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Power Quality Assessment of Wind and Solar Based Grid Tied Hybrid Power System

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Abstract— ***The synchronization of two sources includes power converters at various ends of the power system for power conversion. There are various types of DC-DC and AC-AC converters available in literature. The analysis of these converters is done in order to find the best suited converter. The power electronics converters are a major source of harmonics, the elimination of these harmonics require the installation of filters in the system. This paper comprises of a hybrid power system comprising of two renewable sources of energy namely wind and solar, and a synchronized output with grid parameters, various types of DC converters are analyzed by assessment of THD content in the output waveforms. The DC-DC converters analyzed in this research work are Boost, Cuk and zeta converter.***

Keywords- DC-DC, SPV, PV Cell.

I. INTRODUCTION

Renewable sources like Solar, Wind, Hydro, tidal etc are majorly used for power generation at various ends according to the geographical conditions of the place. [1] Since the output of the renewable sources is a role of atmospheric and geographical conditions they could be used in combination with Solar-wind, Solar-Fuel cells, etc. [2]

The output of these renewable sources is used in synchronization with the grid, where the power can be obtained from the grid during outages and emergency conditions.[3]

The synchronization of two sources includes power converters at various ends of the power system for power conversion. There are various types of DC-DC and AC-AC converters available in literature. [4-5] The analysis of these converters is done in order to find the best suited converter. The power electronics converters are a major source of harmonics, the elimination of these harmonics require the installation of filters in the system.[6]

II. ENERGY SOURCES

Solar Photovoltaic System

PV cells are the primary building block for generating electricity from the sun, which is an infinite supply of energy. Module or array refers to a group of PV cells.[7]

A photovoltaic system architecture includes several solar cells connected in series or parallel to produce the required yield voltages, a diode, two resistors, and a current source.[8]

One current source connected in parallel to a diode, two resistors coupled in series and shunt positions, and a corresponding circuit can simulate an SPV array. These resistors are labelled RS and Rush, which stand for respectively Rs for series resistance with a very small value and Rsh for shunt resistance with a relatively high value.

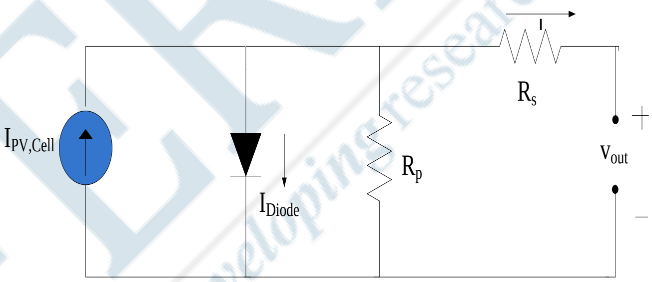

Figure1. schematic diagram corresponding solar cell

The output of the photovoltaic cell could be as follows:

$$I = I_{PV_{Cell}} - I_{diode}$$
$$= I_{PV_{Cell}} - I_{0.Cell}\left[exp\left(\frac{q*v}{\alpha*K*T}\right)-1\right] \quad (1.1)$$

Here,

- I pv, cell indicates the current produced by dropping radiations.
- The Shockley diode equation is represented by the symbol I.
- The cell's reverse saturation current is represented by I0, CELL.
- Q is a representation of an electron's charge (1.60217646 * 10e-19 Coulomb).
- K is the Boltzmann constant, which has the value [1.3806503 * 10e-23J/K]. presents the equation for the Shockley diode.
- $I_{0,\ CELL}$ represents the reverse saturation current.
- q represents the charge on an electron [1.60217646 * 10e-19 Coulomb].
- K stands for the value of Boltzmann constant [1.3806503 * 10e-23J/K].

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Wind Generator

a) AC Synchronous Generator

Induction devices are mostly used in modern wind turbine systems.These generators have been divided into two further categories.

- (FSIG) Fixed speed induction generators
- (DFIG) Doubly fed induction generators

The main reason why induction generators are utilised is due of their straightforward, low-cost, and robust design.

In the case of fixed speed induction generators, the rotor is coupled to the turbine with the aid of a gearbox, while the stator's output is connected to a grid via a transformer. Variable speeds could be employed with SCIGs. [9] The output voltage of these generators could not be controlled, hence reactive power from an external source is necessary.

These generators' primary drawbacks include their size, effectiveness, noise, etc. These days, 5MW-capable wind turbines are utilised most frequently with DFIGs.[10]

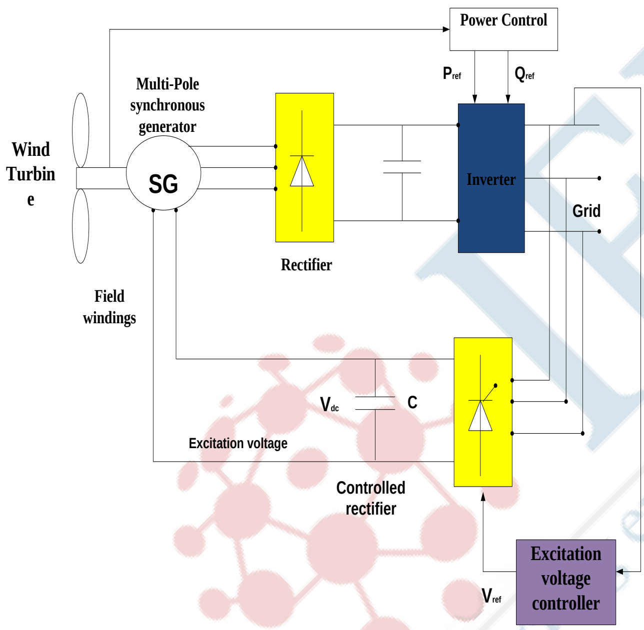

Figure 2. The system's block diagram for the wind turbines

III. DC-DC CONVERTER

A. Boost Converter

This converter, which can provide outputs better than the input, could be referred to as a step-up transformer for DC circuits. This type of converter can be produced with just two semiconductor switches, a diode, a transistor, and one energy-storing component. These converters' output power quality could potentially be enhanced with the use of filters.

The following suppositions are taken into account when studying a boost converter:

- The circuit operates in a steady-state condition.
- The inductor current is assumed to be continuous.
- The output voltage is assumed to remain constant at V0.
- Every component is regarded as excellent.
- A boost converter often operates in two different modes.
- While the Boost converter functions as an energy source in the second mode, the first mode causes it to operate as a load, absorbing the energy from the inductor. Regardless of the charging voltages, the voltage generated during the discharge time is entirely reliant on the magnitude of the change in current.
- Two types of operation for the Boost converter can be described.

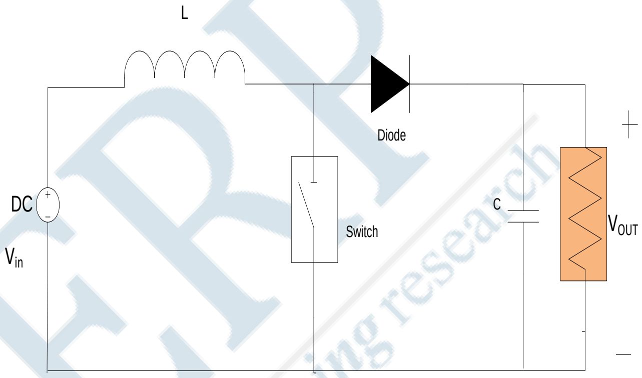

Figure 3. Basic diagram of a boost converter

Figures

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MODE-I

The Boost converter's charging mode is another name for this function. In this mode, the current only travels via the SW switch and inductor. This is in charge of how much energy the inductor can store.

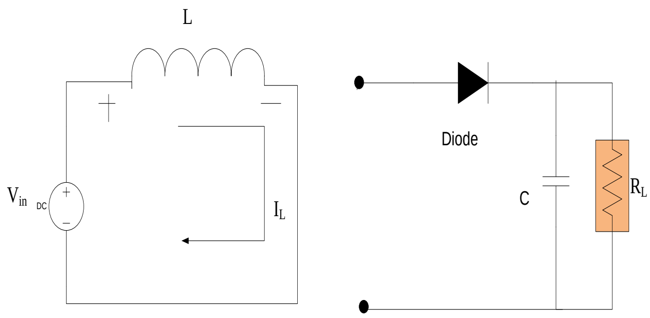

Figure 4. Mode-I boost converter

MODE-II

When the switch is first turned off in this discharging mode, the current that was previously flowing through it switches to flowing through the capacitor and across the load resistance. The inductor's stored energy is released in this state.

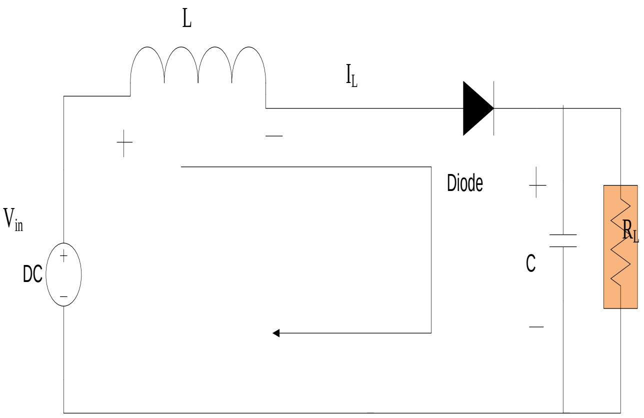

Figure 5. Boost converter operating in Mode-II

B. Cuk Converter

This particular sort of converter is classified as a converter due to its special ability to produce an output voltage with reversed polarity and a change in magnitude.

The yield voltage from this converter could be larger or less than the output voltage. This converter's inductor serves as a filter, enhancing the output power's quality.

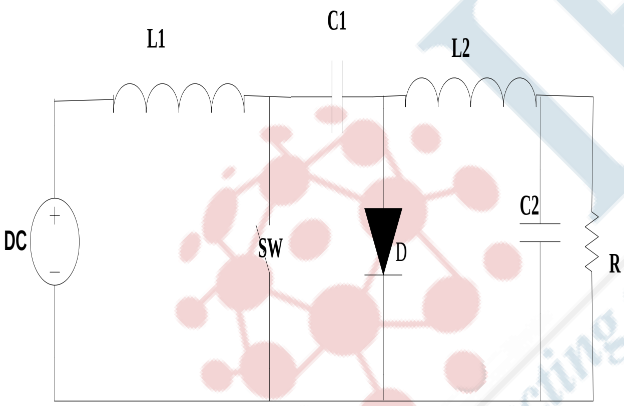

Figure 6. The Cuk converter

Operating Principle

The two inductors L1 and L2 first transform the voltage sources into the current sources. Since resistances are needed when connecting a capacitor to a voltage source in order to limit the current, this form of conversion is necessary.

This Cuk converter can operate in both the continuous and discontinuous modes, just like the other converters can. It can also operate in the discontinuous voltage mode in addition to this.

C. Zeta Converter

This sort of converter performs a similar function to the Buck-Boost converter in that it can deliver output voltage that is either amplified or attenuated in amplitude

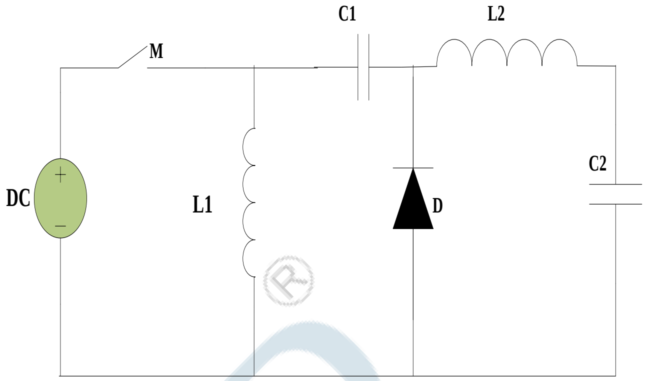

Figure 7. Schematic diagram of Zeta converter

MODE-1

Switch (SW) is ON and the diode is OFF in this mode. The two inductors, L1 and L2, are across which the current flows. The charging mode is another name for this mode.

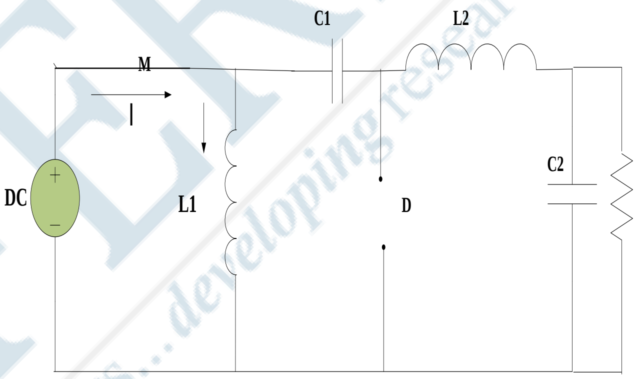

Figure 8. In-Mode-I Zeta converter

MODE-II

The switch is merely in the OFF state while the diode is conducting, making this mode the exact opposite of the one before it. This mode is sometimes referred to as the discharging mode since the energy is discharged across the source resistance.

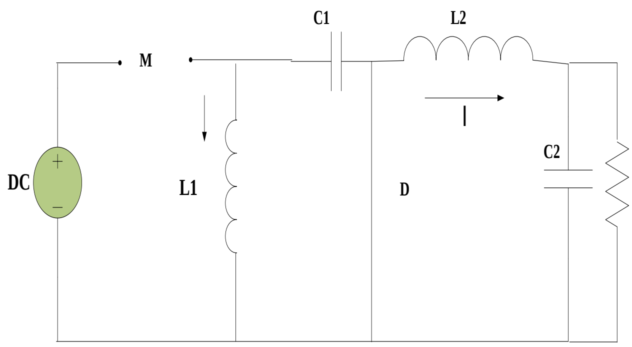

Figure 9. The Zeta converter's Mode-II

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IV. SIMULATION MODEL

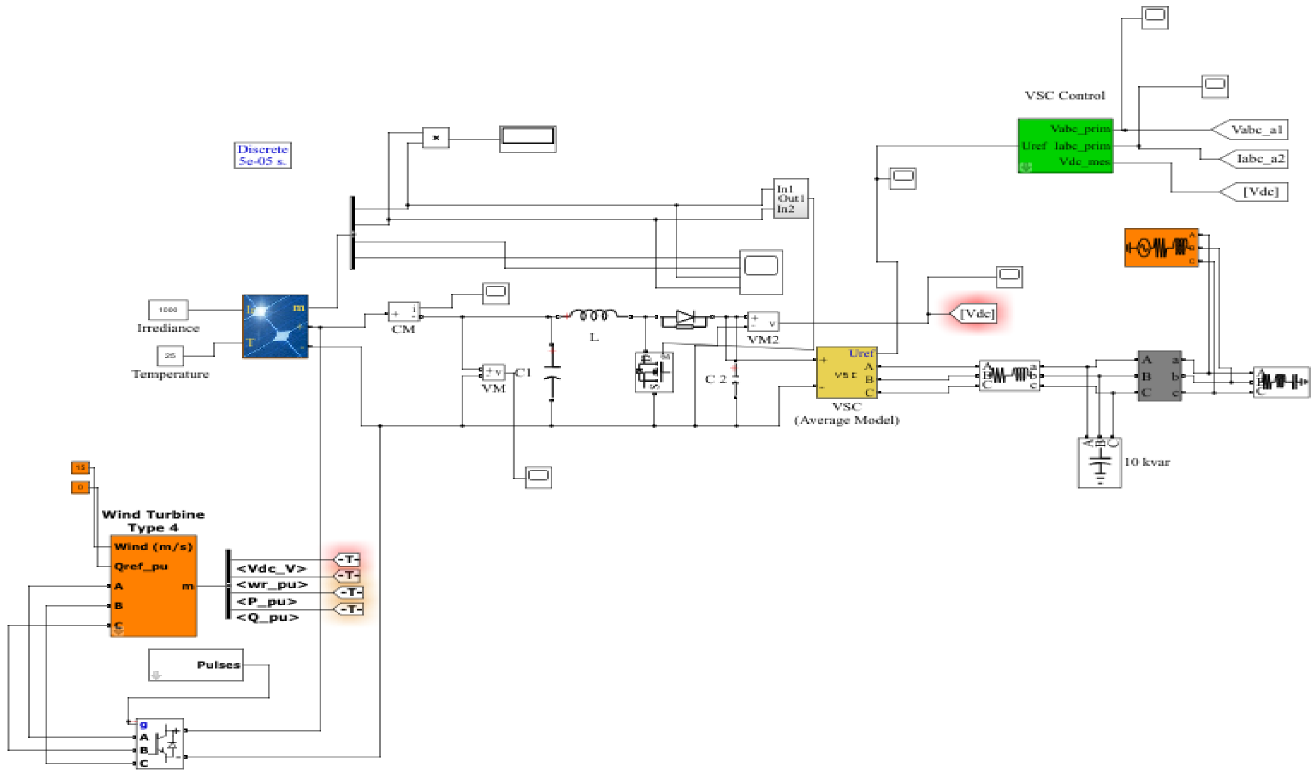

Figure 10. Simulation Model of Boost converter

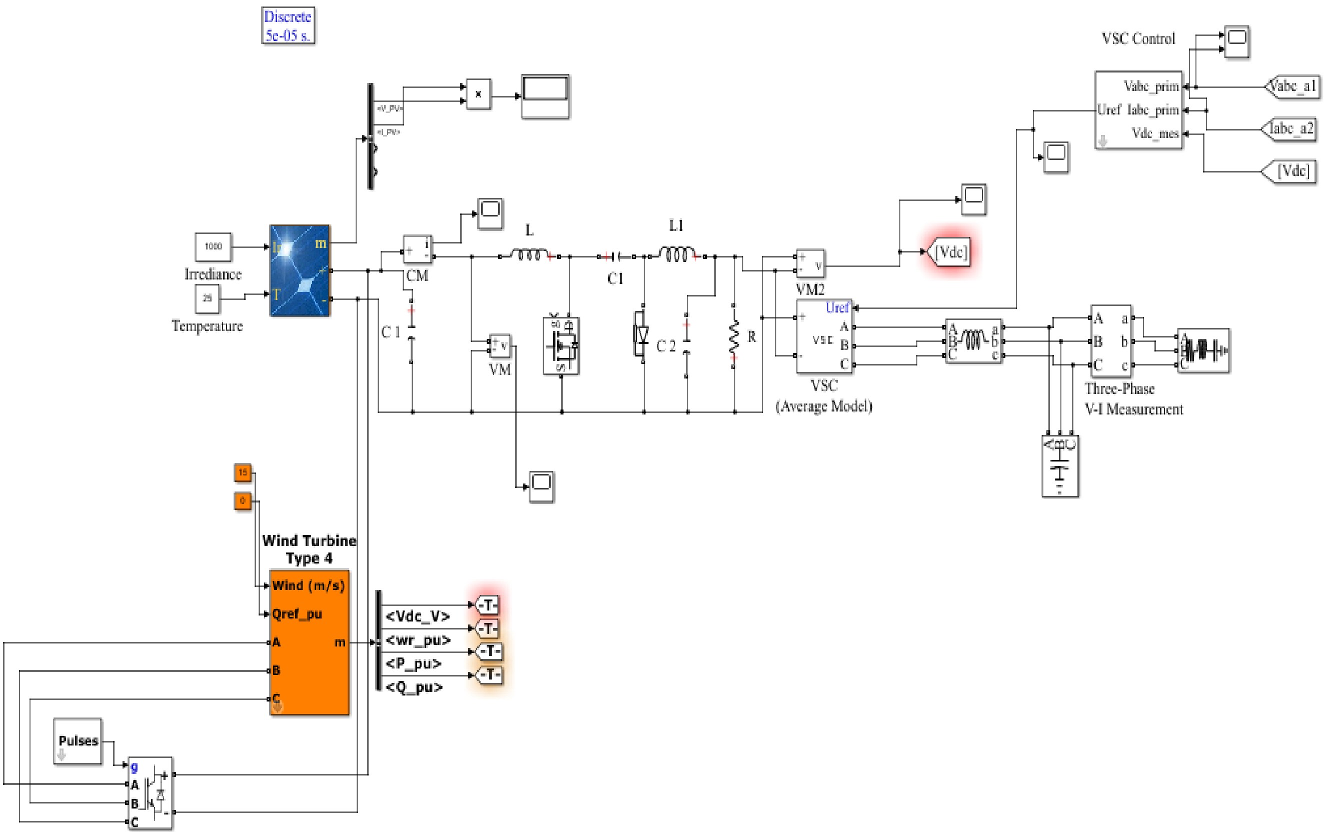

Figure 11. Simulation Model of Cuk converter

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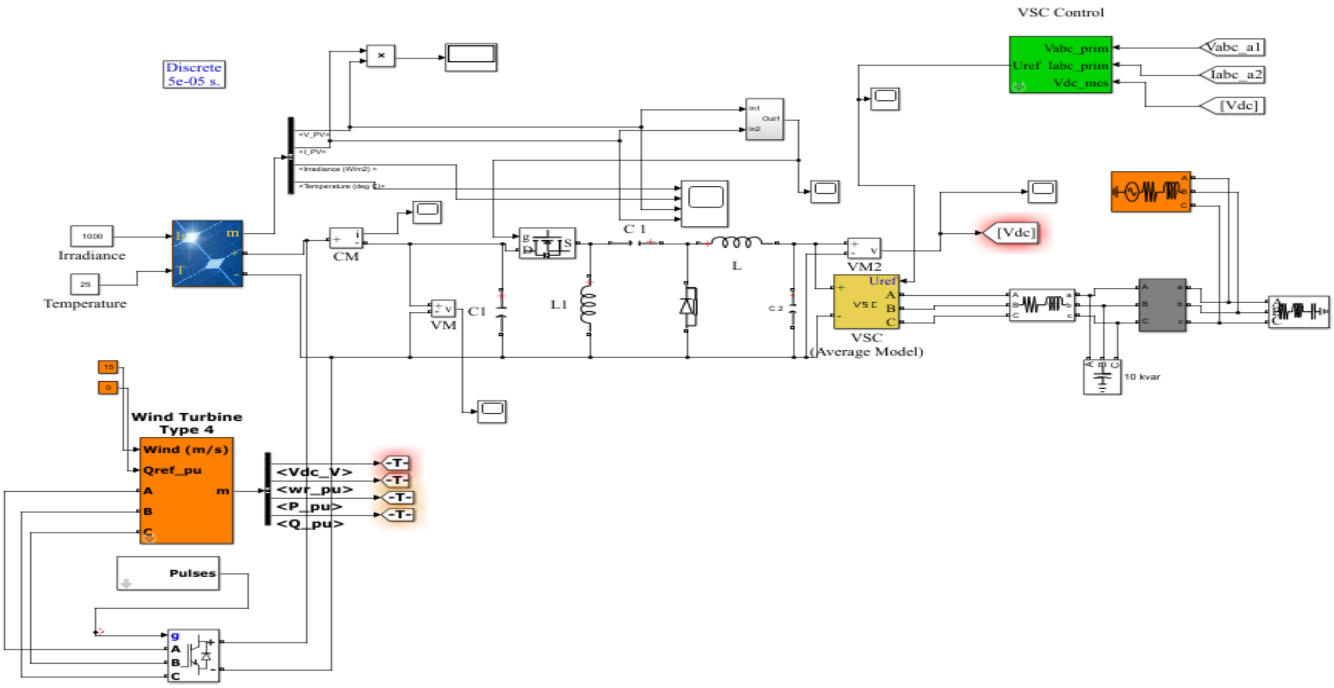

Figure 12. Simulation Model of Zeta converter

V. SIMULATION RESULTS

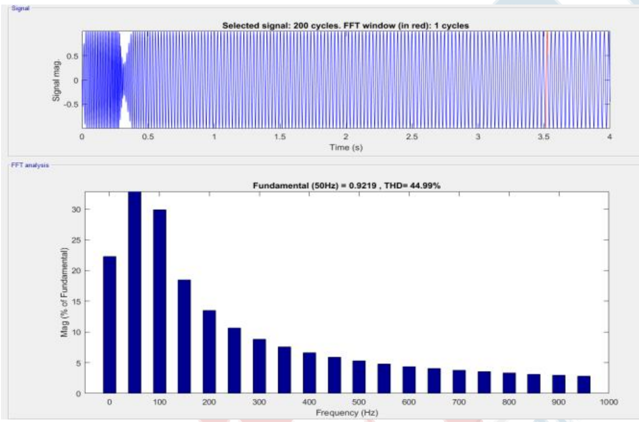

Figure 13. THD analysis of VSC output waveforms in the simulation model with a Boost converter.

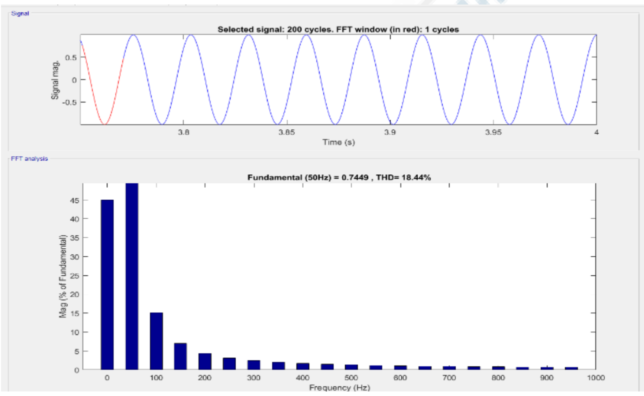

Figure 14. THD analysis of VSC output waveforms in the simulation model with Zeta converter.

VI. RESULTS

In this thesis, the simulation of a standalone solar power system is done. In which the input and output voltages of several DC-DC converters are recorded. The load and source are always kept constant during the whole simulation.

The solar PV array is also assembled with the MPPT technique in the direction of enhancing the effectiveness of the system.

The parameters that are analyzed in the system are the steady-state response time, THD and output DC voltage of the converters.

After analysis, a below-given table is being prepared in order to provide the users with the system details so that according to the type of application the converter could be chosen.

TABLE 1: Power Quality Assessment parameters table

Converter	DC Converter Output Voltage	Settling Time	THD %
Boost Converter	1400	0.32 sec	45%
Cuk Converter	800	0.47 sec	18%
Zeta Converter	1450	0.63 sec	4.85%

VII. CONCLUSION

The modernity of this research work is that the analysis is done on the basis of the settling time, output voltage and THD. The zeta and boost converters are found to be better than the other converters while talking in terms of output voltage and settling time. The zeta converter is the most efficient and reliable as it has inferior THD as compared to other four converters at the time period of steady state about 0.7 sec. which will lead to a more reliable and efficient power system.

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