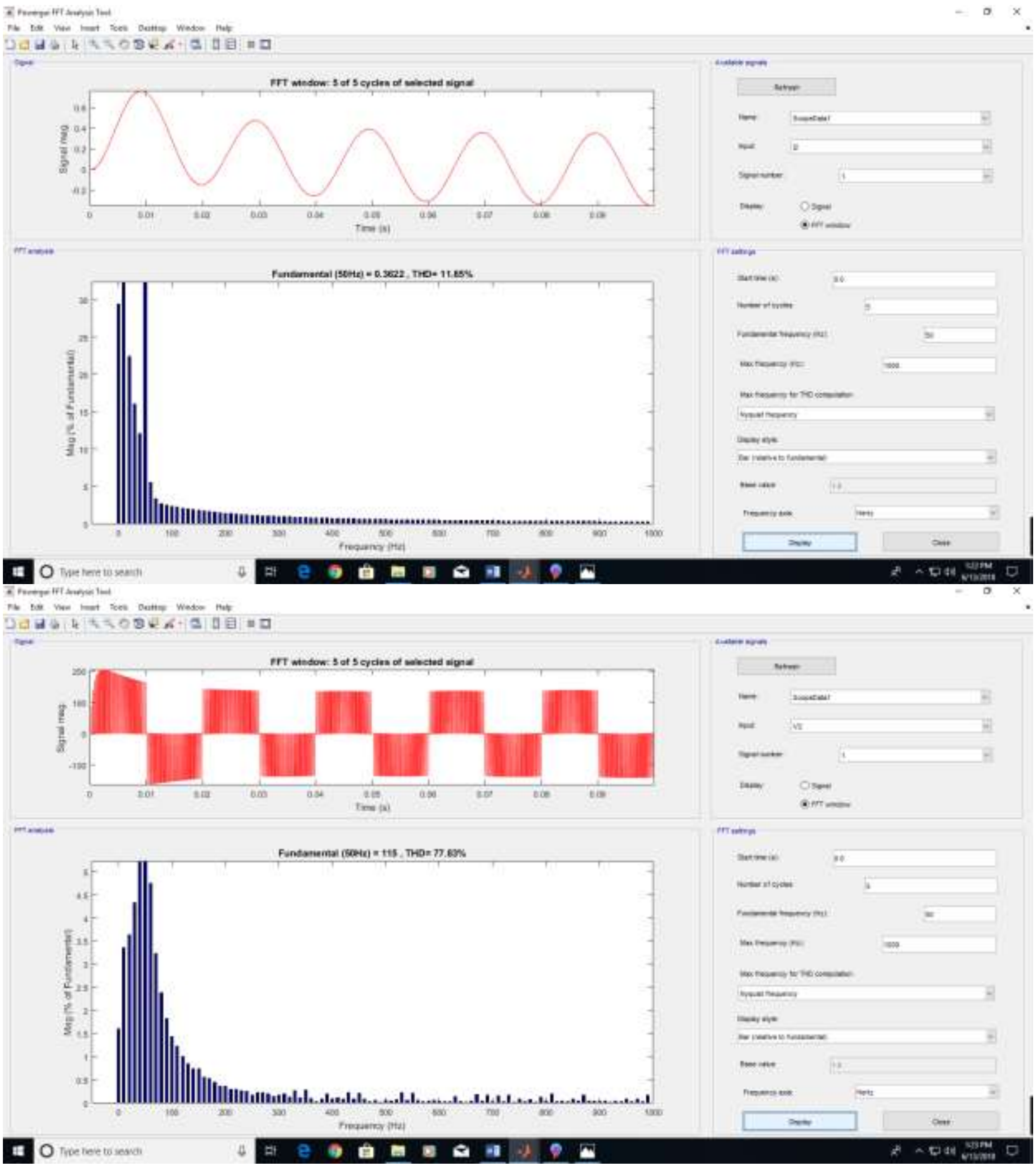

Figure 11: Current and Voltage FFT at load 50ohm and 1H

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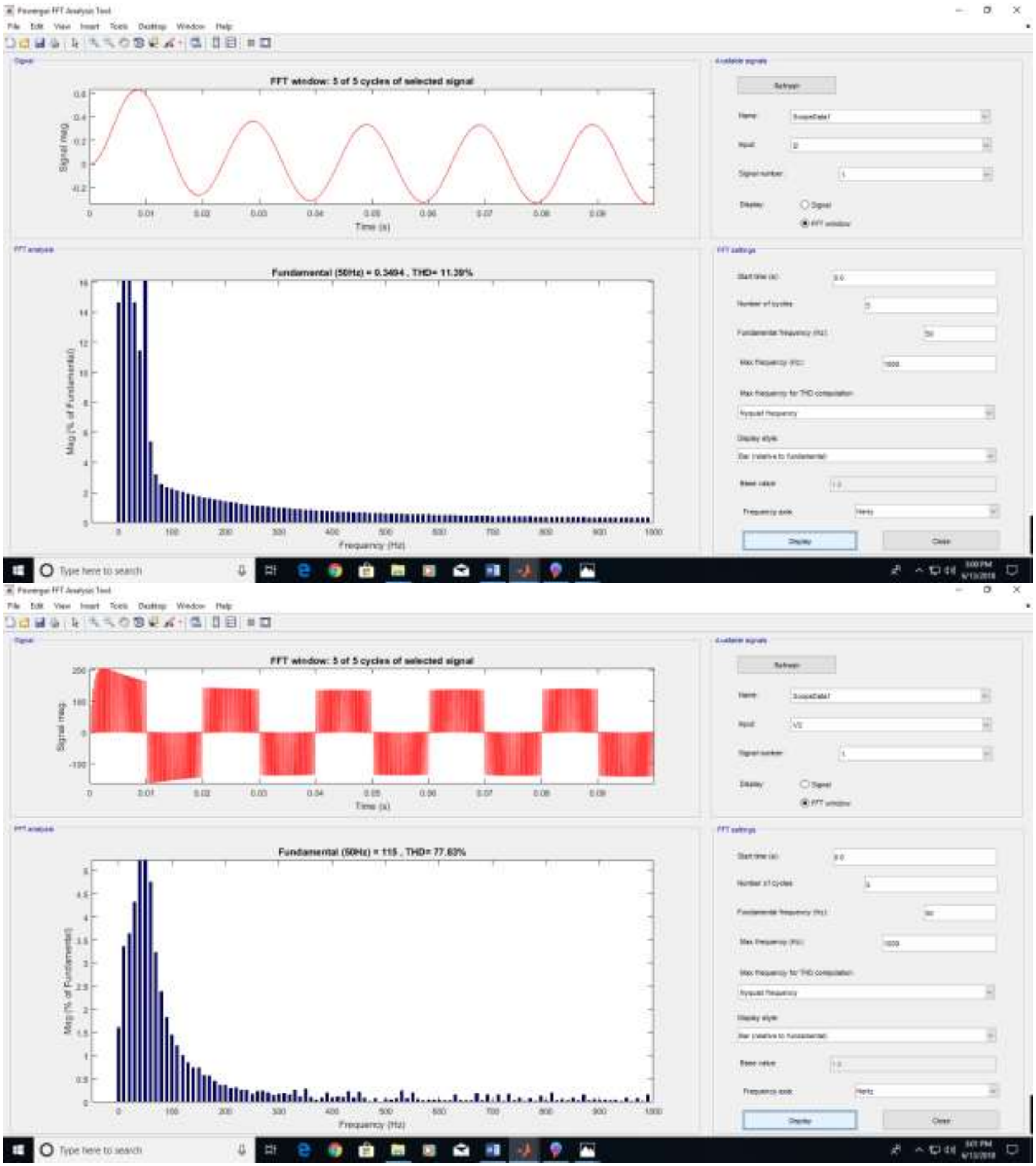

Figure 12: Current and Voltage FFT at load 100ohm and 1H

From the above figures, the total harmonic distortion for load current is increasing in percentage as the resistance is varied. The number of pulses in current output waveform increases as resistance increases and the number of pulses decreases as the inductance is increased. The voltage distortion does not vary too much as compared to current.

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CONCLUSION

From the above FFT analysis output, it is clear that the distortion in current (in percentage) increases and the number of pulses in the load current increases as resistance is increased and is decreased by increasing the inductance value. Thus for proper functioning of AC load the inductance must be high or it can be used as a filter in output terminal as per requirement of the load.

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