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A review on Simulation of Hybrid Microgrid System with Renewable Energy Sources

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Abstract: The novel hybrid renewable energy system consists of different sources such as the Photovoltaic (PV) system, Wind Energy system (PMSG), Fuel Cell, and the AC source are implemented as energy sources. The battery and Super Capacitor are used to store excess energy from all sources together which are connected to the DC microgrid. The rapid growth of industries and load consumption increases the energy demand that needs to fulfilling this energy demand can be obtained from various alternative sources has much importance. The DC microgrid simulated in the MATLAB Simulink, the observations and results authenticate that the power generation sources enhance the stability of power, reliability, and power efficiency in the microgrid. Therefore, the grid provides good quality of power to two different loads namely 48V DC output and 110V AC single-phase output. In this proposed system many individualized converters are used in the DC bus to deliver appropriate power in it.
Keywords: MPPT, Organic solar cell, DC micro-grid, Solar PV system, Stability analysis.

I. INTRODUCTION

A microgrid is a local energy grid with control capability consisting of interconnected loads and distributed generators, which means it can disconnect from the traditional power grid and operate autonomously. In recent years all know how rapidly industries are growing and load consumption is increasing because of that the energy demand was increases day by day. In the early 20th century AC power stations and transmission lines would be placed more throughout the countries to the generation of a large number of AC power grids, with the quick adoption of AC power supplies, DC power grids were left behind. Renewable energy sources like wind turbines (PMSG), Photovoltaics (PV) are majorly used in the design of microgrids. If the larger grid fails, a microgrid can provide backup power with the help of a diesel generator to a single building, for a small-town generating power getting from the renewable energy sources and distribute throughout [1].

These DC Microgrids consist of hybrid renewable energy systems consists different sources such as Photovoltaic (PV) system, Wind Energy system (PMSG), Fuel Cell, and the AC source are implemented as energy sources. Microgrid does not define with their size associated to the power consumption, but the U.S. Department of Energy defines them as systems consisting of less than 10MVA which is the standards of load. The battery and Super Capacitor are used to store excess energy from all sources together which are connected to the microgrid [1]. To isolate the system from a larger utility microgrid having an interconnection switch that is used to operate upstream of the grid. The operating voltage of microgrid is depend upon their applications and it must have control capabilities, protection, and monitoring system of all units.

The renewable energy sources and storing units has able to carry a partial load or full load within acceptable and frequency variations. The microgrid consists of a DC sub-system that is used to cover smaller areas, such as a small industry or single building, which may operate at low 120V voltage levels. While the other side a system covering a larger area of several miles can operate at 12kV – 70kV voltage levels commonly seen in sub-transmission and distribution systems [2]. However, the recent power grids failure across the country, communities, and government looking for a more reliable, efficient, and sustainable solution for power needs, DC microgrid has been a solution of unresisted power supply.

Combining renewable energy sources is an important feature because it is decreasing the capital cost required to changeover a system into a microgrid design. Usage microgrid and hybrid renewable energy sources can be utilized and the overall cost of consumers electric bills will be decreased. Using DC microgrids the power generation is localized and minimum energy losses from transmission lines by around 6% decreasing average emissions to produce energy. Additionally, the DC microgrids can Fargo some AC/DC or DC/AC conversions which cause around a 10% efficiency loss because the sources are natively DC producing [2]. Therefore, the system can be economical as well environmentally friendly.

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The hybrid renewable sources self-generated DC power supply with the help of individual convertors and fid to a grid for fulfilling energy demand, sometimes that system-generated excessive power then it will be stored in storing units like battery and super capacitor, etc., also it can supply to the main grid when total production exceeds consumption, the excess power generated is sold back to the main grid.

II. MODELLING OF DC MICROGRID

A DC microgrid system uses the different renewable sources that are generating the power required by the load. The system has comprised the following elements.

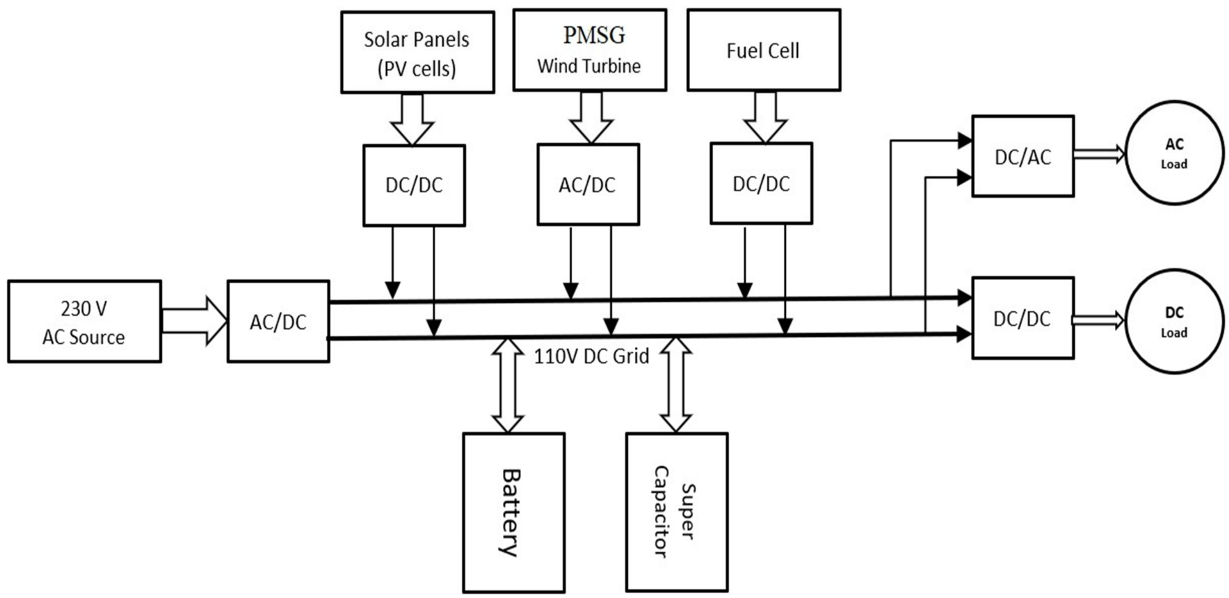

Fig. 1 Configuration of DC Microgrid

1) 110V DC bus which integrates renewable sources, converters, storage components with the local loads.
2) The wind energy system consists of 1kW PMSG, which has a gearless wind rotor and generator, because of that it does not require frequent maintenance.
3) PV module which is made up of semiconductor device (i.e. silicon) with boost converter based on the requirement.
4) 200V Battery and Super Capacitor are integrated into the DC grid via a buck-boost converter.
5) 48V DC load and Varying Single-phase load integrated to the DC grid through Inverter.

III. CONFIGURATION OF PROPOSED SYSTEM

The proposed system is shown in fig.1. It can be divided into three main parts as mentioned above; in this section, we explained the modeling of each source.

A. Solar Pv Panel

The first photovoltaic (PV) module was built in 1954, at Bell Laboratory. PV module is the collection of PV cells and it's made up of semiconductor devices (i.e. silicon) with a boost converter. This system uses one or more solar panels which are connected in series and parallel combinations based on the required power output. The integrated PV module has electrical connections for regulating and modifying the electrical output. When sunlight falls on it with a certain frequency, they produce free electrons due to the electromotive force. The output voltage of the PV array is boosted by a boost converter. Generating energy from the Solar system (PV) is an auspicious and easy technology among renewable energy, and it can be used to find both output voltage and current.

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To understand the performance of PV modules and arrays it is useful to consider the equivalent circuit, which is shown in fig.2,

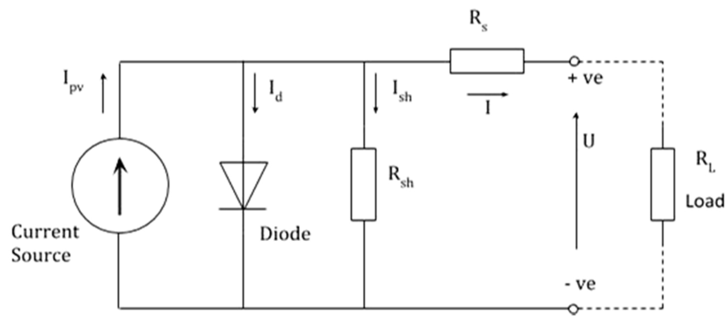

Fig. 2 Equivalent circuit of PV module

Where I be the current through load in ampere, I_{pv} is the current generated by PV in ampere, I_d be the current through a diode in ampere, I_{sh} be the current through a shunt resistor, R_s be the series resistance in ohm, R_{sh} be the shunt resistance in ohm, U be the voltage applied to the load in volt, U_{sh} is the shunt voltage in volt, K be the Boltzmann's constant[7].

The output voltage of the PV array is boosted by a boost converter. Generating energy from the Solar system (PV) is an auspicious and easy technology among renewable energy, and it can be used to find both output voltage and current. If the power increases then a voltage is increased further, if the power decreases then the voltage is reduced [6]. Equation (2) is used to draw the I-V characteristic of the PV cell and shows their I-V Characteristic Curve of PV module in fig. (3).

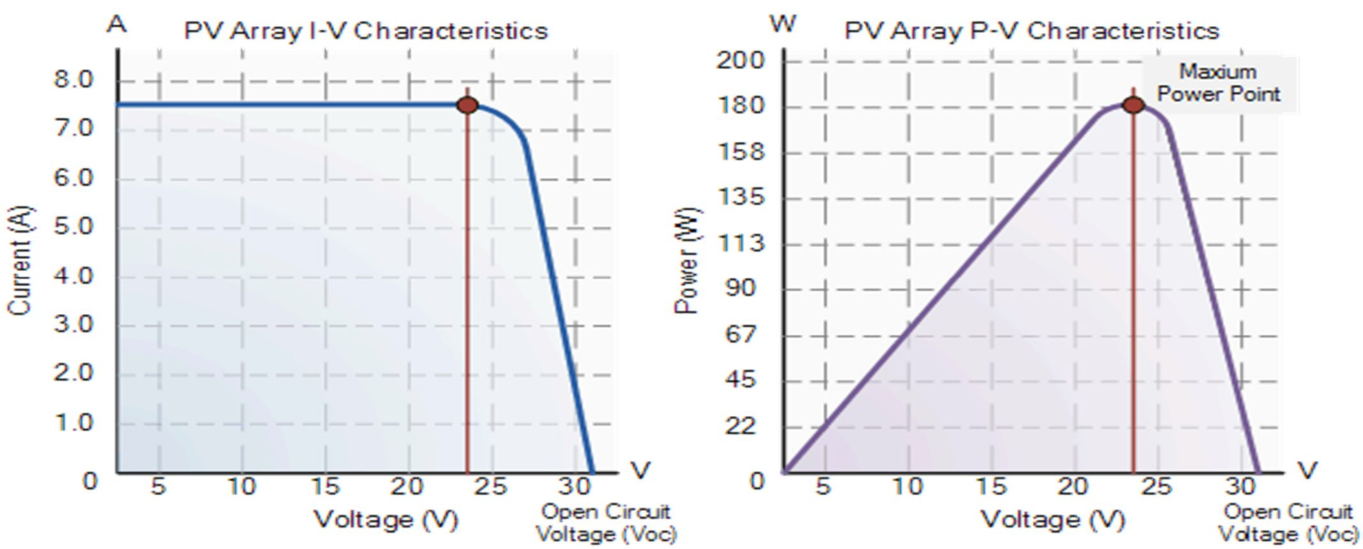

Fig. 3 I-V Characteristic Curve of PV module

Normally the equivalent circuit generally consists of diode, a parallel resistor which limits leakage current, a series resistor (R_s) describing internal resistance to the current flow and a photocurrent.

B. Wind Energy System (WES)

The WES comprises a wind turbine, a PMSG, a rectifier to convert AC-DC and DC-DC boost converter are connected in sequence with the grid. The generating power from wind turbine system is expressed as,

$$P_{WE} = \frac{1}{2} A V^3_{wind} \rho \, Cp\,(\theta, \lambda) \qquad (1)$$

Where, A is the swiping area of the rotor blades in m^2, V_{wind} is the wind velocity in m/s, ρ is the air density in kg/m^3 which is $1.225 kg/m^3$, C_p is the power coefficient and is a function of tip speed ratio (λ) and pitch angle (θ)[3].

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In this system, the variable speed turbine is used. Fig. 2 shows the characteristics of a wind turbine, C_p for different pitch angles at various wind speeds. A gearless permanent magnet synchronous generator (PMSG) is used for its low operation cost and low maintenance. The three-phase output power is rectified by using a diode bridge rectifier (DBR) and with the help of a DC-DC boost converter increases the voltage level as shown in fig. 4.

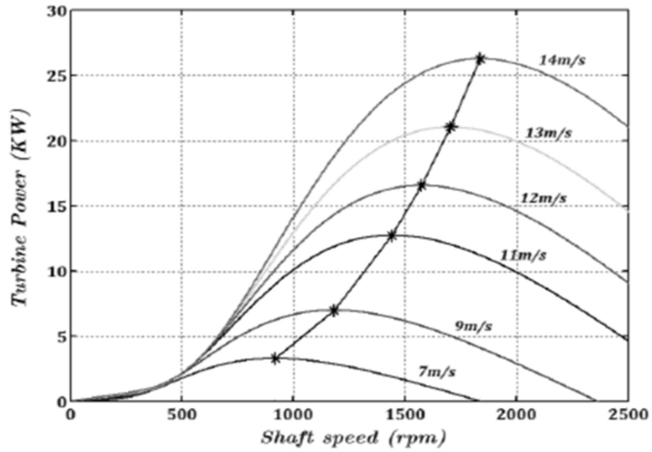

Fig. 4 Characteristics of a wind turbine at a different speed

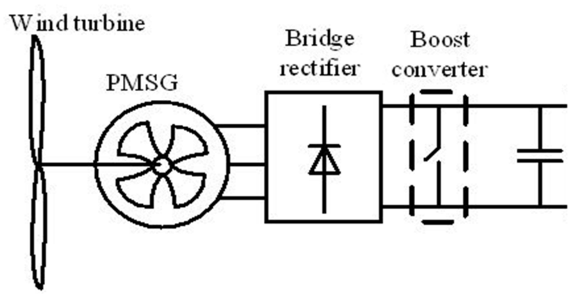

Fig. 5 Wind Energy System (WES)

C. Storage System

The Storage system consists of two units, one a rechargeable battery (Battery energy storage) and the other a super capacitor. Both are connected with a bidirectional DC-DC buck-boost converter for maintaining DC bus voltage.

1) Super Capacitors

A super capacitor is a work on the principle of storing electrical energy, it is the most modernized technology to serve electrical energy storage. A super capacitor is preferred in the place of batteries because they have a quick and simple charging method and can deliver quality power at a faster rate. They have a long life span, reliable and efficient, do not require much maintenance, and do get affected by wear and tear [9-10]. Super capacitors can deliver high load current without any inconvenience because they have a low value of resistance and hence it prohibits from overheating.

Table 1. represent the ambient temperature of some materials for values of relative permittivity.

Materials	ε_r
Bakelite	5.1
Nylon	2.2
Soft Glass	6-7
Teflon	2.6
High permeability oxides	(10-15) e^3
Distilled water	80

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2) Battery Energy Storage

Storing of generated excessive energy in batteries is the most common and useful method in the field of electrical energy storage. In a hybrid renewable energy system, the batteries are charged from chemical energy. Batteries are classified according to the materials that are made, for a long life purpose customer uses nickel-cadmium (Ni-Cd), for higher density they used sodium-sulfur (Na-S), lead-acid batteries easily available at the cheapest cost, lithium (Li-ion) batteries are the most widely used by the costumers [8]. The capacity of the battery can depend on the size and mass of the electrolyte; each battery has a different energy rating based on the capacity. Fig. (6) Shows the working of rechargeable batteries.

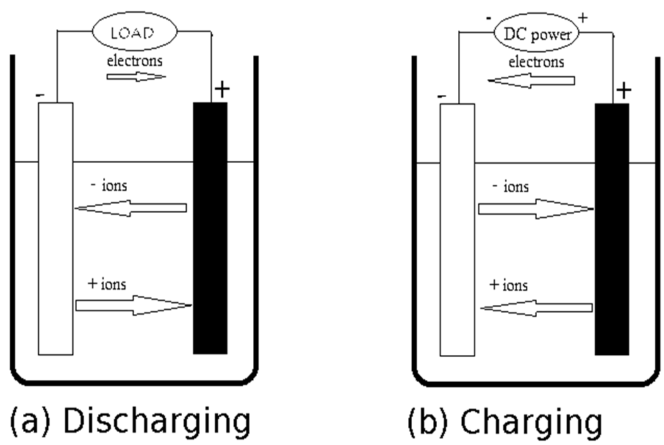

Fig. 6 Working of rechargeable batteries

IV. SIMULATION RESULT

The working simulation diagram of the hybrid renewable system is shown in the fig. (7) this model consists of PVA, wind farm, loads, and AC source with buck and Zeta converter and storage units is designed in MATLAB Simulink environment. After total analysis of this hybrid system, it's clear that the voltage rating of DC bus has 110V from all the renewable sources and it remains constant at whole simulation time, fig. (8) shows the bus voltage.

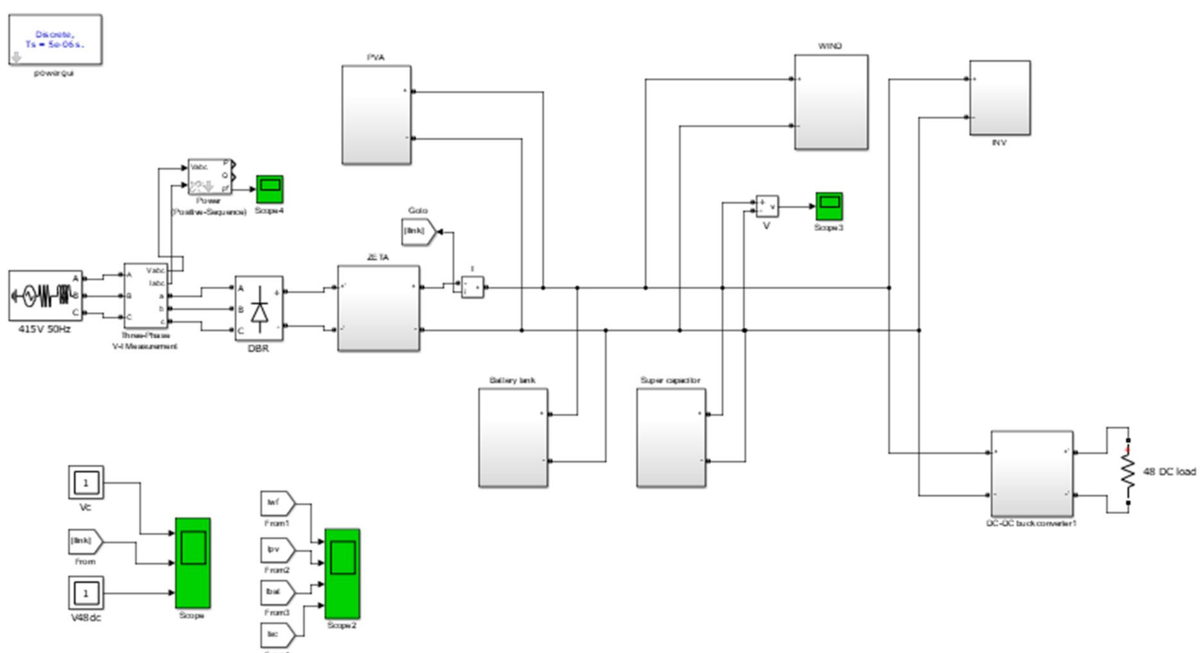

Fig.7 Simulation diagram of the proposed system

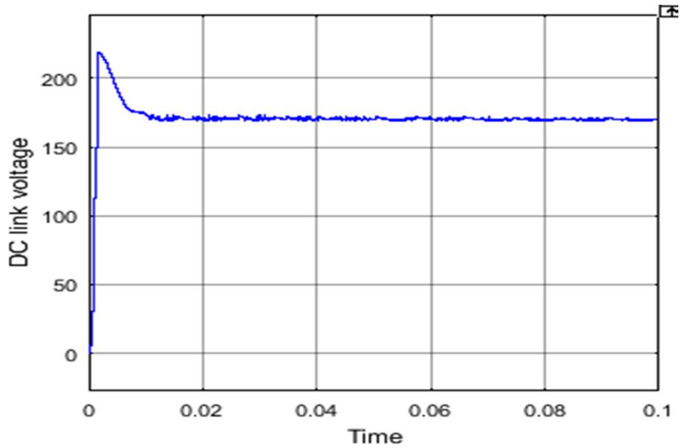

Fig. 8 DC bus voltage

From the graph, the DC bus has 110V and at the load side, we have variable single-phase AC voltage through the inverter circuit and 48V DC load which are shown in fig. (9) and Fig. (10).

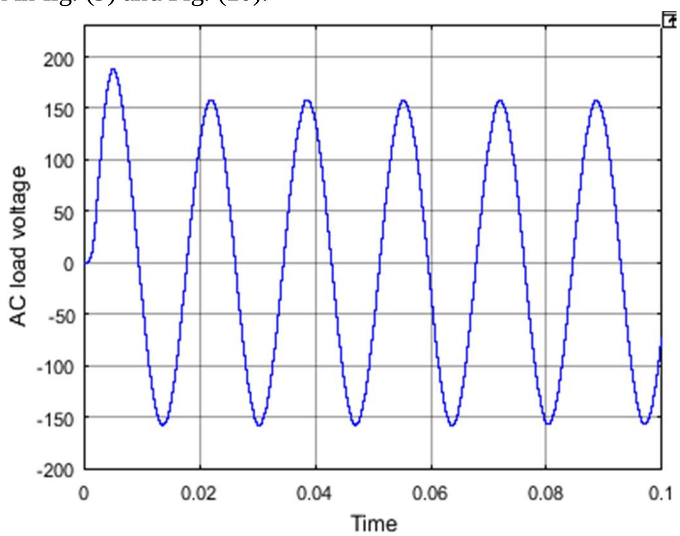

Fig. 9 Output voltage for AC load

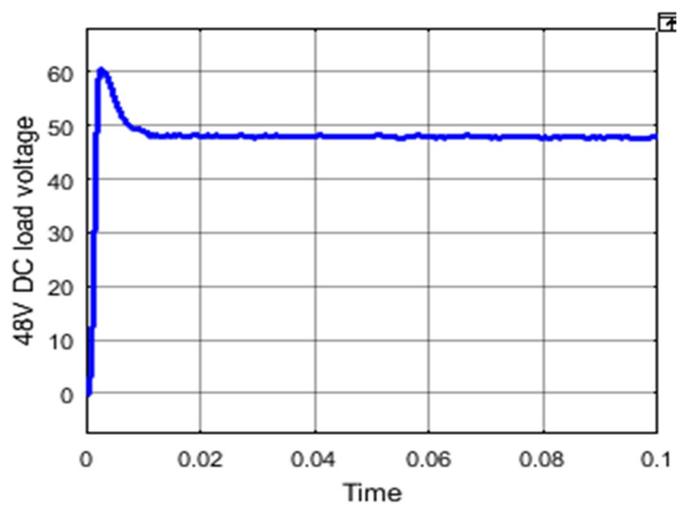

Fig. 10 48V DC load voltage

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The above figures show the modeling of hybrid microgrid with renewable energy sources are reliable, power-efficient, economic, and low maintenance systems. Some results of the simulation are described as follows.

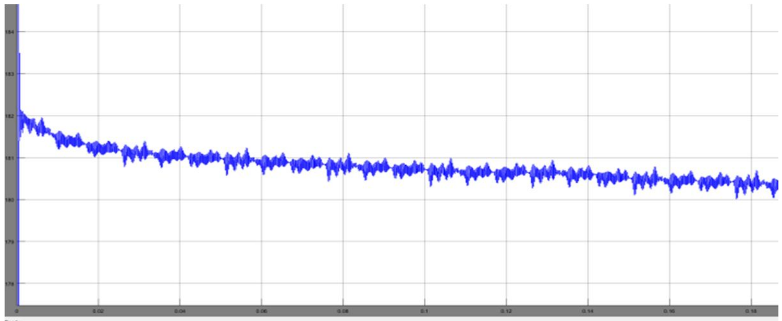

Fig. 12 DC link voltage at Buck converter

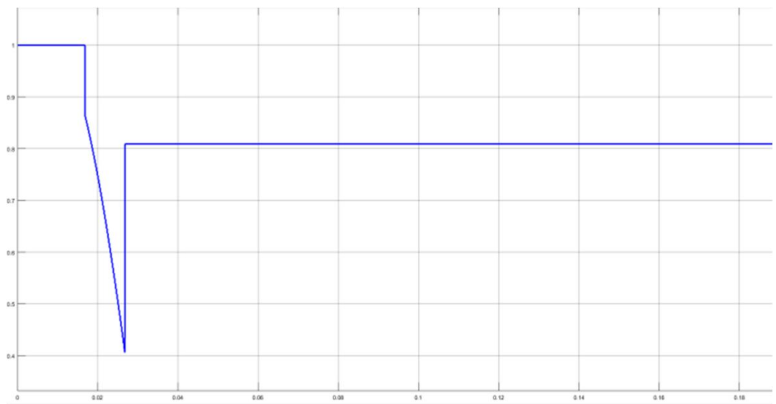

Fig. 13 Power factor of three-phase source with buck converter

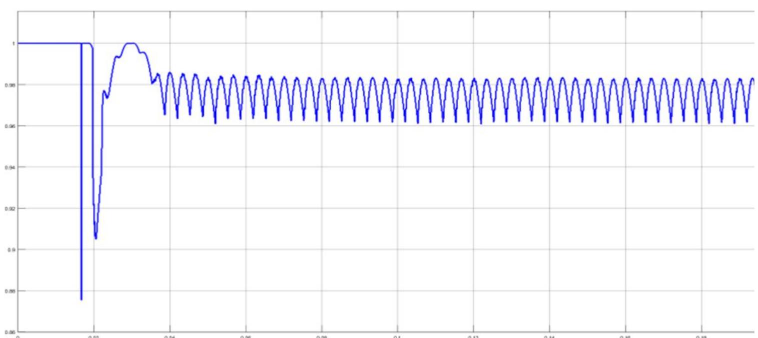

Fig. 14 Power factor of three-phase source with Zeta converter

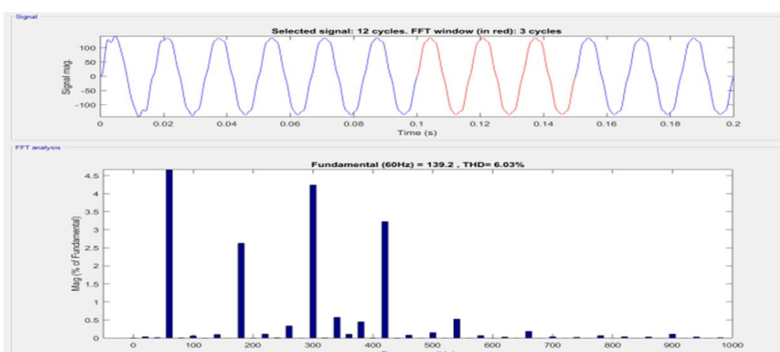

Fig. 15 Total Harmonic Distortion of AC load

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V. CONCLUSION

In this paper, a hybrid renewable energy based microgrid system is developed, analysed, and investigated. In that, we study the behaviour of the grid connected hybrid system with two different loads are connected to them. Using zeta converter ripples are less in DC link, improved power factor 0.8 -0.96, and reducing harmonics in the voltage waveform. This system utilizes an alternating off-grid power transmission system with economic parameters. Various techniques and modeling of storage devices were presented. The simulation result shows that the system has desirable, can maintain better quality power, cost efficient to the customers and utilities easily in all domains.

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