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Total Harmonic Distortion of Bidirectional AC-DC Microgrid System for PV Application

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Abstract

For the increasing energy demand and continuously decreasing rate of fossil fuel the Hybrid AC/DC Microgrid system with renewable energy sources (RES) is the one of the sustainable solution. The Hybrid AC/DC Microgrid system improves the power flow in distribution network and reduces power losses in transmission lines. In the Hybrid AC/DC Microgrid system multiple reverse conversion operation reduces with efficient bidirectional power converter is the another preferable solution. Similarly to increase the system reliability extendable voltage range battery system should be utilized. The proposed hybrid Microgrid operates in grid-tied or isolated mode. AC sources and loads are connected to AC network, whereas DC sources and loads are connected to DC network. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature and load are additionally considered in the system model and operation.

Keywords: -Solar Power, PV Array, Inverter, Seven Level, Cascaded Multilevel

INTRODUCTION

Electrical energy plays a crucial role in human civilization. Providing continuous electrical energy is an emergency service because it is an integral part of our life. Also, it is a crucial factor to develop the nation with all respect. However, the present scenario shows the noticeable difference between demand and supply of electrical energy [1]. The energy demand is continuously increasing in various sectors such as residential, commercial, and industrial sectors. To fulfill the continuously increasing demand for electrical energy, it has to change the face of energy generation and utilize energy efficiently [2, 3]. Due to the continuous use of electrical energy in every field, like the fast-growing industrial sector, fossil fuel is decaying

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gradually, and hazardous pollution is increasing rapidly. Therefore, engineers, researchers, and policymakers have to find appropriate ways to meet the world's growing demand for electric energy considering all critical issues. These issues are like increasing energy demand, making various available sources to generate energy, fossil fuel availability, reliability, sustainability, energy storage, quality power, security, efficient use, and environmental effects like global warming, Etc. So everyone has necessitated an urgent search for alternative sources of electric energy with considering above listed issues and trying to reduce the gap between demand and supply [4–6]. In India, generation of energy with independently resources is not considered till today due to lack of awareness about it. If we could generate energy at tiny level and cope up with an individual demand then definitely gap between demand and supply will reduce.

But unfortunately, there are lots of technical constraints in front of them. For that Microgrid is the best suited system with integration of distributed energy resources (DER) [7–9]. DERs are energy generation units in the range of 3–50 kW installed below 25 kV distribution systems at or near the end-user. Wind turbine, fuel cell, microturbine, diesel generator, hydro turbine, internal combustion engine, gas turbine, and solar array are the standard available DERs [10]. Solar array and wind turbines are the two most promising sources of DER. They can improve reliability, power quality (PQ), and global warming with reduced power generation, transmission, and distribution costs. Grid-connected DERs supports and strengthen the central bulk power station to meet peak demands or support significant consumers. Moreover, DERs provide power to the remote application where it is not possible to deliver power from traditional transmission and distribution lines [11, 12]. Microgrid reduces dependency on fossil fuels by using renewable energy sources abundantly available in an environment such as wind and solar power. The rapid development of distributed generation (DG) technology is gradually reshaping the conventional power systems in several countries, including India.

MICROGRID AND THEIR CLASSIFICATION

The microgrid consists of distributed energy resources, and it can operate the loads in parallel or independent of the central power grid. The primary purpose of this system is to ensure reliable and affordable energy to urban and rural communities for commercial, industrial, and federal governments. The microgrid is a smaller version of the traditional power grid in many respects. Like the conventional power grid, it consists of power generation, distribution, and control of voltage regulation and switch gears. However, microgrids differ from the traditional electrical grid by providing closer proximity between power generation and load, resulting in

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increased efficiency and reduced transmission losses. Microgrid performs dynamic control over energy sources, enabling autonomous and automatic self-healing operations. A microgrid can operate independently during average or peak load or at the failure of the primary power grid. It can work in isolating mode without affecting the larger grid's integrity. Microgrid exchanges the power with existing grid under healthy condition and separates from it under faulty condition. Microgrids had mainly classified according to load handled by the grid, such as AC microgrid, DC microgrid, and hybrid microgrid [13]. Power is generated from different distributed energy resources in an AC microgrid system and converted into AC form and supplies to ac load only, as shown in Figure 1.

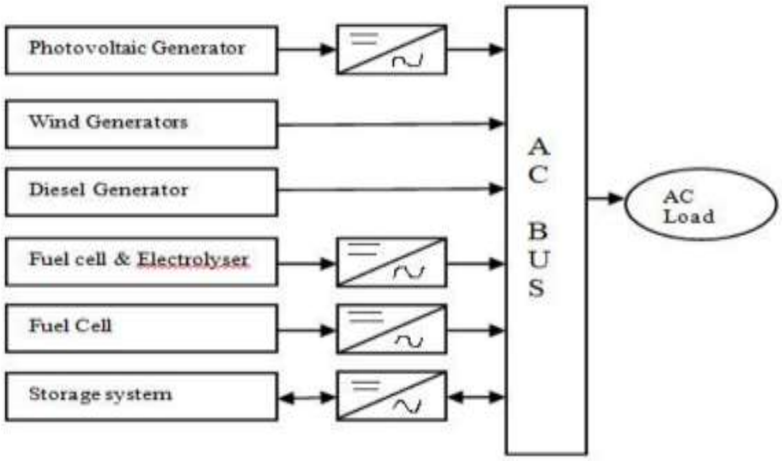

Figure 1.1: AC Microgrid

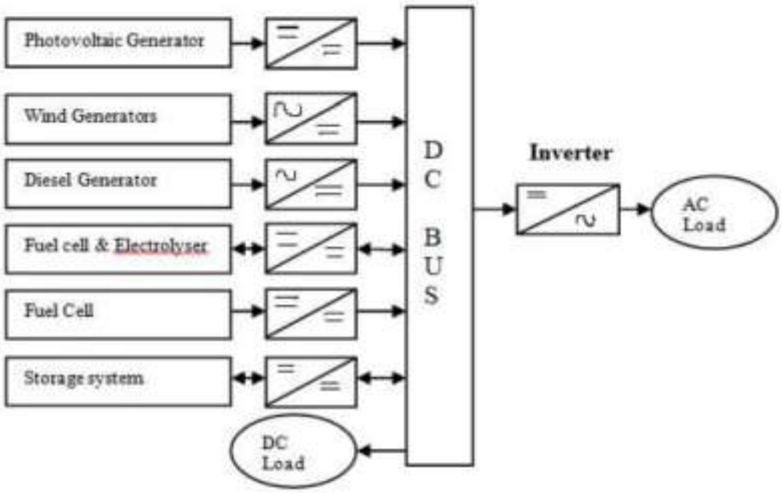

Figure 2: DC Microgrid

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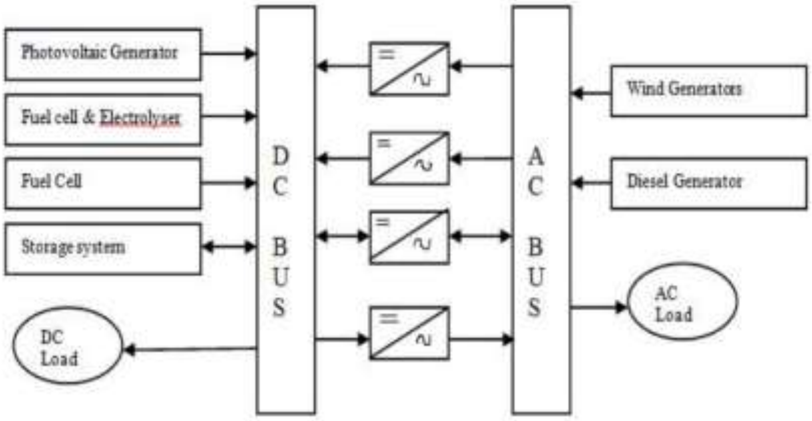

Figure 3: DC Microgrid

In the DC microgrid system, the generated power is in dc form, and it handles both dc and ac loads, as shown in Figure 2. The DC Microgrid system is more efficient than AC Microgrid. It has no active and reactive power control, has fewer losses, and is easy to interface with the energy storage system. A Hybrid Microgrid is the combination of AC Microgrid and DC Microgrid [14]. In the Hybrid system, ac loads had connected to the ac bus, and dc loads had connected to the dc bus.

As shown in Figure 3 both ac and dc buses had mutually interconnected through power converters. In all the above types of Microgrid systems, a power converter plays a vital role in power conversion operation. However, in separate AC Microgrid and DC Microgrid systems, multiple reverse conversion operations occur, which leads to more conversion losses as the number of distributed energy resources increases the corresponding number of power converters and associated control circuit increases. Hence, a Hybrid AC/DC Microgrid system had introduced to improve the converter's efficiency. In a Hybrid AC/DC microgrid system, multiple reverse conversion operations had minimized and reduced the corresponding losses.

PROPOSED METHODOLOGY

In the present trend, Renewable energy sources are attractive choices for providing power in the places where an association to the utility network is either not possible or unduly costly. As electric distribution technology steps into next century, several trends have become noticeable which will modify the necessities of energy delivery. The ever-increasing energy consumption, soaring value and exhaustible nature of fossil fuels, and also the worsening international environment have created enhanced interest in green power generation systems. Renewable sources have gained worldwide attention because of quick depletion of fossil fuels in conjunction with growing energy demand

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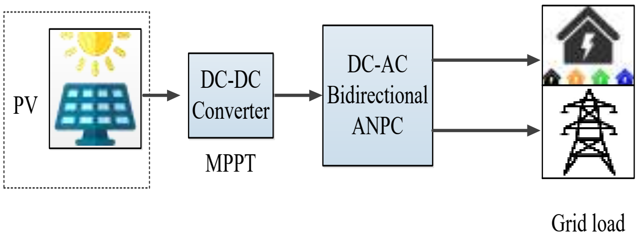

Figure 4: Representation of cascaded PV to grid connected system

Microgrid concept integrates large amounts of micro sources without disrupting the operation of main utility grid. This hybrid Microgrid consists of PV/wind energy sources for DC and AC networks respectively. Energy storage systems may be connected to either AC or DC Microgrids.

The proposed hybrid Microgrid operates in grid-tied or isolated mode. AC sources and loads are connected to AC network, whereas DC sources and loads are connected to DC network. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature and load are additionally considered in the system model and operation. Representation of microgrid system is shown in figure 4.

Designing of AC bus

In the proposed microgrid system design AC bus which is connected with three phase grid so it is suitable to power supply to the bus. As shown in figure 5 microgrid system have AC load at the AC side and it is directly connected to the AC-bus. AC side load and grid simulation diagram is shown in figure 5.

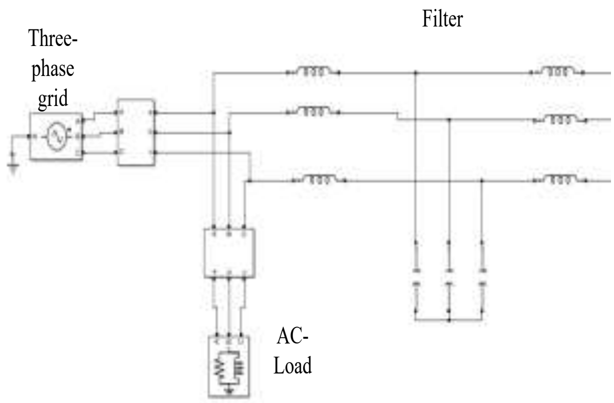

Figure 5: Simulation of AC side load and grid

DC-DC BOOST CONVERTER

In many industrial applications, it is required to convert a fixed-voltage dc source into a variable-voltage dc source. A dc-dc converter converts directly from dc to dc and is simply

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known as a dc converter. A dc converter can be considered as dc equivalent to an AC transformer. Like a transformer, it can be used to step down or step up a dc voltage. They provide smooth acceleration control, high efficiency, and fast dynamic response.

Its operation is generally of two separate states:

- During the ON period, switch is made to close its contacts which results in increase of inductor current.
- During the OFF period, switch is made to open and thus the only path for inductor current to flow through the fly-back diode 'D' and the parallel combination of capacitor and load. This enables capacitor to transfer energy gained by it during its ON period.

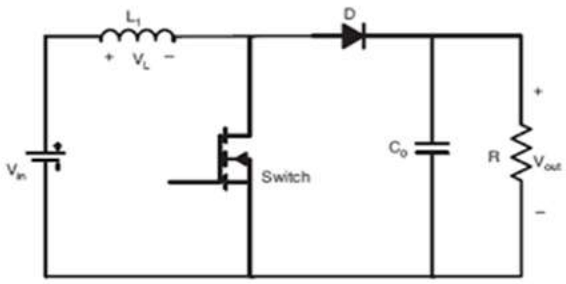

Figure 6: DC-DC Boost Converter

When switch is ON then,

Vs = +VL (1)

VL = VS (2)

When switch OFF then,

VS = - VL + Vo (3)

VL = Vo – VS (4)

Vs TON = (Vo – Vs) TOFF (5)

VS (TON + TOFF) = Vo TOFF (6)

Vo = VS(TON + TOFF) / TOFF (7)

= VS (T / TOFF) (8)

VS (T / T - TON) (9)

= VS (1/1-k) (10)

Where,

Vo or Vout = Output DC voltage (V)

Vs or Vin = Output voltage of PV panel (V)

VL = Voltage across inductor (V)

k = Duty cycle (unit less)

T = Total time (seconds)

The power semiconductor devices require a minimum time to turn on and turn off. Therefore, the duty cycle k can only be controlled between a minimum value kmin and a maximum value kmax, thereby limiting the minimum and maximum value of output voltage. The switching frequency of the converter is also limited and the load ripple current depends inversely on chopping frequency (f) as ΔImax = Vs / 4fL. The frequency should be as high as possible to reduce the load ripple current and to minimize the size of any additional series inductor in the load circuit.

SIMLATION RESULT

The proposed Microgrid operates in grid-tied or isolated mode. AC sources and loads are connected to AC network, whereas DC sources and loads are connected to DC network. Figure 7 shows the three-phase grid voltage and grid current. Which used to connect to AC bus by using LCL filter. This three-phase voltage and current stabilised unity power factor at the grid side and also its have lower harmonics.

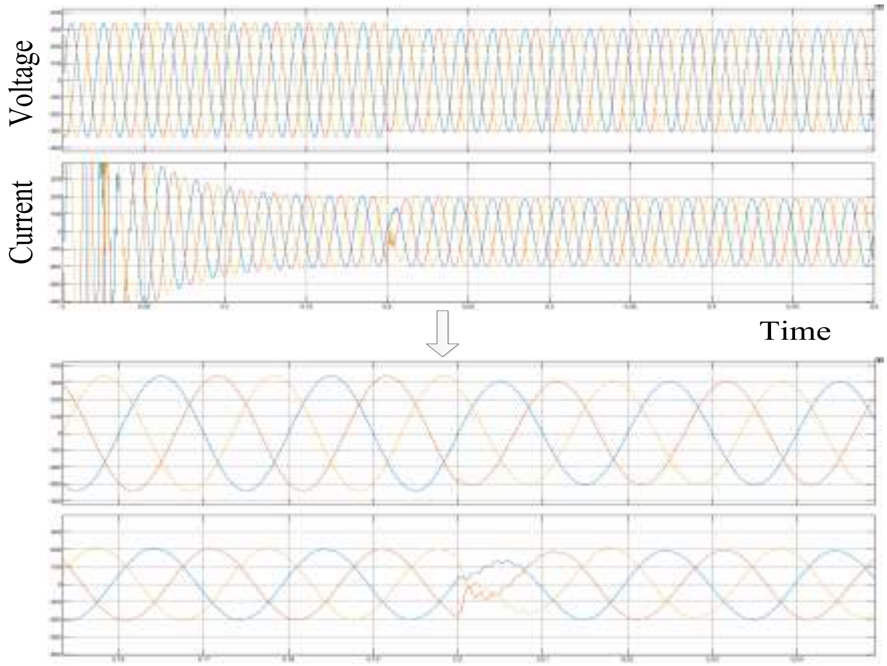

Figure 7: Three phase grid voltage and current

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By creating some disturbance through grid at time of 0.2 sec it reduces a voltage by 10%. So, it created a sudden disturbance at this time renewable energy sources perform a role so it maintains this voltage to the same condition. In figure 8 voltage reduces by 10% but current maintain same peak to peak amplitude.

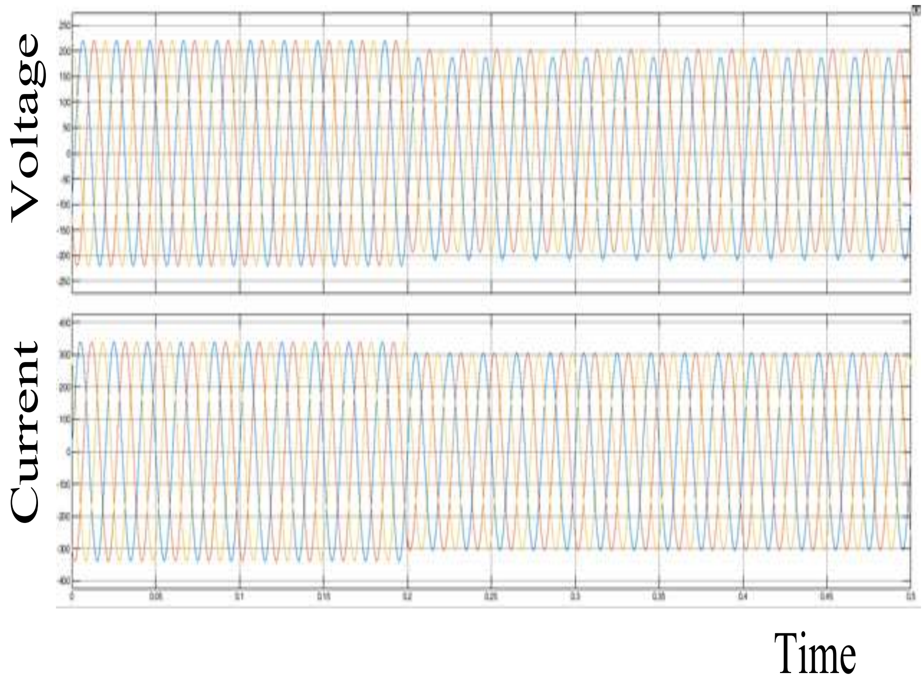

Figure 8: Three phase AC load voltage and current

In this work PV simulates at a 2 KW power rating and use a PV module as 1 parallel and 6 series connected string at specific module. Also, specified 290 maximum dc output voltage. Graph plot of current and power with respect to voltage shown in figure 9.

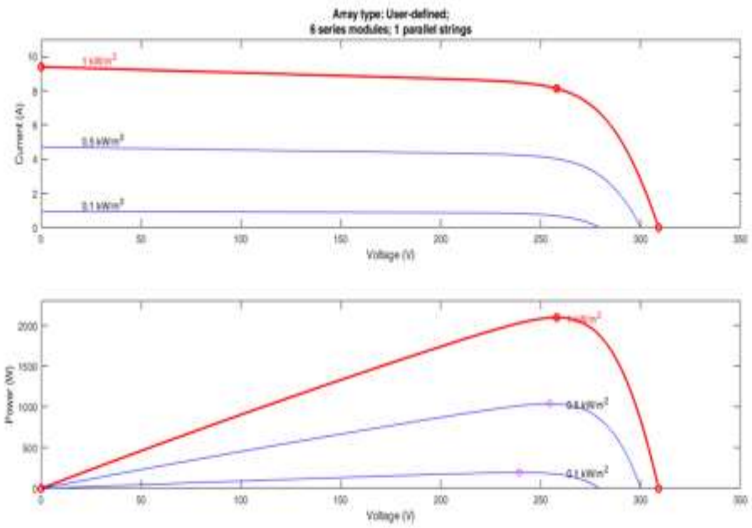

Figure 9: PV power and current with respect to voltage

For reduction of this ripple and increase the dc voltage required a DC-DC boost converter. Output voltage of DC-DC boost converter is ripple free and high voltage as 400V so it can be easily connected to the single-phase grid by using inverter. This DC-DC boost converter also useful for MPPT (Maximum Power point tracking) which is performed by perturb and observe method. This converter worked as a first stage of our system and work on a 5KHz Switching frequency. Output voltage of the first stage as a DC-DC boost converter is shown in figure 10.

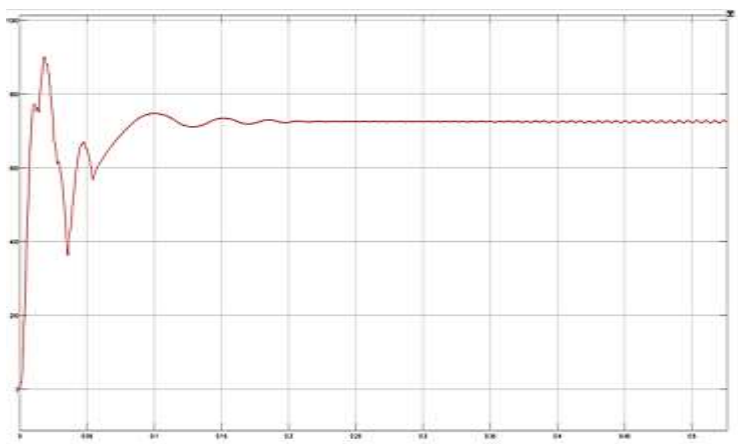

Figure 10: DC link voltage

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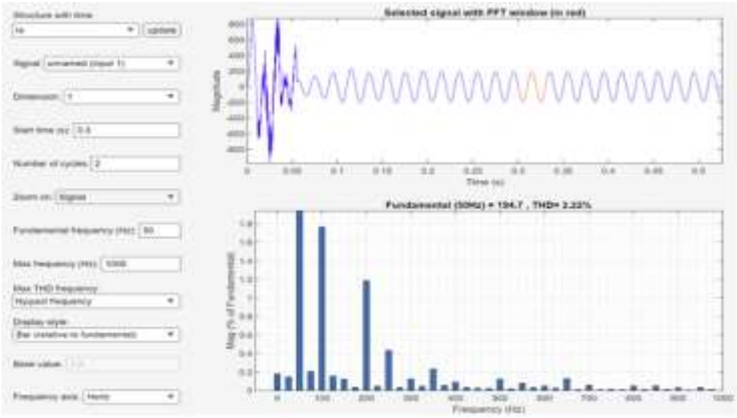

Figure 11: THD profile of current-A

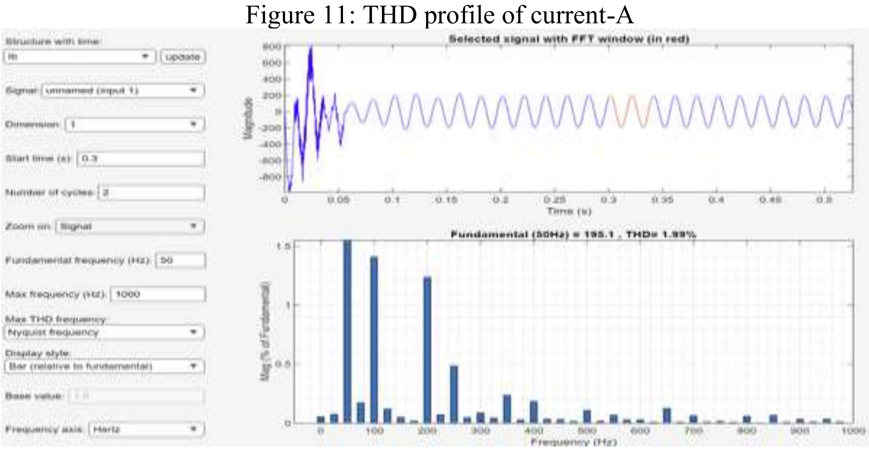

Figure 12: THD profile of current-B

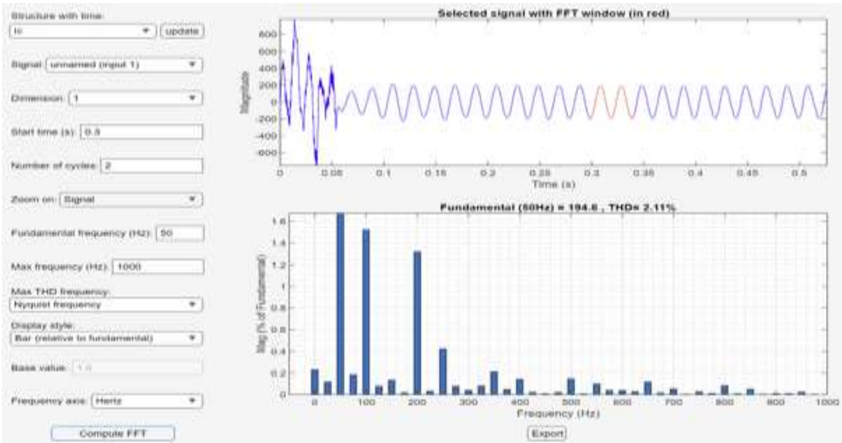

Figure 13: THD profile of current-C

CONCLUSION

In this work PV simulates at a 2 KW power rating and use a PV module as 1 parallel and 6 series connected string at specific module. Also, specified 290 maximum dc output voltage. Maximum PV output voltage is set to 290 according to the PV module and this voltage has approximately 50V peak to peak ripple. This high voltage ripple can damage a system and reduces the efficiency also increases the losses of the system. DC voltage of the PV output. For reduction of this ripple and increase the dc voltage required a DC-DC boost converter. Output voltage of DC-DC boost converter is ripple free and high voltage as 400V so it can be easily connected to the single-phase grid by using inverter. This DC-DC boost converter also useful for MPPT (Maximum Power point tracking) which is performed by perturb and observe method. This converter worked as a first stage of our system and work on a 5KHz Switching frequency.

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