DESIGN AND MODELLING OF MICROGRID

A PROJECT REPORT

Submitted in Partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING

By

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CERTIFICATE

This is to certify that the thesis entitled, "**Design and Modelling of Microgrid"** being submitted by **Mr. Shivanand M. N. and Mr. Maruthi Siva Prasad .Y** for the award of the degree of Bachelor of Technology in Electrical Engineering is a record of bonafide project work carried out by him in the Department of Electrical Engineering of Central University of Karnataka, Kalaburagi.

Mr. Shivanand M N and Mr. Maruthi Siva Prasad has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard. The results obtained here in have not been submitted to any other University or Institute for the award of any degree.

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Shivanand

ABSTRACT

Solar and wind energies are the need of the hour worldwide and their high penetration in electricity power grid cause sensible amount of problems (stick to the grid code of respective country) due to randomness and uncertain generation pattern. Therefore reinforcement of intermittent renewable energy sources requires due attention to achieve optimum economical as well as operational benefit. This paper presents a novel techno-economic optimization method for proper location and size selection of multiple solar and wind generation units in distribution network. The strategic planning method has been tested on a typical Indian rural distribution network. It is shown that the proposed method offers the workable solution to get the desired result.

Nowadays Renewable Energy plays a great role in power system around the world. It is a demanding task to integrate the renewable energy resources into the power grid .The integration of the renewable resources use the communication systems as the key technology, which play exceedingly important role in monitoring, operating, and protecting both renewable energy generators and power systems. This paper presents about the integration of renewable energy mainly focused on wind and solar to the grid.

KEYWORDS: Communication Systems, Grid, Renewable Energy, Solar Power, Wind Power

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CHAPTER-1

INTRODUCTION

Due to the critical condition of industrial fuels which include oil, gas and others, the development of renewable energy sources is continuously improving. This is the reason why renewable energy sources have become more important these days. Few other reasons include advantages like abundant availability in nature, eco-friendly and recyclable. Many renewable energy sources like solar, wind, hydel and tidal are there. Among these renewable sources solar and wind energy are the world's fastest growing energy resources. With no emission of pollutants, energy conversion is done through wind and PV cells.

Day by day, the demand for electricity is rapidly increasing. But the available base load plants are not able to supply electricity as per demand. So these energy sources can be used to bridge the gap between supply and demand during peak loads. This kind of small scale stand-alone power generating systems can also be used in remote areas where conventional power generation is impractical.

In this thesis, a wind, photovoltaic, battery and Diesel Generator hybrid power generation system model is studied and simulated. A hybrid system is more advantageous as individual power generation system is not completely reliable. When any one of the system is shutdown the other can supply power.

1.1 Feature of Micro Grid

- Hybrid systems can address limitations in terms of fuel flexibility, efficiency, reliability, emissions and / or economics.
- Incorporating heat, power, and highly efficient devices (fuel cells, advanced materials, cooling systems, etc.) can increase overall efficiency.
- Conserve energy for a hybrid system when compared with individual technologies.

- Achieving higher reliability can be accomplished with redundant technologies and/or energy storage.
- Some hybrid systems typically include both, which can simultaneously improve the quality and availability of power.

  i. Hybrid systems can be designed to maximize the use of renewable.
  ii. Resulting in a system with lower emissions than traditional fossil-fueled technologies.
  iii. Hybrid systems can be designed to achieve desired attributes at the lowest acceptable cost, which is the key to market acceptance.

Advantages of Micro Grid.

Hybrid systems that use renewable energy sources, such as solar and wind resource, may be feasible and an alternative to supply electricity to remote or isolated areas from the national grid and help in reducing the use of fossil fuels, dependence on costly fuel, and reduce the emission of greenhouse gases.

The main advantages of hybrid systems compared to single ones are presented below:

- Complementarity between sources of the system: intermittency of sources involved can be partially or completely overcome, ensuring continuity and quality of the electricity produced by the system;

- Modularity of the involved sources: photovoltaic modules, turbines, and batteries can be purchased gradually of the system, provided there is natural growth of the system in line with the availability of financial resources, energy potential and area for the system installation;

- The socio-economic impacts, in general, are characterized as products for the deployment of hybrid systems. In most instances the impacts have more beneficial features than harmful, especially when treating with small generation systems as is proposed in the present work. It is also noted the Rural population growth, because it can combat the rural exodus, the increase of local commercial activities (bars, warehouses), agriculture, education and telecommunication, which is made possible by the wider use of electricity.

As for environmental impacts, they are primarily related to the end-of-life issues and recycling of the used equipment, primarily the management of batteries (there is a need for a recycling program); to the visual and noise aspect from the rotation of the wind turbines blades, and occupation of space used for equipment installation of the hybrid system. Hybrid systems may represent a viable alternative for technical, financial, social and environmental criteria, including advantages with regard to the extension of the power grid or the local power generation by diesel systems.

Block Diagram of Micro Grid

The fig.1 shows complete architectural development of Micro Grid system with different energy sources. AC bus and DC bus are included in the system to provide the separate load voltages. Sources of energy includes Solar Photovoltaic system, Wind energy and Diesel Generator with Battery Connected. Power electronic devices are used in controlling and converting different voltages.

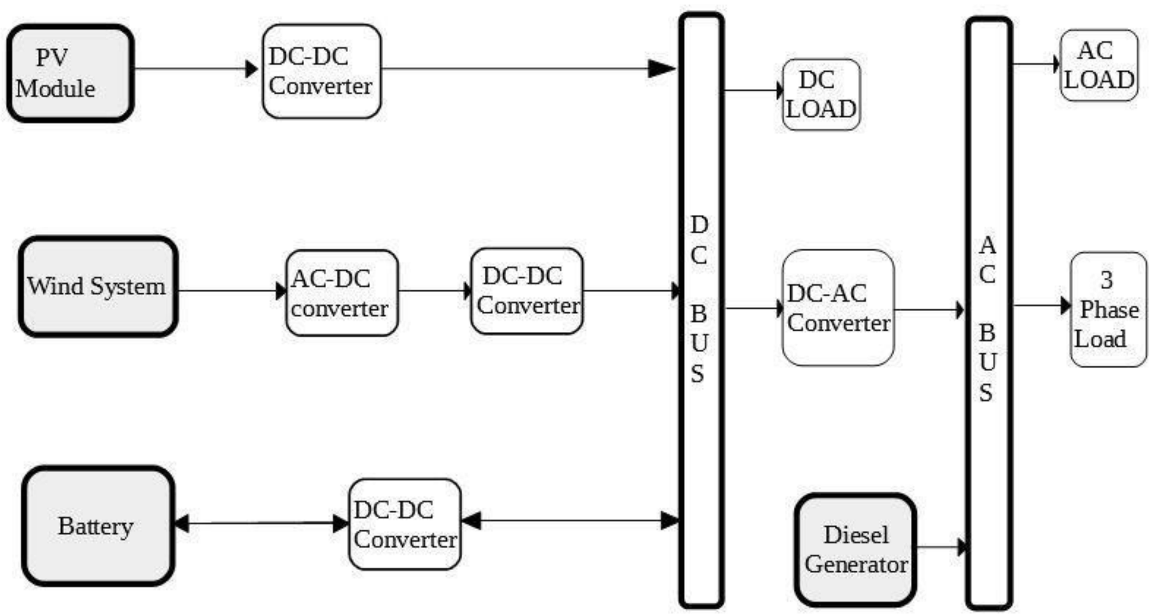

Fig. 1 Block Diagram of Micro-grid

CHAPTER-2

LITERATURE REVIEW

In India, there is severe power shortage and associated power quality problems. The quality of the grid supply in some places is characterized by large voltage and frequency fluctuations, scheduled and unscheduled power cuts and load restrictions. Load shedding in many cities in India due to power shortage and faults is a major problem for which there is no immediate remedy in the near future since the gap between the power demand and supply is increasing every year. Wind and solar energy sources are available all over the year at free of cost whereas tidal and wave are coastal area. Geothermal is available at specific location. To meet the demand and for the sake of continuity of power supply, storing of energy is necessary.[1]

The term hybrid power system is used to describe any power system combine two or more energy conversion devices, or two or more fuels for the same device, that when integrated, overcome limitations inherent in either.[2]

Usually one of the energy sources is a conventional one (which necessarily does not depend on renewable energy resource) powered by a diesel engine. While the other(s) would be renewable viz. solar photovoltaic, wind or hydro. The design and structure of a hybrid energy system obviously take into account the types of renewable energy sources available locally, and the consumption the system supports. For example, the hybrid energy system presented here is a small-scale system and the consumption of power for higher load demand.[4]

The wind energy component will make a more significant contribution in the hybrid system than solar energy. Although the energy produced by wind during night can be used directly without storage. Battery is needed to store solar and wind energy produced during the day. In addition to the technical considerations, cost benefit is a factor that has to be incorporated into the process of optimizing a hybrid energy system. In general, the use of wind energy is cheaper than that of solar energy. In areas where there is a limited wind source, a wind system has to be over-dimensioned in order to produce the required power, and this results in higher plant costs. It has been demonstrated that hybrid energy systems (renewable coupled with conventional energy source) can significantly reduce the total life cycle cost of a stand-alone power supplies in many off-grid situations.[11]

While at the same time providing a reliable supply of electricity using a combination of energy sources. Numerous hybrid systems have been installed across the world, and expanding renewable energy industry has now developed reliable and cost competitive systems using a variety of technologies. Research in the development of hybrid systems focused on the performance analysis of demonstration systems and development of efficient power converters. [5]

India has a large potential for renewable energy (RE), an estimated aggregate of more than 100,000 MW. In addition, the scope for generating power and thermal applications using solar energy (since most parts of the country receive sunlight almost throughout the year) is huge. However, only a fraction of the aggregate potential in renewable, and particularly solar energy, has been utilized so far. [3]

CHAPTER-3

COMPONENTS OF MICRO GRID

3.1 PHOTOVOLTAIC ENERGY SYSTEM

Solar energy is that energy which is gets by the radiation of the sun. Solar energy is present on the earth continuously and in abundant manner. Solar energy is freely available. It doesn't produce any gases that mean it is pollution free. It is affordable in cost. It has low maintenance cost. Only problem with solar system it cannot produce energy in bad weather condition. But it has greater efficiency than other energy sources. It only need initial investment. It has long life span and has lower emission.

A simulation must be performed for system analysis and parameter settings during design process of PV powered systems. Therefore an efficient user friendly simulation model of the PV Arrays is always needed.

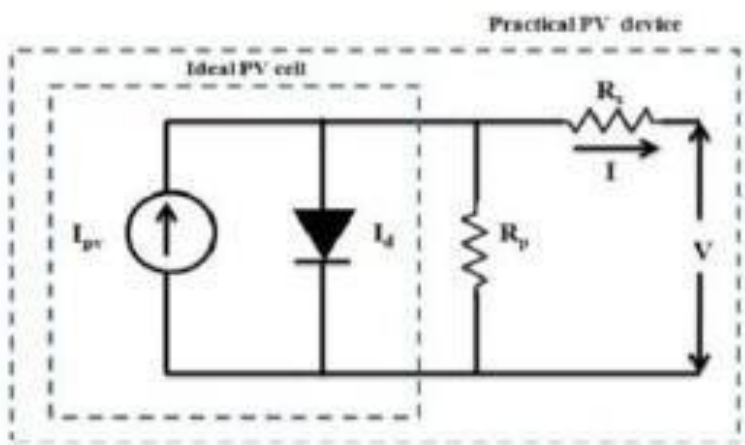

Fig.2. Generalized model of PV Cell

The model can be developed by using equivalent circuit of PV cell. From the theory of Photovoltaic system the basic equation that mathematically describes I-V characteristic of the ideal photovoltaic cell shown in Fig. 2

$$I = I_{pv,cell} - I_{0,cell}\left[exp\left(\frac{qV}{akT}\right) - 1\right]$$ ---- 3.1.1

- $I_{pv,cell}$ - the photo-generated current
- $I_{o,cell}$ -reverse saturation or leakage current of diode
- a - the diode quality factor
- q - the electronic charge, $1.6 \times 10^{-19} C$
- k - the Boltzmann's constant, $1.38 \times 10^{-23} J/K$
- T - the ambient temperature, in Kelvin

3.1.1 Photovoltaic Module

PV Module Available in the Matlab library which is used for modeling solar energy.

Table-1 Solar Module parameter

Module	Soltech 1STH-215-P(Matlab Library)
Maximum Power	213.15W
Open circuit Voltage	36.3V
Short-Circuit Current	7.84A
Diode Saturation current	2.9259e-10A
Diode ideality factor	0.98117
Shunt Resistance	313.3991 ohm
Series resistance	0.39383 ohm

Parallel strings	40
Series-connected modules per string	10

3.1.2 PV Model designed by using Simulink

The PV array has 40 parallel string in which each string has 40 series connected modules giving out 36.3V as open circuit voltage and 7.84A as Short circuit current. Constant voltage at output terminal maintained by using the PI controller, by providing gate pulse to IGBT as shown in the fig.3

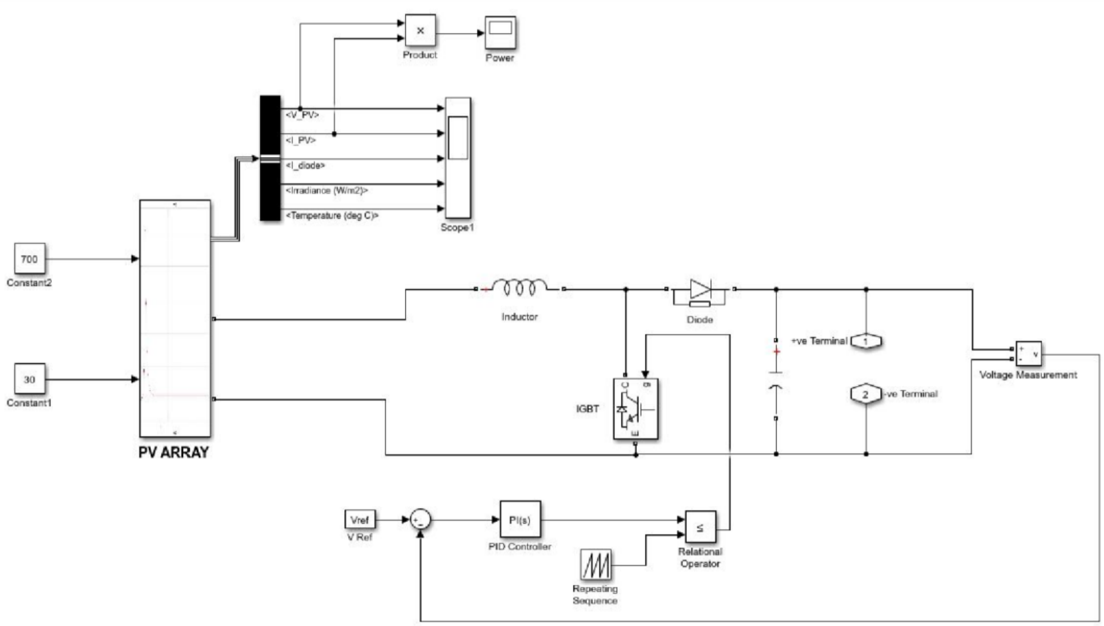

Fig. 3 Matlab Model of PV system with Boost Converter

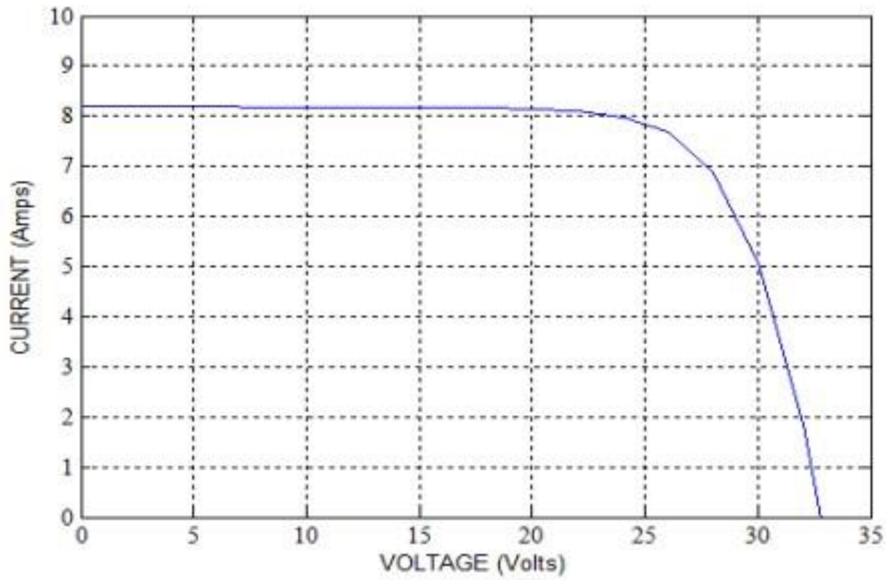

Fig. 4 I-V Characteristics of Solar PV

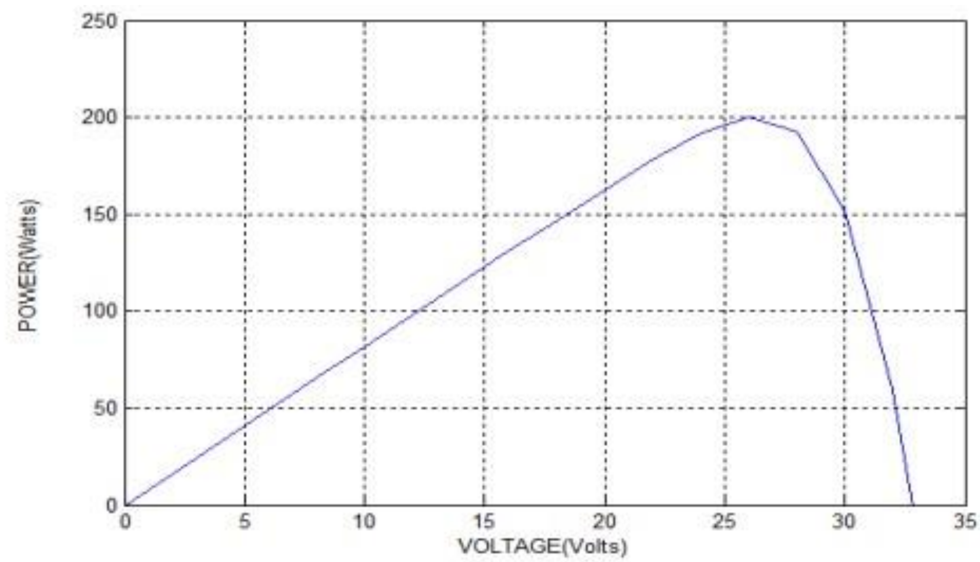

Fig. 5 P-V Characteristics of Solar PV

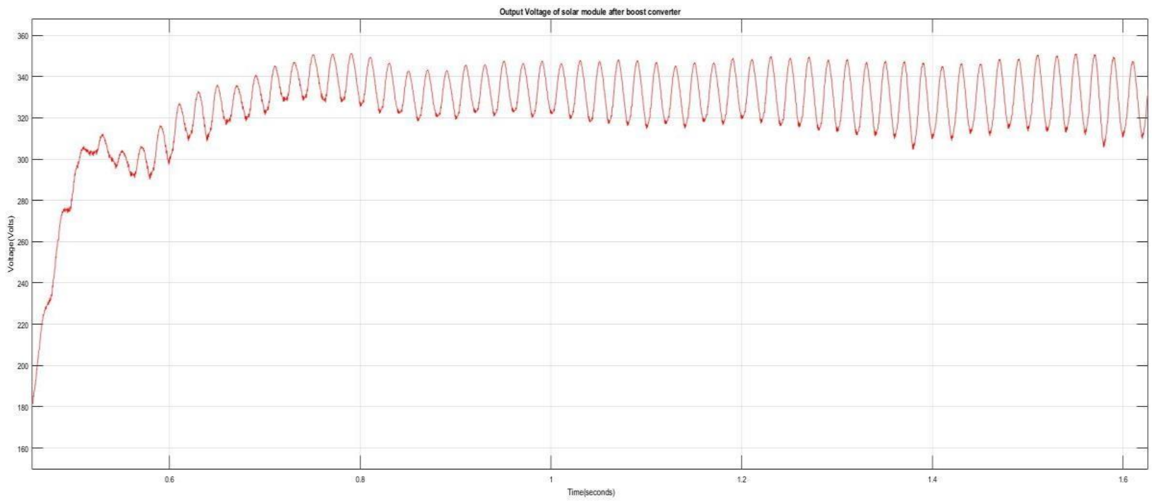

Fig.6 Output Voltage of PV after using Boost Converter**.**

3.2 Wind Energy System

3.2.1 Introduction

The Wind is the continuous movement of atmospheric air masses and is determined by its speed and orientation. This movement derives from the changes and the different values of the atmospheric pressure while these values are the result of the solar heating of different parts of the earth's surface. Despite the fact that the atmospheric air moves horizontally and vertically as well, only its horizontal movement is actually considered as wind.

Wind energy is the conversion of a small percentage, about 0.2%, of the solar radiation that reaches the surface of the earth. The wind power around the globe is estimated in 3.6×109 MW while, according to valid estimations of the world meteorology organization, the percentage which is available for energy exploitation in various parts of the world is only 1% and it is estimated around 0.6Q (175×1012 KWh).

Many scientists support that the proper exploitation of the wind energy can resolve in a way the world's energy problem. For instances, the energy needs in here hardly constitute the one tenth of the wind energy potential of the country.

Nowadays a total of 59,100 MW of wind generated capacity is installed around the world, with an average annual growth rate of 29 percent over the last ten year. Although each coin has two sides and thus wind energy can't be easily predicted neither can its continuous operation. Wind is a form of energy with low density, something which implies that large structures have to be made for its exploitation.

Undoubtedly the wide use of the wind energy and its efficient exploitation is going to improve the global energy balancing without overloading at the same time the environment with dangerous gases.

3.2.2 Wind Turbine

This system comprises of a wind turbine which transforms wind's kinetic energy into rotating motion, a generator which converts mechanical energy into electrical energy and the output ac is fed to rectifier to convert it into dc voltage. Control and Supervision unit will match the maximum power point tracing parameter to extract maximum energy.

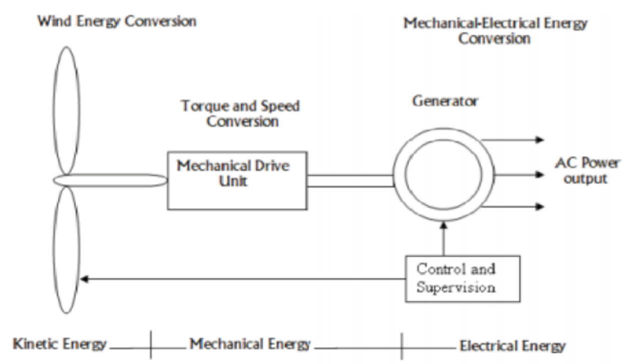

Fig. 7 The schematic diagram of the wind energy system

3.2.3 Mathematical modeling of Wind Turbine

A wind turbine converts kinetic energy of air i.e. wind power into mechanical power i.e. rotating motion of the turbine that can be used directly to run the machine or generator. Power captured by wind turbine blade is a concomitant of the blade shape, the pitch angle, speed of rotation, radius of the rotor . The equation for the power generated is shown below

$$Pm = 0.5 * \Pi * \rho * Cp * R^2 * V^3 \text{ ------------ } 3.2.1$$

Where, Pm -- Power captured by wind turbine

ρ -- Air density

β -- Pitch angle (in degrees)

R --- Blade radius (in meters)

V -- Wind speed (in m/s)

The term is the tip-speed ratio, given by the equation

$$\lambda = \omega * R \div V \text{ -------------- } 3.2.2$$

Where

ω = Rotar speed of rotation(in rad/sec)

Cp can be expressed as the function of tip speed ratio(λ)

$$Cp\ (\lambda, \beta) = C1 * (C2/\lambda i - C3 * \beta - C4)^{(-C5/\lambda i)} + C6 * \lambda) \text{ ----------- } 3.2.3$$

$$1/\lambda i = 1/(\lambda + 0.08 * \beta) - 0.035/(\beta^3 + 1) \text{ ---------------- } 3.2.4$$

Where,

Cp - wind turbine performance coefficient

λ - Tip speed Ratio

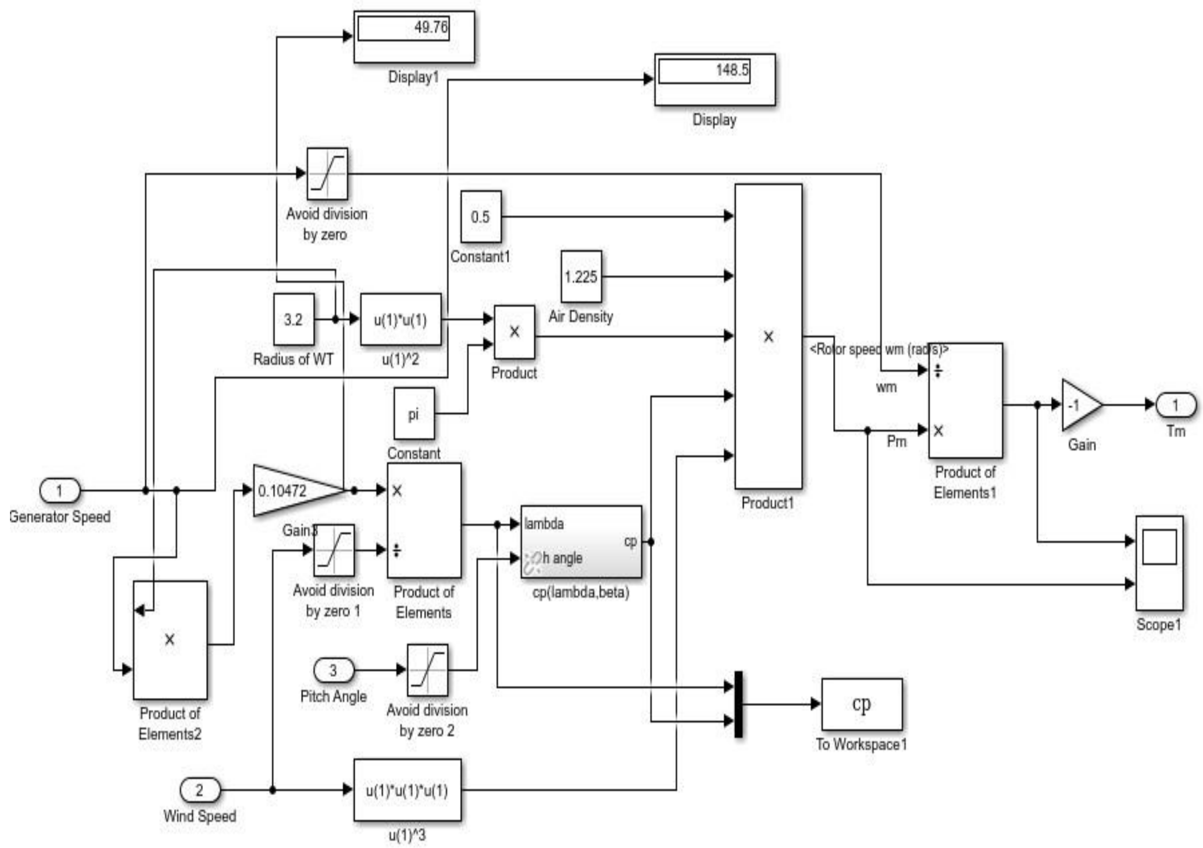

Fig. 8 Matlab Model of Turbine

Wind Turbine parameters

Tableno.2 Wind Turbine Parameter

PARAMETER	VALUE
Base wind speed	9(m/s)
Coefficient(C1- C6)	[0.5176,116,0.4,5,21,0.0068]
Nominal performance coefficient	0.48pu for [$\beta = 0, \lambda = 8.1$]

3.2.4 Generator

The shaft of the wind turbine is mechanically coupled to the rotor shaft of the generator, so that the mechanical power developed by the wind turbine (by kinetic energy to mechanical energy conversion) is transmitted to the rotor shaft. This rotor structure has a rotor winding (either field or armature).In both the cases, we get a moving conductor in a stationary magnetic field or a stationary conductor in moving magnetic field. In either case, electric voltage is generated by the generator principle.

3.2.4.1 Types of Generator

Generators can be basically classified on the type of current. There are alternating current generators and direct current generators. But in either case, the voltage generated is alternating. By adding a commutator, we convert it to direct current. So for convenience, we go for alternating current generator In the AC generators, we can further classify them based on the rotor speed. There are synchronous generators (constant speed machine) and asynchronous generators (variable speed machine or the induction machine).

In the synchronous generators we have salient pole rotor and the cylindrical (non-salient pole) rotor. Based on the speed requirement/availability, we can go for cylindrical rotor for high-speeds and salient pole rotor for low speeds. Another classification is based on the magnetic field. The magnetism can be done by either permanent magnet or an Electromagnet. In order to reduce the supply requirement, we go for the permanent magnet synchronous generator (PMSG) for the power generation using wind energy An induction motor running with negative slip can operate as an induction generator. But this generator is not self-exciting and this has to be excited by a source of fixed frequency. It already needs an exciter for stator. So this machine has to be fed by two supplies and hence it is called doubly fed induction machine or generator So doubly fed induction generator (DFIG) and permanent magnet synchronous generator (PMSG) are suitable for wind power generation. We are using PMSG in our work.

Table no. 3 Generator Parameter

Rotor type	Salient pole
Nominal voltage(line to line)	300(V)
Nominal frequency	50(hz)
Nominal Revolution per minute	2300(rpm)
Stator Resistance	0.01282(pu)
Stator Inductance	0.05051(pu)
Rotar resistance	0.00702(pu)
Rotar inductance	0.05051(pu)
Pair of poles	4
Magnetizing Inductance	6.77(pu)

3.2.5 Simulink model of Wind turbine with PMSG

Model designed with power rating of 3.18KW and voltage rating of 300V. Wind speed at pitch angle values are fed into the wind turbine block to get the unidirectional torque which drives the generator hence provide the voltage across the terminals. Rectified voltage is boosted to rated dc bus voltage level.

The following figures are outputs obtained from the wind energy system of the microgrid system. Fig.9 describes the mathematical model of the wind energy system. Fig.10 describes the turbine power characteristics w.r.t to the varaiable speeds for tracking the maximum power point of the system. Fig.11 describes the three phase line to line output of PMSG. Fig.12 Describes the DC-link voltage of the DC Converter.Fig.13 Describes the final output of the wind turbine after boost converter.

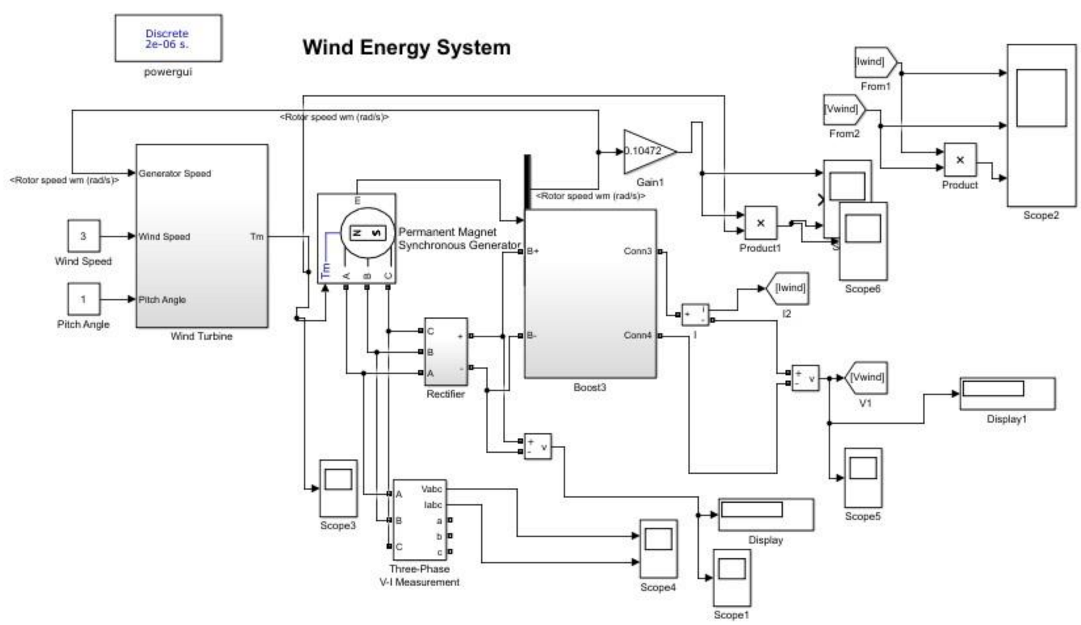

Fig. 9 Matlab Model of wind energy system

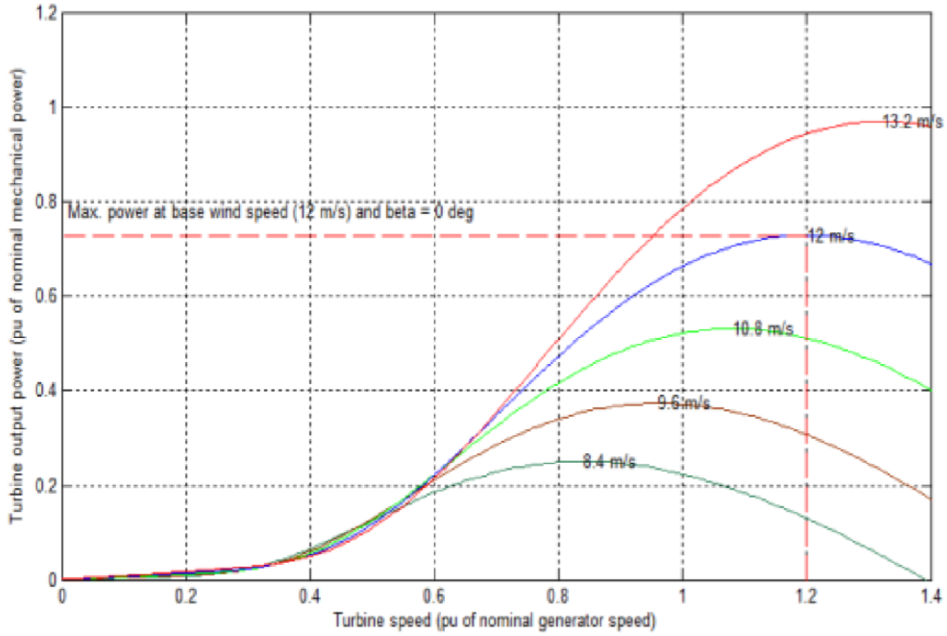

Fig. 10 Turbine Power Characteristics

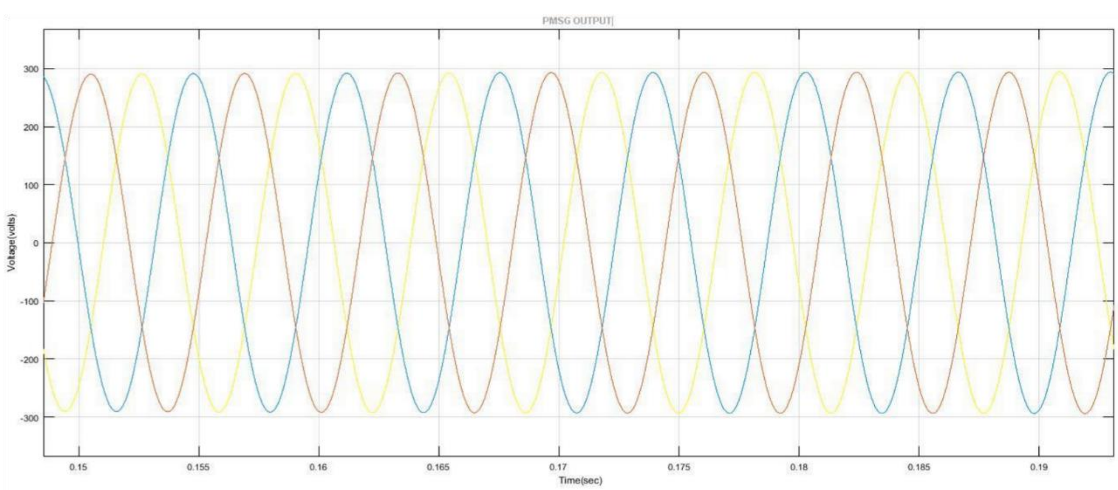

Fig. 11 Three phase line output voltage of PMSG

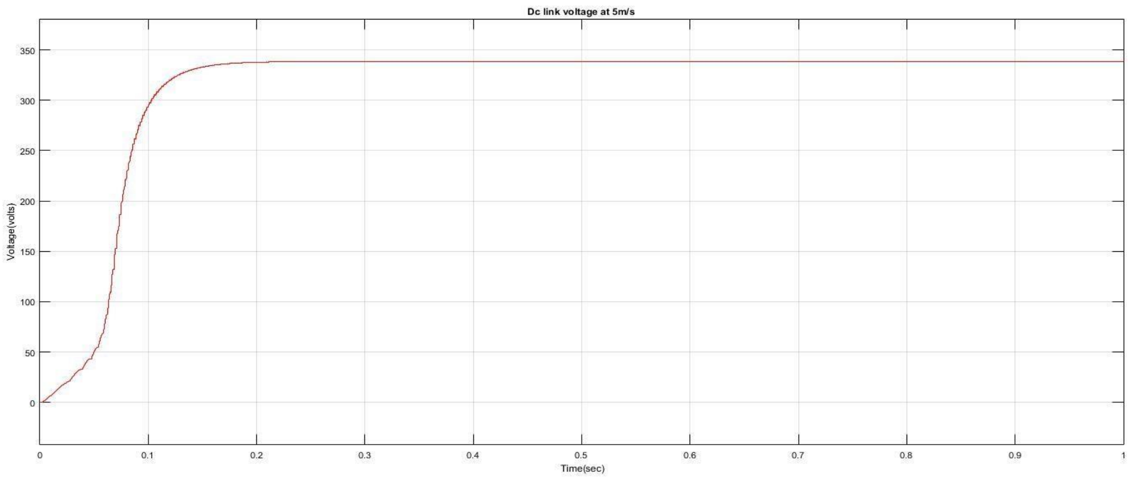

Fig. 12 Dc link voltage of wind turbine

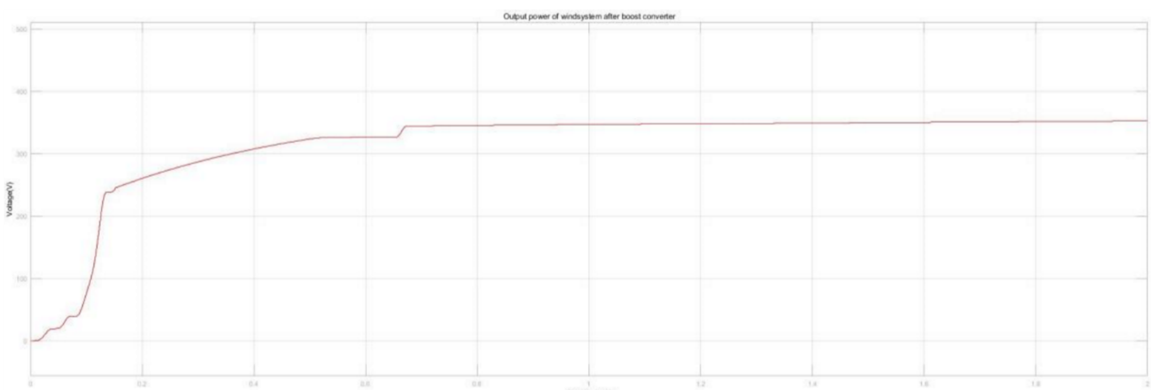

Fig. 13 Output of wind turbine after boost converter

3.3 Diesel Energy System

A diesel generator is the combination of a diesel engine with an electric generator to generate electricity for emergency need. In our model Diesel generator is used mainly as emergency energy employment at exceeded load demand or the isolation of the system from the renewable energy sources. As you can see from the fig. 1.1 Diesel generator is connected to AC. Generated output voltage is constant 415V by stepping down the voltage by using transformer.

Table 4 are the Synchronous Machine parameter used for designing the diesel generator

Table-4 Synchronous Machine Parameters

Type of Machine	Synchronous Machine
Nominal Power	8100W
Voltage	400V
Frequency	50Hz
Number of poles	4
Angular Speed(w)	1500rpm

Providing mechanical power to the synchronous generator as engine output to get the electrical energy. As shown in fig 7, inputs are provided at constant rate and the RMS value is measure at mean value block. Terminals are connected to Transformer for stepping down the voltage.

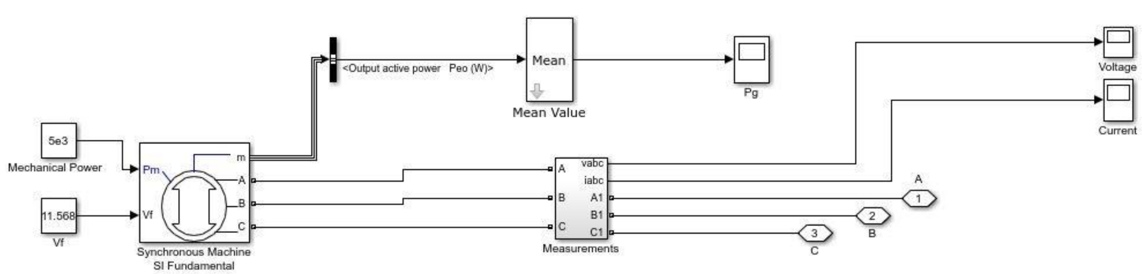

Fig. 14 Matlab Model of Diesel Generator

3.4 Battery System

To support the typical micro-grid structure and to provide the backup power to dc power loads as well as few ac loads. This batter is designed to give Boosted 380V to Dc bus.

Which is controlled by using controller for charging and discharging of the system

Table-5 Battery parameters

Type of Battery	Lead-Acid
Nominal Voltage	12V
Rated Capacity	360Ah
Battery response time	30s
Cut-off Voltage	9V
Nominal Discharge Current	72A
Internal Resistance	0.0003333333Ohm
Fully Charged Voltage	13.0658V
Maximum Capacity	375Ah
Number batteries	10

3.5 DC-DC Converters

The current carried by inductor starts rising and it stores energy during ON time of the switching element. The circuit is said to be in charging state. During OFF condition, the reserve energy of the inductor starts dissipating into the load along with the supply. The output voltage level exceeds that of the input voltage and is dependent on the inductor time constant. The load side voltage is the ratio of source side voltage and the duty ratio of the switching device.

CHAPTER-4

MODELLING OF MICROGRID

To uninterrupted power supply to consumer after shifting from conventional energy system to renewable energy sources. It is necessary to have more than one energy resource. Basically this system involves integrating wind, solar and diesel generator with Battery storage as the resources of energy. To give continuous power supply to load demand. Solar panels are used for converting solar energy and wind turbines are used for converting wind energy into electricity. This electrical power can utilize for various purpose. Generation of electricity will be takes place at affordable cost.

Rectified three phase of wind generation is connected to DC bus of 380V. Solar panel voltage is boosted to get 380v of dc to DC bus. Combination of Battery storage with same voltage is connected to the DC bus giving the Out terminals to connect the DC load.

Those DC BUS terminals can be used to convert from dc to three phase supply and connected different loads. It is connected to AC Bus with Diesel generator giving 415V of three phase supply to loads.

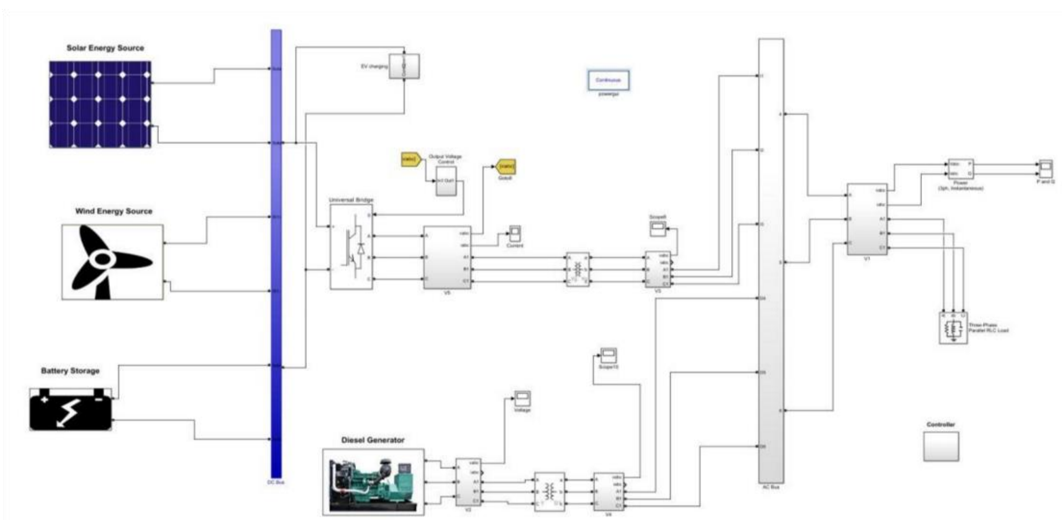

Fig.15 Matlab Model of Micro-grid System

4.1 Matlab Simulink Results for Overall Micro grid

The Fig 16-21 are the results obtained when the wind energy system is integrated with different energy sources like diesel generator, PV-system, and other backup systems like Battery charger and its controllers.Fig.16 describes the inverter three phase line-line output voltage.Fig.17 describes the active and reactive power output for 1KW rating loadFig.18 describes the three phase transformer output without using ripple filter.

Fig.19 Describes the voltage and current reading for 1KW rating of load.Fig.20 describes the micro-grid AC bus voltage.Fig.21 describes the micro-grid DC bus voltage of the system The AC and DC bus voltages are maintained under the limits and following the prescribed International standard.

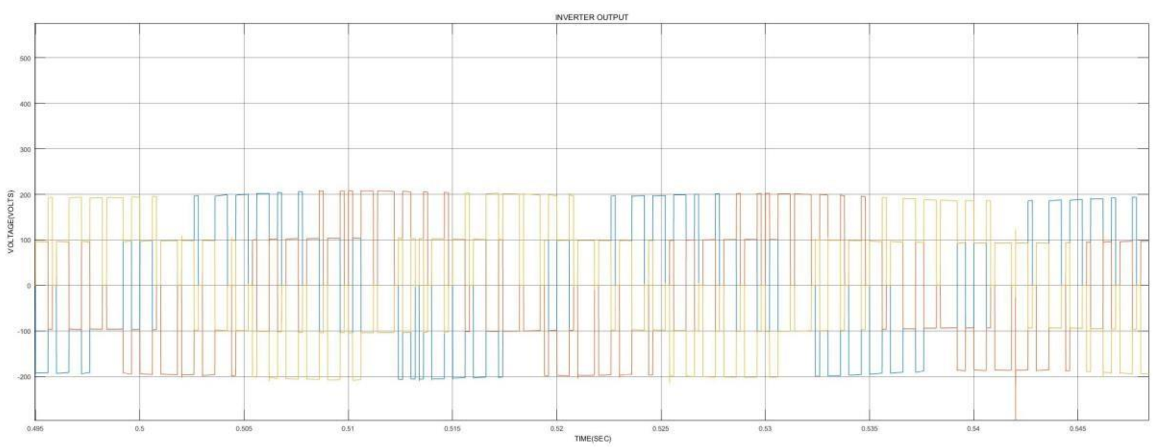

Fig. 16 Three phase inverter Output

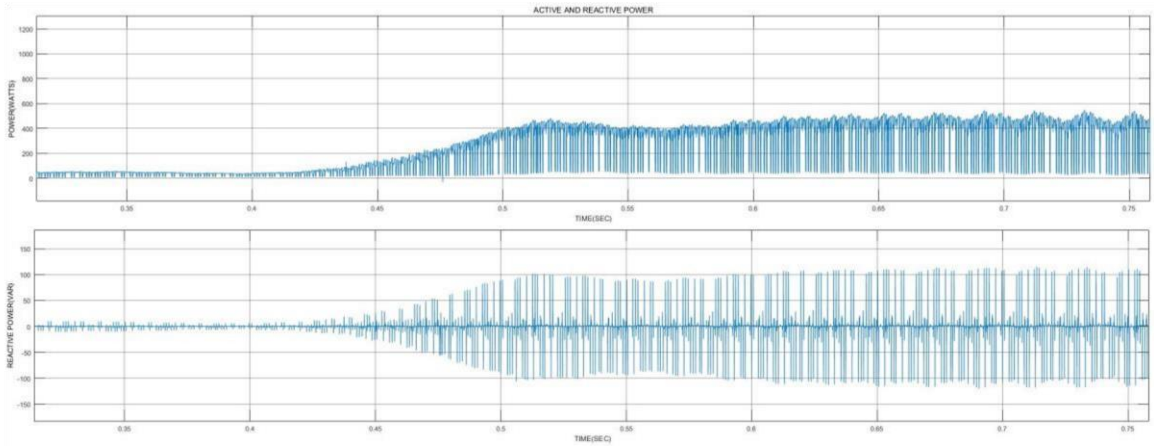

Fig.17 Active and Reactive power for 1KWatt

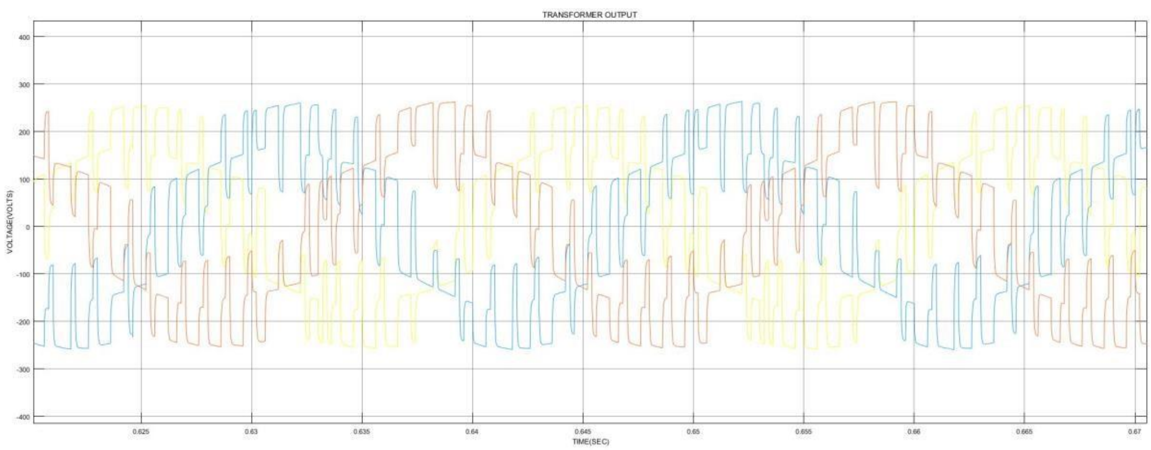

Fig.18 Output voltage of Three phase Transformer without filter

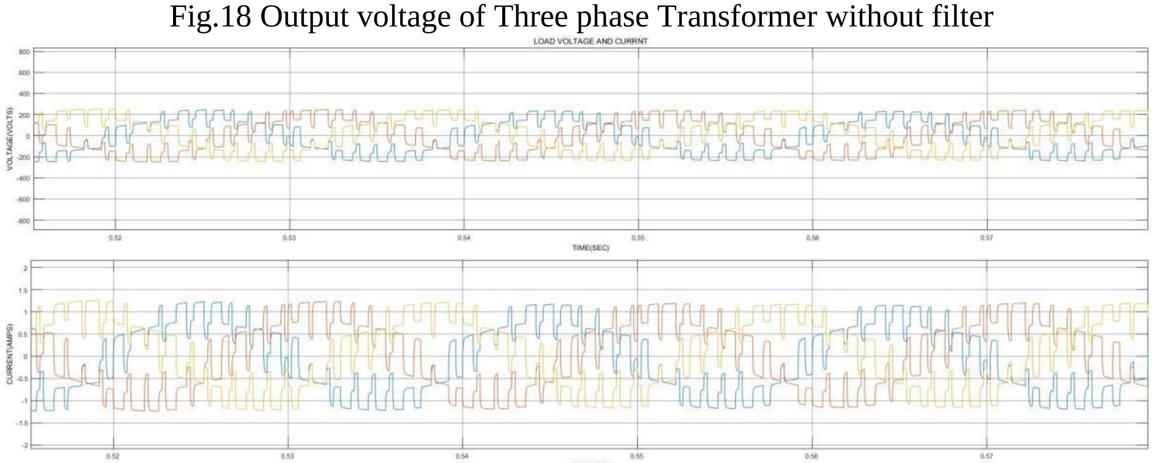

Fig.19 Voltage and Current for 1KW Load

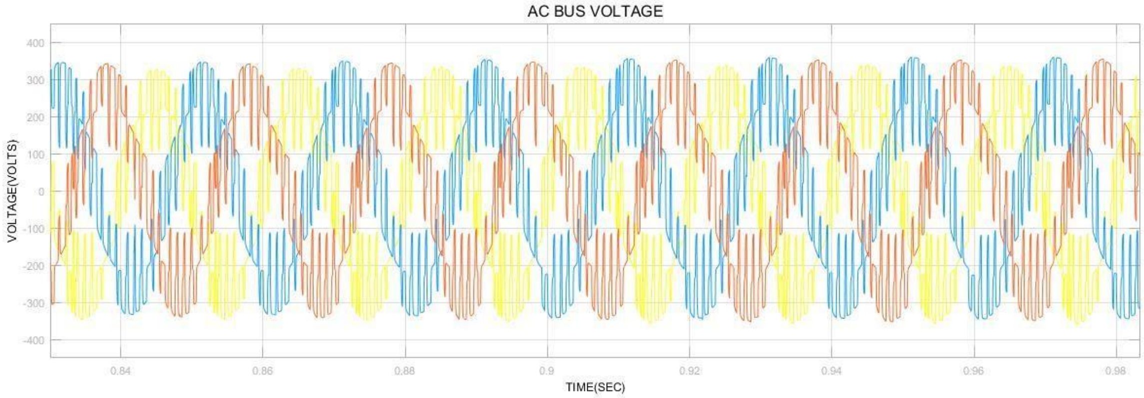

Fig.20 Micro-grid AC BUS Voltage

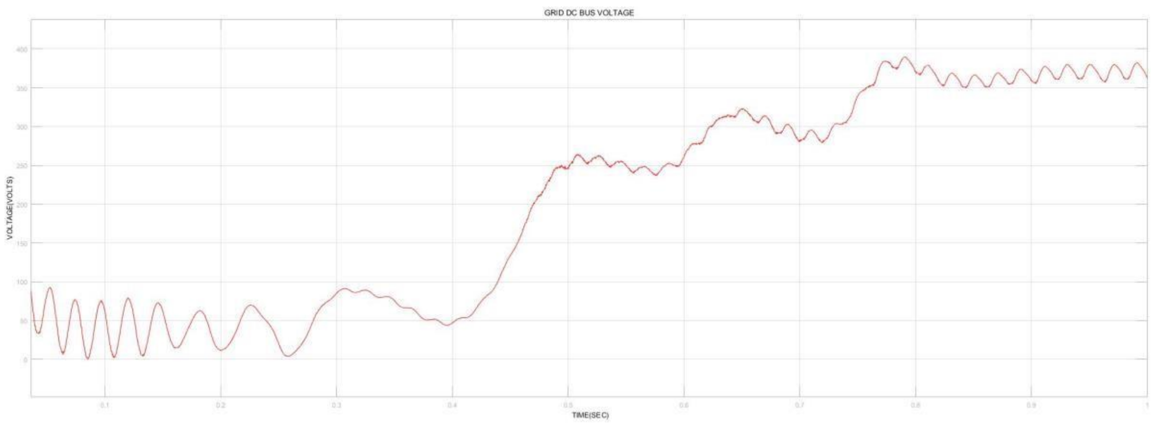

Fig.21 Micro-Grid DC BUS Voltage

CHAPTER-5

CONCLUSION AND FUTURE SCOPE

Hybrid power generation system is good and effective solution for power generation than conventional energy resources. It has greater efficiency. It can provide to remote places where government is unable to reach. So that the power can be utilize where it generated so that it will reduce the transmission losses and cost. Cost reduction can be done by increasing the production of the equipment. People should motivate to use the nonconventional energy resources. It is highly safe for the environment as it doesn't produce any emission and harmful waste product like conventional energy resources. It is cost effective solution for generation. It only need initial investment. It has also long life span. Overall it good, reliable and affordable solution for electricity generation.

The following Objectives are met-

- Studied individual energy source system and developed the Matlab Model, individual sources are solar and wind.
- Interconnecting solar and wind and providing a dc bus to analyze the system output.
- Battery and Diesel generator are added to the solar and wind generation system to provide energy storage and emergency supply.
- Power Quality analysis has been inherently controlled within the system without any special power quality controller.

Future Scope

- Centralized controller is designed for micro-grid application to monitor, control and to operate the system.
- Adopting this model to both on-grid and off-grid system.
- Embedding the advanced technology like Internet of Things, Artificial Intelligence and Block chain.

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