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Analysis and Implementation of Power Quality Enhancement Techniques in Hybrid AC/DC Microgrid

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ABSTRACT

With the growth in global warming, renewable energy-based distributed generators (DGs) play a prominent role in power generation. Wind, solar energy, biomass, mini-hydro, and the usage of fuel cells and microturbines will provide substantial impetus in the near future. Environmental friendliness, expandability, and flexibility have made distributed generation, powered by a variety of renewable and unconventional energy sources, an appealing alternative for building contemporary electrical systems. A microgrid is made up of a group of loads and dispersed generators that work together to form a single controlled system. Microgrids, as an integrated energy delivery system, may function in tandem with or independently of the main power grid. The microgrid idea reduces the number of reverse conversions in a single AC or DC grid while also making it easier to link variable renewable AC and DC sources and loads to power systems. The connectivity of DGs to the utility/grid through power electronic converters has raised concerns regarding equipment safety and protection. The microgrid may be configured to fulfil the customer's specific needs, such as greater local dependability, reduced feeder losses, local voltage support, greater efficiency via waste heat usage, voltage sag correction, or uninterruptible power supply. The performance of a hybrid AC/DC microgrid system in grid tethered mode is examined in this paper. For the creation of a microgrid, a solar system, a wind turbine generator, and a battery are utilized. Control methods are also included to allow the converters to appropriately coordinate the AC sub-grid with the DC sub-grid. The MATLAB/SIMULINK environment was used to achieve the findings.

KEYWORDS: *Solar (PV), Wind Energy (WECS), Hybrid System, AC/DC Microgrid, Distributed Generators, Power Enhancement, Stability, DFIG*

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1. INTRODUCTION:

As electric distribution technology steps into the next century, many trends are becoming noticeable that will change the requirements of energy delivery. These modifications are being driven from both the demand side where higher energy availability and efficiency are desired and from the supply side where the integration of distributed generation and peak-shaving technologies must be accommodated [1].

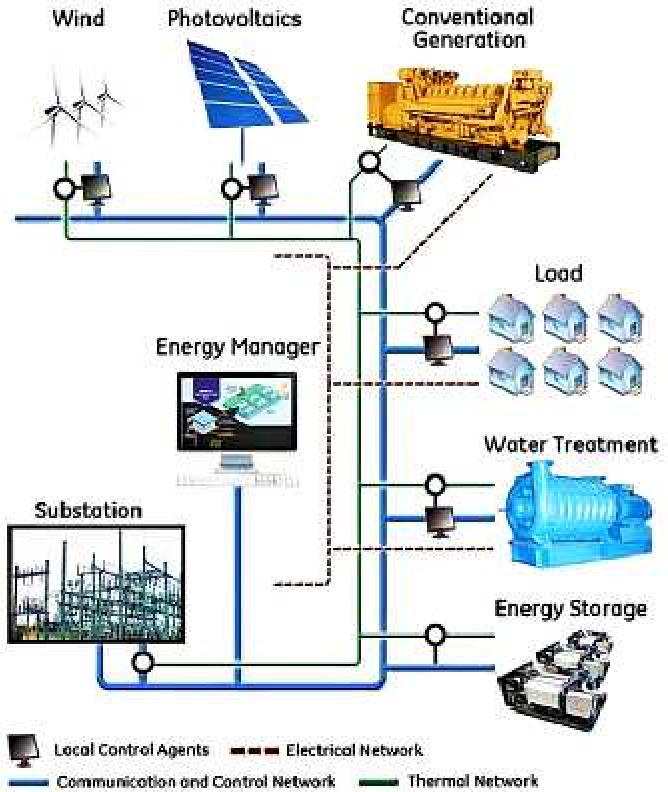


Fig.1.1. Microgrid power system

Power systems currently undergo considerable change in operating requirements mainly as a result of deregulation and due to an increasing amount of distributed energy resources (DER). In many cases DERs include different technologies that allow generation in small scale (micro sources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy. Having micro sources close to the load has the advantage of reducing transmission losses as well as preventing network congestions. Moreover, the possibility of having a power supply interruption of end-customers connected to a low voltage (LV) distribution grid (in Europe 230 V and in the USA 110 V) is diminished since adjacent micro sources, controllable loads and energy storage systems can operate in the islanded mode in case of severe system disturbances. This is identified nowadays as a microgrid. Figure 1.1 depicts a typical microgrid. The distinctive microgrid has the similar size as a low voltage distribution feeder and will rare exceed a capacity of 1 MVA and a geographic span of 1 km. Generally, more than 90% of low voltage domestic customers are supplied by underground cable when the rest is supplied by overhead lines. The microgrid often supplies both electricity and heat to the customers by means of combined heat and power plants (CHP), gas turbines, fuel cells, photovoltaic (PV) systems, wind turbines, etc. The energy storage systems usually include batteries and flywheels [2].The storing device in the microgrid is equivalent to the rotating reserve of large generators in the conventional grid which ensures the balance between energy generation and consumption especially during rapid changes in load or generation [3].

From the customer point of view, microgrids deliver both thermal and electricity requirements and in addition improve local reliability, reduce emissions, improve power excellence by supportive voltage and reducing voltage dips and potentially lower costs of energy supply. From the utility viewpoint, application of distributed energy sources can potentially reduce the demand for distribution and transmission facilities. Clearly, distributed generation located close to loads will reduce flows in transmission and distribution circuits with two important effects: loss reduction and ability to potentially substitute for network assets. In addition, the presence of generation close to demand could increase service quality seen by end customers. Microgrids can offer network support during the time of stress by relieving congestions and aiding restoration after faults. The development of microgrids can contribute to the reduction of emissions and the mitigation of climate changes. This is due to the availability and developing technologies for distributed generation units are based on renewable sources and micro sources that are characterized by very low emissions [4].

There are various advantages offered by microgrids to end-consumers, utilities and society, such as: improved energy efficiency, minimized overall energy consumption, reduced greenhouse gases and pollutant emissions, improved service quality and reliability, cost efficient electricity infrastructure replacement[2].

Technical challenges linked with the operation and controls of microgrids are immense. Ensuring stable operation during network disturbances, maintaining stability and power quality in the islanding mode of operation necessitates the improvement of sophisticated control strategies for microgrid's inverters in order to provide stable frequency and voltage in the presence of arbitrarily varying loads [4]. In light of these, the microgrid concept has stimulated many researchers and attracted the attention of governmental organizations in Europe, USA and Japan. Nevertheless, there are various technical issues associated with the integration and operation of microgrids.

TECHNICAL CHALLENGES IN MICROGRID

Protection system is one of the major challenges for microgrid which must react to both main grid and microgrid faults. The protection system should cut off the microgrid from the main grid as rapidly as necessary to protect the microgrid loads for the first case and for the second case the protection system should isolate the smallest part of the microgrid when clears the fault [30]. A segmentation of microgrid, i.e. a design of multiple islands or sub- microgrids must be supported by micro source and load controllers. In these conditions problems related to selectivity (false, unnecessary tripping) and sensitivity (undetected faults or delayed tripping) of protection system may arise. Mainly, there are two main issues concerning the protection of microgrids, first is related to a number of installed DER units in the microgrid and second is related to an availability of a sufficient level of short-circuit current in the islanded operating mode of microgrid since this level may substantially drop down after a disconnection from a stiff main grid. In [30] the authors have made short-circuit current calculations for radial feeders with DER and studied that short-circuit currents which are used in over-current (OC) protection relays depend on a connection point of and a feed-in power from DER. The directions and amplitudes of short circuit currents will vary because of these conditions. In reality the operating conditions of microgrid are persistently varying because of the intermittent micro sources (wind and solar) and periodic load variation. Also the network topology can be changed frequently which aims to minimize loss or to achieve other economic or operational targets. In addition controllable islands of different size and content can be formed as a result of faults in them a in grid or in side microgrid. In such situations a loss of relay coordination may happen and generic OC protection with a single setting group may become insufficient, ie. it will not guarantee a selective operation for all possible faults. Hence, it is vital to ensure that settings chosen for OC protection relays take into account a grid topology and changes in location, type and amount of generation. Otherwise, unwanted operation or failure may occur during necessary condition. To deal with bi-directional power flows and low short-circuit current levels in microgrids dominated by micro sources with power electronic interfaces a new protection philosophy is essential, where setting parameters of relays must be checked/updated periodically to make sure that they are still appropriate.

2. LITERATURE REVIEW:

The popularity of distributed generation systems is growing faster from last few years because of their higher operating efficiency and low emission levels. Distributed generators make use of several micro sources for their operation like photovoltaic cells, batteries, micro turbines and fuel cells. During peak load hours DGs provide peak generation when the energy cost is high and stand by generation during system outages. Microgrid is built up by combining cluster of loads and parallel distributed generation systems in a certain local area. Microgrids have large power capacity and more control flexibility which accomplishes the reliability of the system as well as the requirement of power quality. Operation of microgrid needs implementation of high performance power control and voltage regulation algorithm [1]-[5].

To realize the emerging potential of distributed generation, a system approach i.e. microgrid is proposed which considers generation and associated loads as a subsystem. This approach involves local control of distributed generation and hence reduces the need for central dispatch. During disturbances by islanding generation and loads, local reliability can be higher in microgrid than the whole power system. This application makes the system efficiency double. The current implementation of microgrid incorporates sources with loads, permits for intentional islanding and use available waste heat of power generation systems [6].

Microgrid operates as a single controllable system which offers both power and heat to its local area. This concept offers a new prototype for the operation of distributed generation. To the utility microgrid can be regarded as a controllable cell of power system. In case of faults in microgrid, the main utility should be isolated from the distribution section as fast as necessary to protect loads. The isolation depends on customer's load on the microgrid. Sag compensation can be used in some cases with isolation from the distribution system to protect the critical loads [2].

The microgrid concept lowers the cost and improves the reliability of small scale distributed generators. The main purpose of this concept is to accelerate the recognition of the advantage offered by small scale distributed generators like ability to supply waste heat during the time of need. From a grid point of view, microgrid is an attractive option as it recognizes that the nation's distribution system is extensive, old and will change very slowly. This concept permits high penetration of distribution generation without requiring redesign of the distribution system itself[7].

The microgrid concept acts as solution to the problem of integrating large amount of micro generation without interrupting the utility network's operation. The microgrid or distribution network subsystem will create less trouble to the utility network than the conventional micro generation if there is proper and intelligent coordination of micro generation and loads. In case of disturbances on the main network, microgrid could potentially disconnect and continue to operate individually, which helps in improving power quality to the consumer[8].

With advancement in DGs and microgrids there is development of various essential power conditioning interfaces and their associated control for tying multiple microsources to the microgrid, and then tying the microgrids to the traditional power systems. Microgrid operation becomes highly flexible, with such interconnection and can be operated freely in the grid connected or islanded mode of operation. Each microsource can be operated like a current source with maximum power transferred to the grid for the former case. The islanded mode of operation with more balancing requirements of supply-demand would be triggered when the main grid is not comparatively larger or is simply disconnected due to the occurrence of a fault. Without a strong grid and a firm system voltage, each microsource must now regulate its own terminal voltage within an allowed range, determined by its internally generated reference. The microsource thus appears as a controlled voltage source, whose output should rightfully share the load demand with the other sources. The sharing should preferably be in proportion to their power ratings, so as not to overstress any individual entity[9].

The installation of distributed generators involves technical studies of two major fields. First one is the dealing with the influences induced by distributed generators without making large modifications to the control strategy of conventional distribution system and the other one is generating a new concept for utilization of distributed generators. The concept of the microgrid follows the later approach. There includes several advantages with the installation of microgrid. Efficiently microgrid can integrate distributed energy resources with loads. Microgrid considered as a ‘grid friendly entity” and does not give undesirable influence to the connecting distribution network i.e. operation policy of distribution grid does not have to be modified. It can also operate independently in the occurrence of any fault. In case of large disturbances there is possibility of imbalance of supply and demand as microgrid does not have large central generator. Also microgrid involves different DERs. Even if energy balance is being maintained there continues undesirable oscillation [10].

For each component of the microgrid, a peer-to-peer and plug-and-play model is used to improve the reliability of the system. The concept of peer-to-peer guarantees that with loss of any component or generator, microgrid can continue its operation. Plug-and-play feature implies that without re-engineering the controls a unit can be placed at any point on the electrical system thereby helps to reduce the possibilities of engineering errors [11].

The economy of a country mainly depends upon its electric energy supply which should be secure and with high quality. The necessity of customer’s for power quality and energy supply is fulfilled by distributed energy supply. The distribution system mainly includes renewable energy resources, storage systems small size power generating systems and these are normally installed close to the customer’s premises. The benefits of the DERs include power quality with better supply, higher reliability and high efficiency of energy by utilization of waste heat. It is an attractive option from the environmental considerations as there is generation of little pollution. Also it helps the electric utility by reducing congestion on the grid, reducing need for new generation and transmission and services like voltage support and demand response. Microgrid is an integrated system. The integration of the DERs connected to microgrid is critical. Also there is additional problem regarding the control and grouping and control of DERs in an efficient and reliable manner[12].

Integration of wind turbines and photovoltaic systems with grid leads to grid instability. One of the solutions to this problem can be achieved by the implementation of microgrid. Even though there are several advantages associated with microgrid operation, there are high transmission line losses. In a microgrid there are several units which can be utilized in a house or country. In a house renewable energy resources and storage devices are connected to DC bus with different converter topology from which DC loads can get power supply. Inverters are implemented for power transfer between AC and DC buses. Common and sensitive loads are connected to AC bus having different coupling points. During fault in the utility grid microgrid operates in islanded mode. If in any case renewable source can’t supply enough power and state of charge of storage devices are low microgrid disconnects common loads and supply power to the sensitive loads [13].

Renewable energy resources are integrated with microgrid to reduce the emission of CO2 and consumption of fuel. The renewable resources are very fluctuant in nature, and also the production and consumption of these sources are very difficult. Therefore new renewable energy generators should be designed having more flexibility and controllability[14].

In conventional AC power systems AC voltage source is converted into DC power using an AC/DC inverter to supply DC loads. AC/DC/AC converters are also used in industrial drives to control motor speed. Because of the environmental issues associated with conventional power plant renewable resources are connected as distributed generators or ac microgrids. Also more and more DC loads like light emitting diode lights and electric vehicles are connected to AC power systems to save energy and reduce carbon dioxide (CO2)emission. Long distance high voltage transmission is no longer necessary when power can be supplied by local renewable power sources. AC sources in a DC grid have to be converted into DC and AC loads connected into DC grid using DC/AC inverters[15].

DC systems use power electronic based converters to convert AC sources to DC and distribute the power using DC lines. DC distribution becomes attractive for an industrial park with heavy motor controlled loads and sensitive electronic loads. The fast response capability of these power electronic converters help in providing highly reliable power supply and also facilitate effective filtering against disturbances. The employment of power electronic based converters help to suppress two main challenges associated with DC systems as reliable conversion from AC/DC/AC and interruption of DC current under normal as well as fault condition [16]. Over a conventional AC grid system, DC grid has the advantage that power supply connected with the DC grid can be operated cooperatively because DC load voltage are controlled. The DC grid system operates in stand-alone mode in the case of the abnormal or fault situations of AC utility line, in which the generated power is supplied to the loads connected with the DC grid. Changes in the generated power and the load consumed power can be compensated as a lump of power in the DC gird. The system cost and loss reduce because of the requirement of only one AC grid connected inverter [17].

Therefore the efficiency is reduced due to multistage conversions in an AC or a DC grid. So to reduce the process of multiple DC/AC/DC or AC/DC/AC conversions in an individual AC or DC grid, hybrid AC/DC microgrid is proposed, which also helps in reducing the energy loss due to reverse conversion[15].

Mostly renewable power plants are implemented in rural areas which are far away from the main grid network and there is possibility of weak transmission line connection. The microgrid (MG) concept provides an effective solution for such weak systems. The operation can be smoothened by the hybrid generation technologies while minimizing the disturbances due to intermittent nature of energy from PV and wind generation. Also there is possibility of power exchange with the main grid when excess/shortage occurs in the microgrid [18].

Distributed generation is gaining more popularity because of their advantages like environmental friendliness, expandability and availability without making any alternation to the existing transmission and distribution grid. Modern sources depend upon environmental and climatic conditions hence make them uncontrollable. Because of this problem microgrid concept comes into feature which cluster multiple distributed energy resources having different operating principles. In grid tied mode distributed green sources operates like controlled current source with surplus energy channelled by the mains to other distant loads. There is need of continuous tuning of source outputs which can be achieved with or without external communication links. In case of any malfunctions grid tied mode is proved less reliable as this leads to instability [19].

3. PHOTOVOLTAIC SYSTEM AND WIND ENERGY SYSTEM (DFIG)

Photovoltaic system

The photoelectric effect was first noted by French physicist Edmund Becquerel in 1839. He proposed that certain materials have property of producing small amounts of electric current when exposed to sunlight. In 1905, Albert Einstein explained the nature of light and the photoelectric effect which has become the basic principle for photovoltaic technology. In 1954 the first photovoltaic module was built by Bell Laboratories.

A photovoltaic system makes use of one or more solar panels to convert solar energy into electricity. It consists of various components which include the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output.

Photovoltaic arrangements

Photovoltaic cell

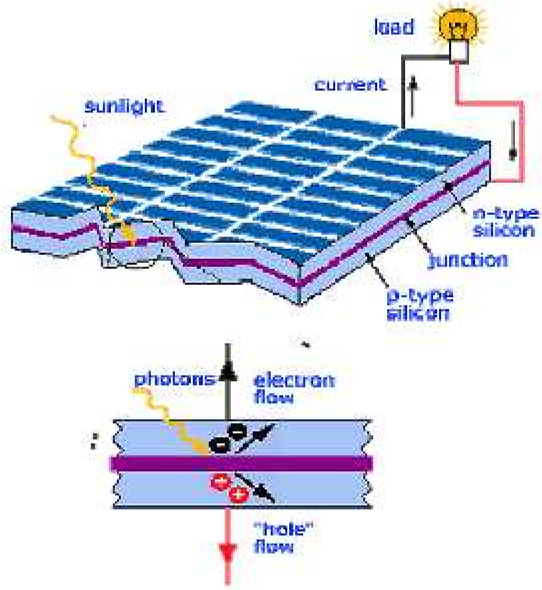


Fig.3.1. Basic structure of PV Cell

The basic ingredients of PV cells are semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer creates an electric field, on one side positive and negative on the other. When light energy hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material. When electrical conductors are connected to the positive and negative sides an electrical circuit is formed and electrons are captured in the form of an electric current that is, electricity. This electricity is used to power a load. A PV cell can either be circular or square in construction.

Photovoltaic module

Because of the low voltage generation in a PV cell (around 0.5V), several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output. In case of partial or total shading, and at night there may be requirement of separate diodes to avoid reverse currents The p-n junctions of mono-crystalline silicon cells may have adequate reverse current characteristics and these are not necessary. There is wastage of power because of reverse currents which directs to overheating of shaded cells. At higher temperatures solar cells provide less efficiency and installers aim to offer good ventilation behind solar panel. Usually there are of 36 or 72 cells in general PV modules. The modules consist of transparent front side, encapsulated PV cell and back side. The front side is usually made up of low-iron and tempered glass material. The efficiency of a PV module is less than a PV cell. This is because of some radiation is reflected by the glass cover and frame shadowing etc.

Photovoltaic array

A photovoltaic array (PV system) is an interconnection of modules which in turn is made up of many PV cells in series or parallel. The power produced by single module is not enough to meet the requirements of commercial applications, so modules are connected to form array to supply the load. In an array the connection of the modules is same as that of cells in a module. The modules in a PV array are usually first connected in series to obtain the desired voltages; the individual modules are then connected in parallel to allow the system to produce more current. In urban uses, generally the arrays are mounted on a rooftop. PV array output can directly feed to a DC motor in agricultural applications.

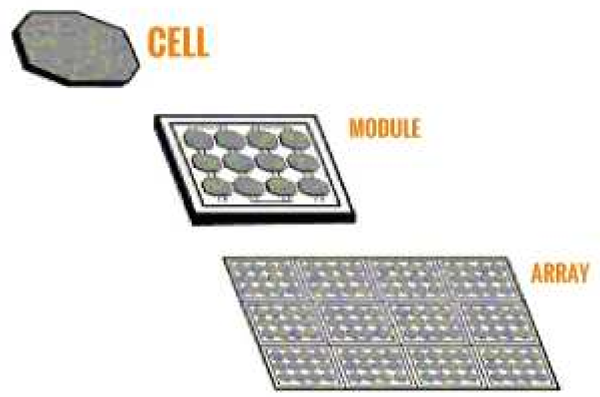


Fig.3.2. Photovoltaic system

Working of PV cell

The basic principle behind the operation of a PV cell is photoelectric effect. In this effect electron gets ejected from the conduction band as a result of the absorption of sunlight of a certain wavelength by the matter (metallic or non-metallic solids, liquids or gases). So, in a photovoltaic cell, when sunlight hits its surface, some portion of the solar energy is absorbed in the semiconductor material.

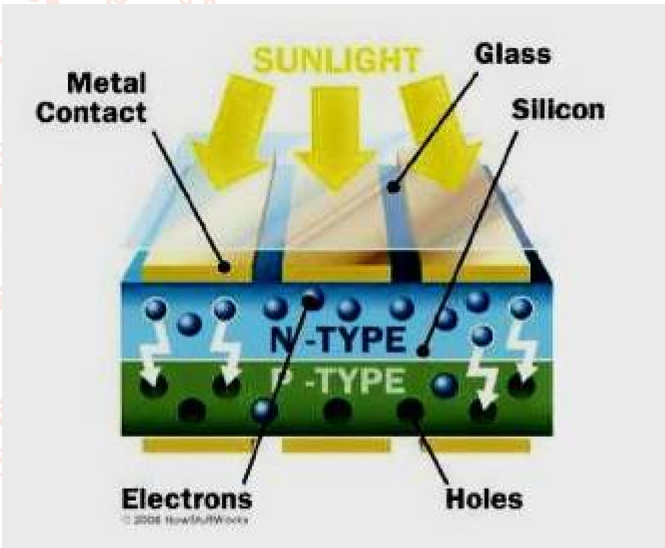


Fig.3.3. Working of PV cell

The electron from valence band jumps to the conduction band when absorbed energy is greater than the band gap energy of the semiconductor. By these hole-electrons pairs are created in the illuminated region of the semiconductor. The electrons created in the conduction band are now free to move. These free electrons are enforced to move in a particular direction by the action of electric field present in the PV cells. These electrons flowing comprise current and can be drawn for external use by connecting a metal plate on top and bottom of PV cell. This current and the voltage produces required power.

Wind turbines

With the use of power of the wind, wind turbines produce electricity to drive an electrical generator. Usually wind passes over the blades, generating lift and exerting a turning force. Inside the nacelle the rotating blades turn a shaft then goes into a gearbox. The gearbox helps in increasing the rotational speed for the operation of the generator and utilizes magnetic fields to convert the rotational energy into electrical energy. Then the output electrical power goes to a transformer, which converts the electricity to the appropriate voltage for the power collection system. A wind turbine extracts kinetic energy from the swept area of the blades.

DFIG.system

The doubly fed induction machine is the most widely machine in these days. The induction machine can be used as a generator or motor. Though demand in the direction of motor is less because of its mechanical wear at the slip rings but they have gained their prominence for generator application in wind and water power plant because of its obvious adoptability capacity and nature of tractability. This section describes the detail analysis of overall DFIG.system along with back-to-back PWM voltage source converters.

4. SYSTEM DESIGN AND IMPLEMENTATION AC/DC MICROGRID

The concept of microgrid is considered as a collection of loads and micro sources which functions as a single controllable system that provides both power and heat to its local area. This idea offers a new paradigm for the definition of the distributed generation operation. To the utility the microgrid can be thought of as a controlled cell of the power system. For example, this cell could be measured as a single dispatch able load, which can reply in seconds to meet the requirements of the transmission system. To the customer the microgrid can be planned to meet their special requirements; such as, enhancement of local reliability, reduction of feeder losses, local voltages support, increased efficiency through use waste heat, voltage sag correction [3]. The main purpose of this concept is to accelerate the recognition of the advantage offered by small scale distributed generators like ability to supply waste heat during the time of need [4]. The microgrid or distribution network subsystem will create less trouble to the utility network than the conventional microgeneration if there is proper and intelligent coordination of micro generation and loads [5]. Microgrid considered as a ‘grid friendly entity” and does not give undesirable influences to the connecting distribution network i.e. operation policy of distribution grid does not have to be modified[7].

Configuration of the hybrid microgrid

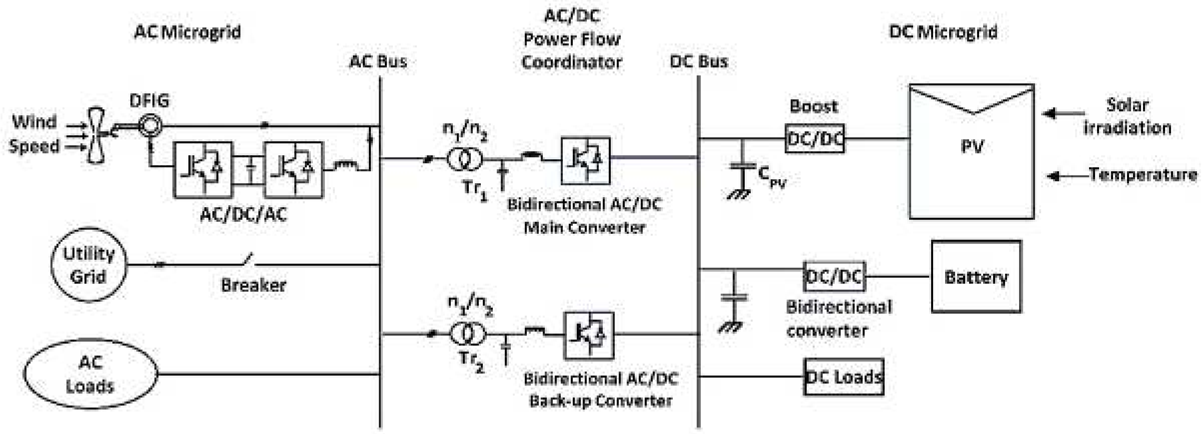


Fig.4.1. A hybrid AC/DC microgrid system

The configuration of the hybrid system is shown in Figure 1 where various AC and DC sources and loads are connected to the corresponding AC and DC networks. The AC and DC links are linked together through two transformers and two four quadrant operating three- phase converters. The AC bus of the hybrid grid is tied to the utility grid.

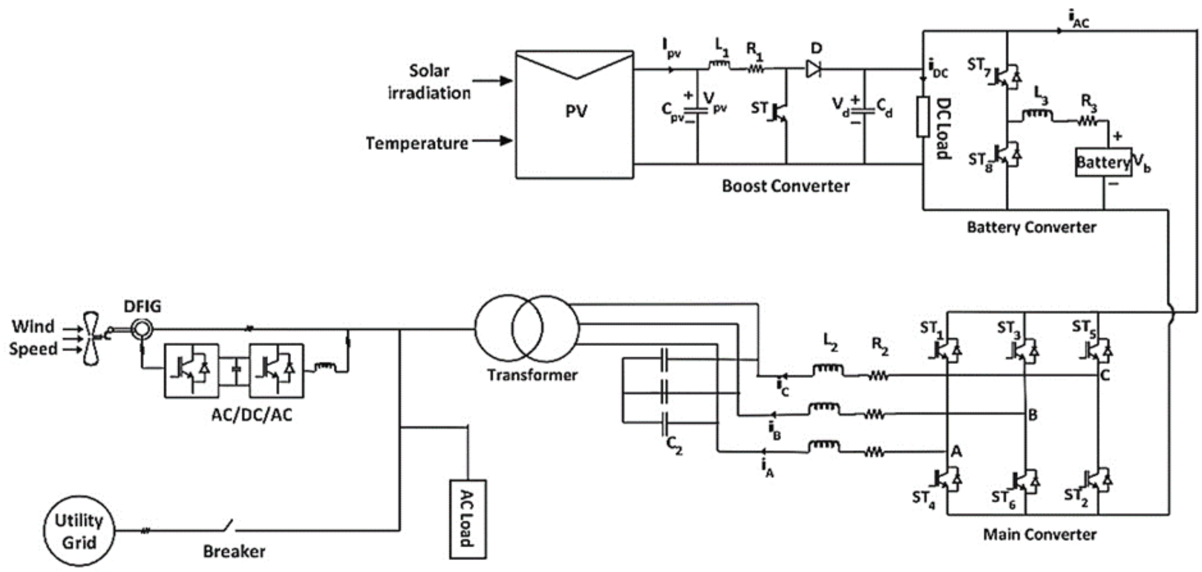


Figure 4.2 describes the hybrid system configuration which consists of AC and DC grid.

The AC and DC grids have their corresponding sources, loads and energy storage elements, and are interconnected by a three phase converter. The AC bus is connected to the utility grid through a transformer and circuit breaker.

In the proposed system, PV arrays are connected to the DC bus through boost converter to simulate DC sources. A DFIG.wind generation system is connected to AC bus to simulate AC sources. A battery with bidirectional DC/DC converter is connected to DC bus as energy storage. A variable DC and AC load are connected to their DC and AC buses to simulate various loads.

PV modules are connected in series and parallel. As solar radiation level and ambient temperature changes the output power of the solar panel alters. A capacitor C_{pv} is added to the PV terminal in order to suppress high frequency ripples of the PV output voltage. The bidirectional DC/DC converter is designed to maintain the stable DC bus voltage through charging or discharging the battery when the system operates in the autonomous operation mode. The three converters (boost converter, main converter, and bidirectional converter) share a common DC bus. A wind generation system consists of doubly fed induction generator (DFIG) with back to back AC/DC/AC PWM converter connected between the rotor through slip rings and AC bus. The AC and DC buses are coupled through a three phase transformer and a main bidirectional power flow converter to exchange power between DC and AC sides. The transformer helps to step up the AC voltage of the main converter to utility voltage level and to isolate AC and DC grids.

Modeling and control of DFIG

The section 3.2.1 explains the detailed modeling of DFIG.The state space equations are considered for induction machine modeling. The parameters and specifications of the DFIG.are given in table 3.1. Flux linkages are used as the state variables in the model. Here two back to back converters are used in the rotor circuit. The main purpose of the machine-side converter is to control the active and reactive power by controlling the d-q components of rotor current, while the grid-side converter controls the dc-link voltage and ensures the operation at unity power factor by making the reactive power drawn by the system from the utility grid to zero.

Two back to back converters are connected to the rotor circuit is shown in Fig.4.3. The firing pulses are given to the devices (IGBTs) using PWM techniques. Two converters are linked to each other by means of dc-link capacitor.

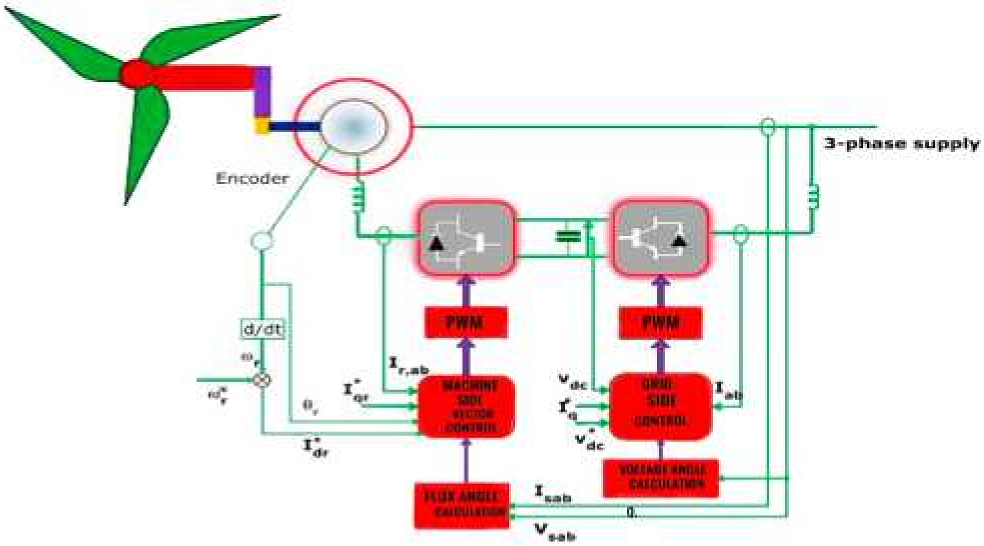
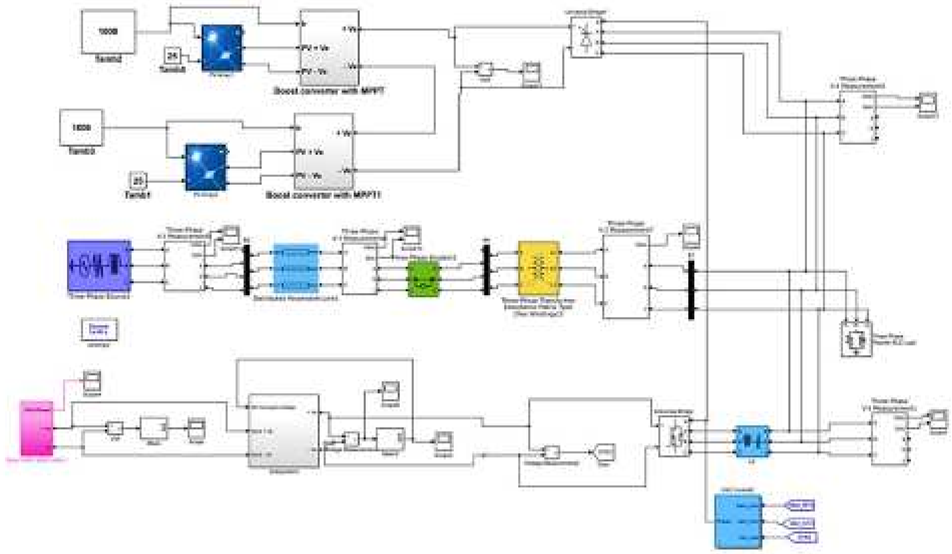


Fig.4.3. Overall DFIG.system

5. RESULTS

A hybrid microgrid whose parameters are given in table 4.1 is simulated using MATLAB/SIMULINK environment. The operation is carried out for the grid connected mode. Along with the hybrid microgrid, the performance of the doubly fed induction generator, photovoltaic system is analyzed. The solar irradiation, cell temperature and wind speed are also taken into consideration for the study of hybrid microgrid. The performance analysis is done using simulated results which are found using MATLAB.



Hybrid AC/DC Microgrid

5.1. Simulation of PV array

Figure (5.1) -(5.6) represents I-V, P-V, P-I characteristics with variation in temperature and solar irradiation. The nonlinear nature of PV cell is noticeable as shown in the figures, i.e., the output current and power of PV cell depend on the cell's terminal operating voltage and temperature, and solar irradiation as well.

Figures (5.1) and (5.2) verify that with increase of cell's working temperature, the current output of PV module increases, whereas the maximum power output reduces. Since the increase in the output current is much less than the decrease in the voltage, the total power decreases at high temperatures.

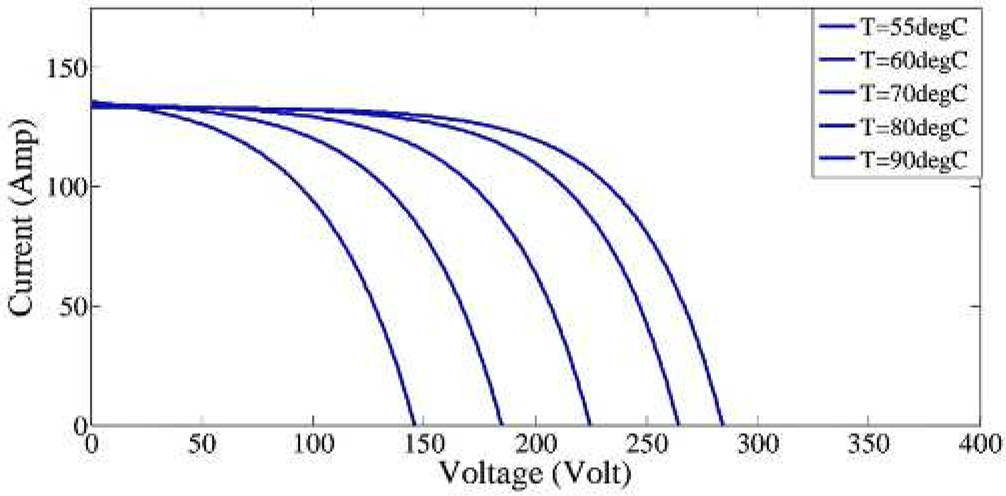


Fig.5.1. I-V output characteristics of PV array for different temperatures

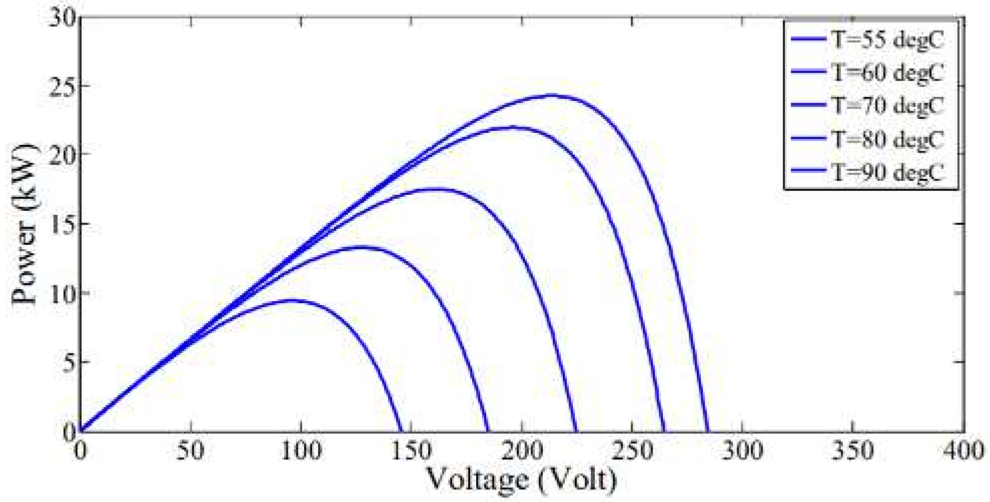


Fig.5.2. P-V output characteristics of PV array for different temperatures

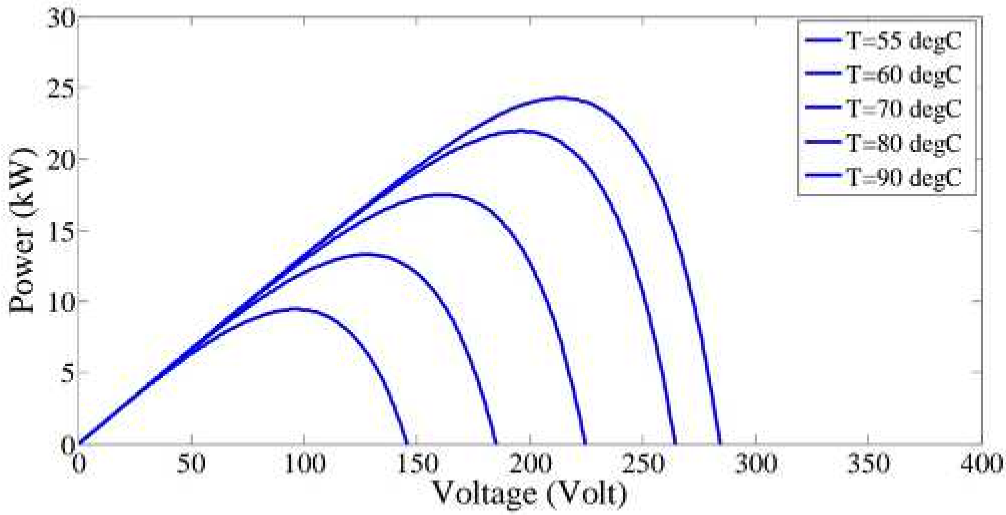


Fig.5.3. P-I output characteristics of PV array for different temperatures

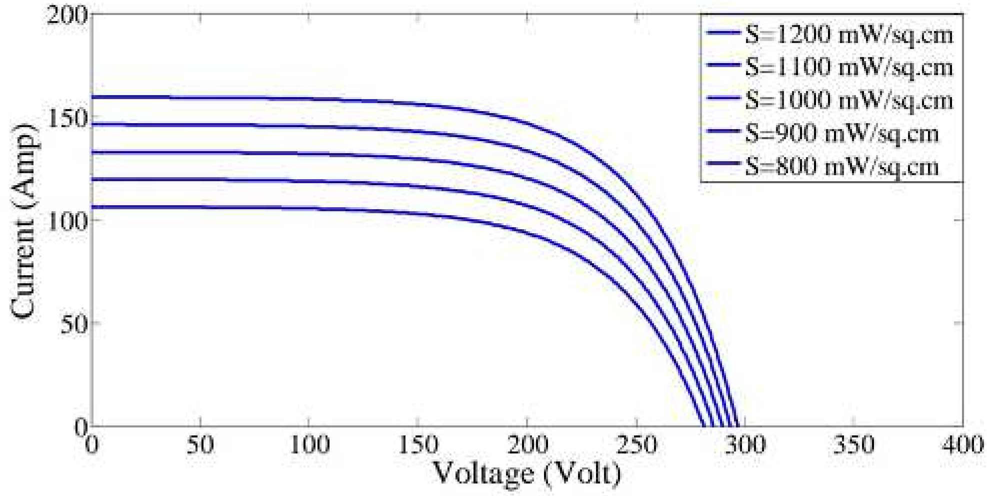


Fig.5.4. I-V output characteristics of PV array for different irradiance levels

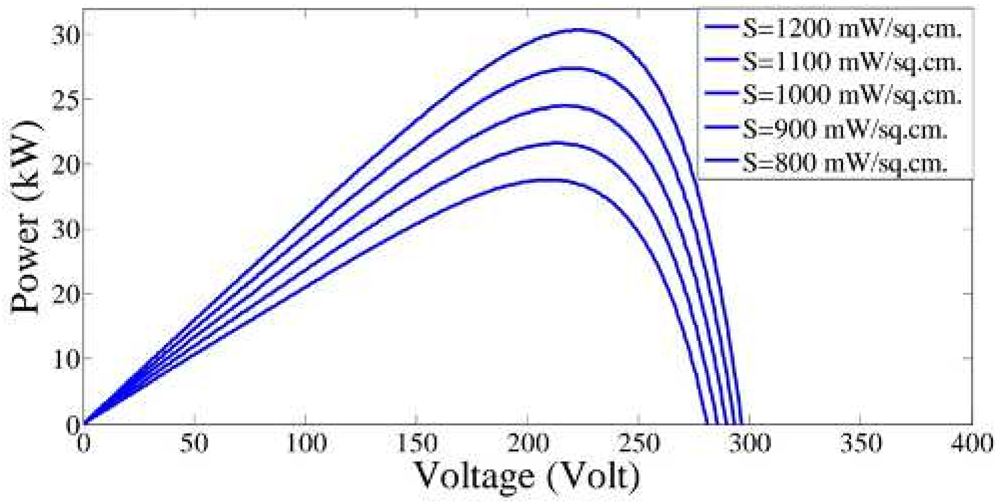


Fig.5.5. P-V characteristics of PV array for different irradiance levels

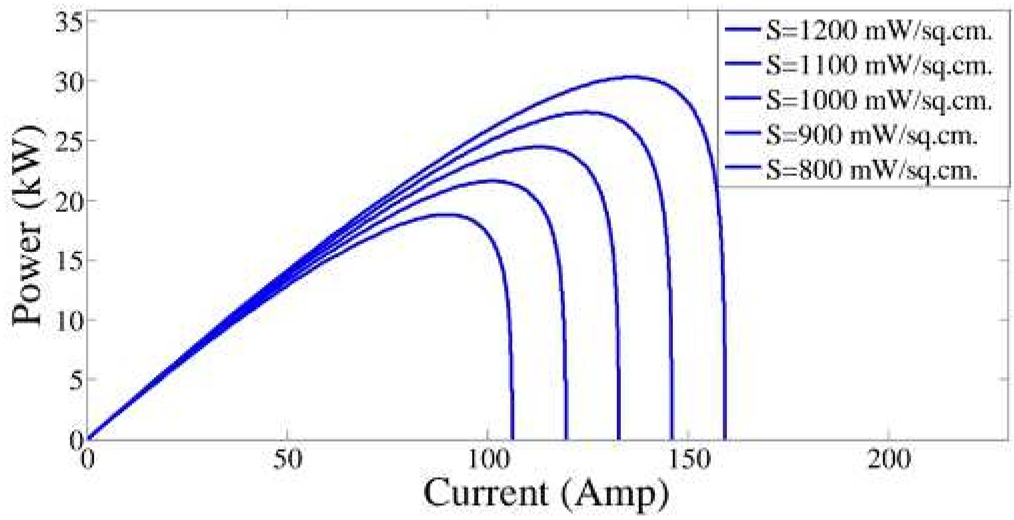


Fig.5.6. P-I characteristics of PV array for different irradiance levels

Figures (5.4) and (5.5) show that with increase of solar irradiation, the current output of PV module increases and also the maximum output power. The reason behind it is the open- circuit voltage is logarithmically dependent on the solar irradiance, however the short-circuit current is directly proportional to the radiant intensity.

5.2. Simulation of doubly fed induction generator

The response of wind speed, three phase stator voltage and three phase rotor voltage are shown in the figures (5.7) - (5.9). Here the value of wind speed varies between 1.0 to 1.05 pu which is necessary for the study of the performance of doubly fed induction generator. The phase-to-phase stator voltage is set to 300V whereas the rotor voltage value is 150V.

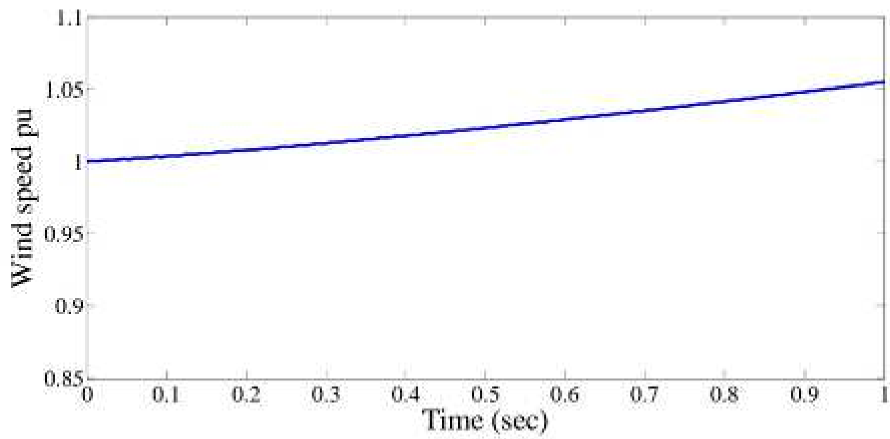


Fig.5.7. Response of wind speed

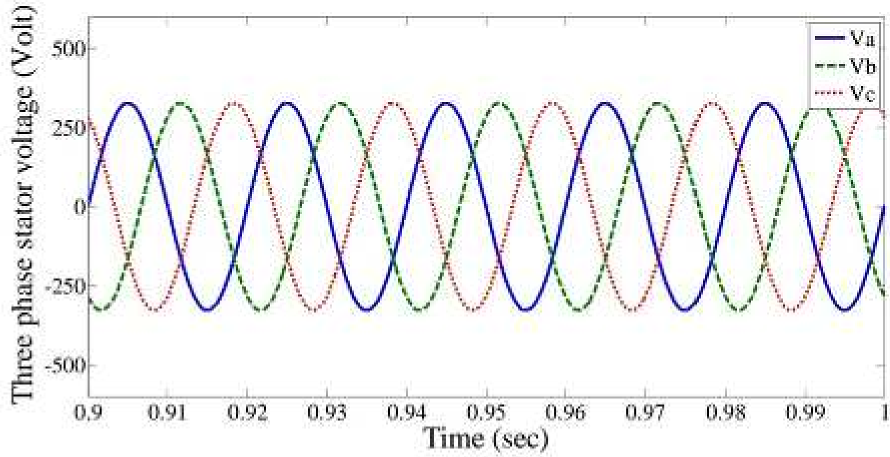


Fig.5.8. Three phase stator voltage of DFIG

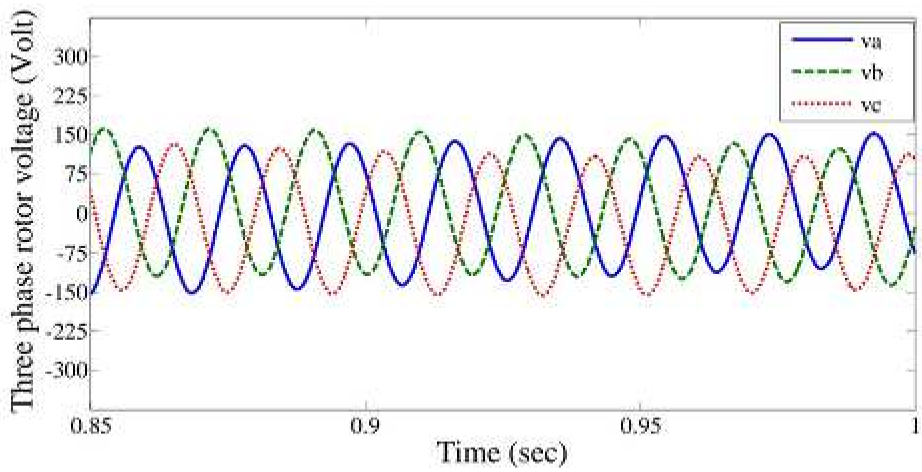


Fig.5.9. Three phase rotor voltage of DFIG

5.3. Simulation results of hybrid grid

The various characteristics of the hybrid microgrid are represented by the figures (5.10) – (5.25). Here the microgrid operates in the grid tied mode. In this mode, the main converter operates in the PQ mode and power is balanced by the utility grid. The battery is fully charged. AC bus voltage is maintained by the utility grid and DC bus voltage is maintained by the main converter.

Figure (5.10) shows the curve of solar irradiation level which value is set as 950 W/sq.m from 0.0s to 0.1s, increases linearly to 1300 W/sq.m from 0.1s to 0.2s, remains constant from 0.3s to 0.4s, decreases to 950 W/sq.m and keeps that value until 1s. Figures (5.11) – (5.13) signify output voltage, current and power with respect to the solar irradiation signal. The output power of PV panel varies 11.25 kW to 13 kW, which closely follows the solar irradiation when the ambient temperature is fixed.

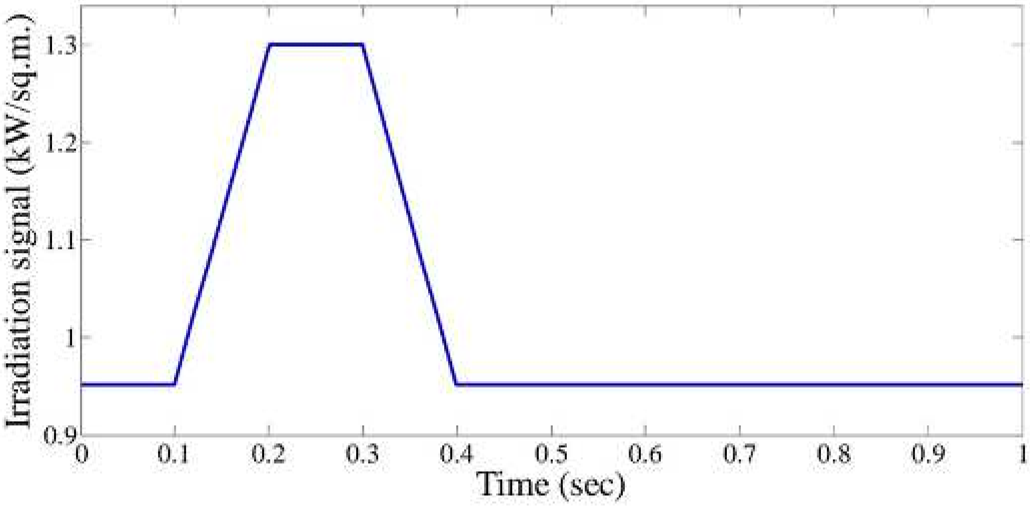


Fig.5.10. Irradiation signal of the PV array

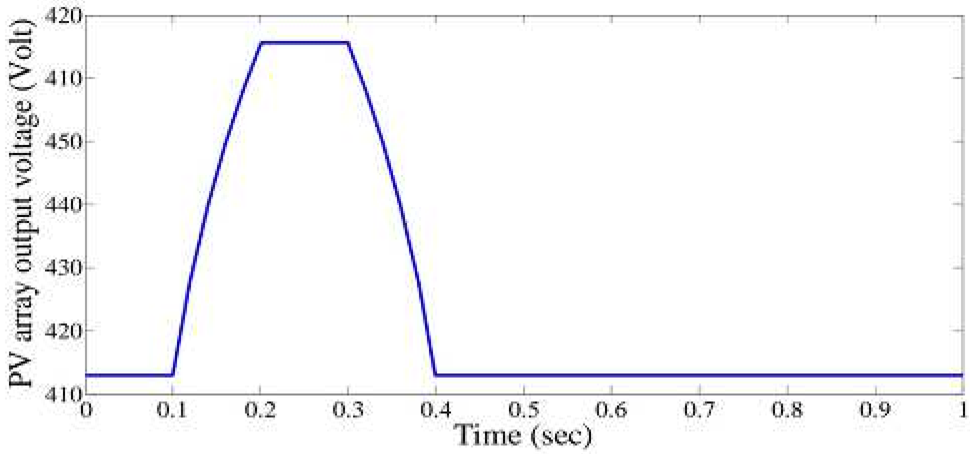


Fig.5.11. Output voltage of PV array

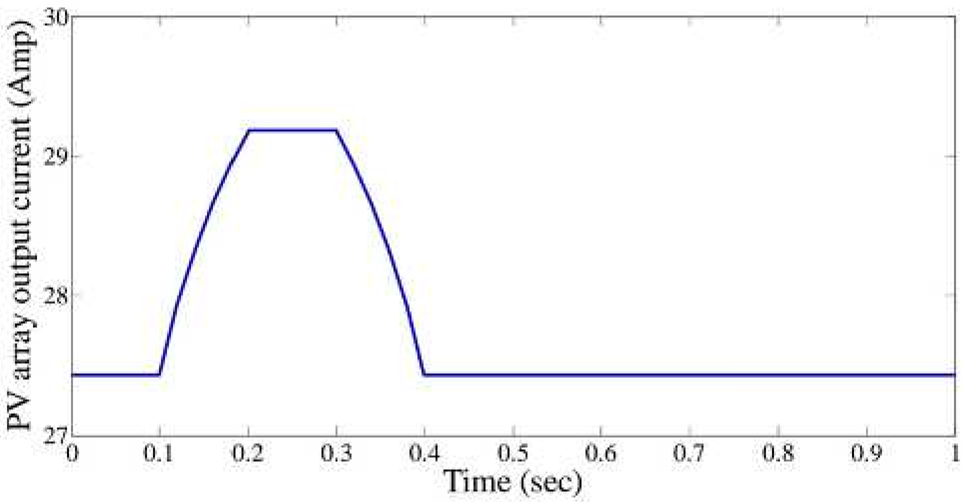


Fig.5.12. Output current of PV array

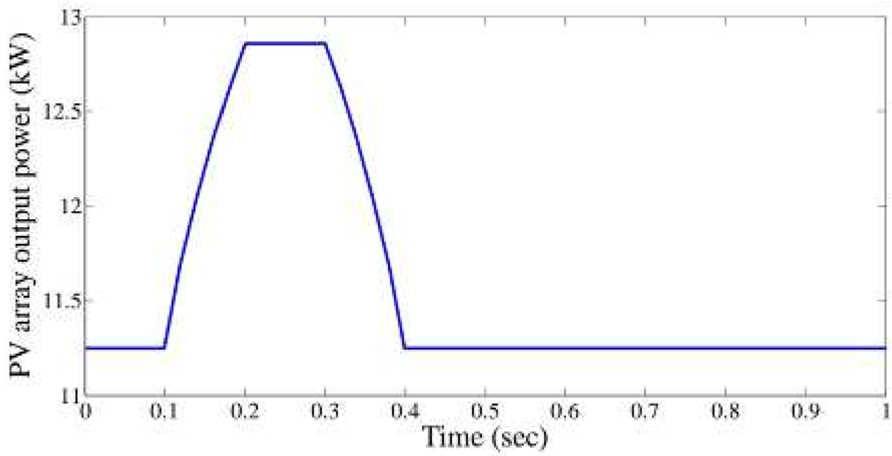


Fig.5.13. Output power of PV array

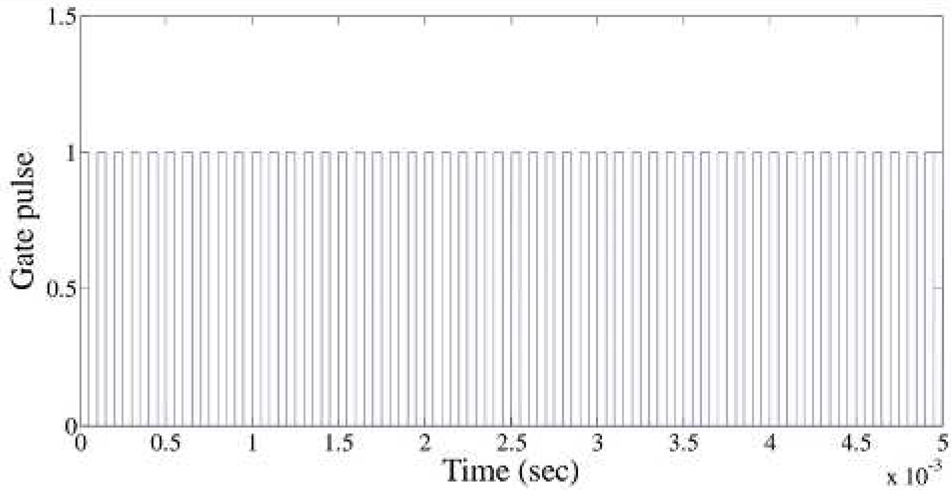


Fig.5.14. Generated PWM signal for the boost converter

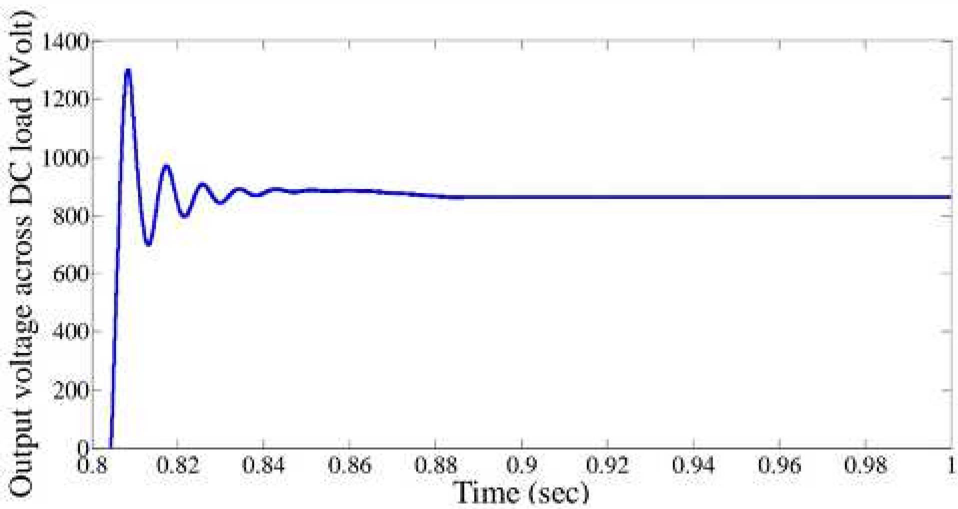


Fig.5.15. Output voltage across DC load

Figure (5.14) shows the gate pulse signal which is fed to the switch of boost converter. The output voltage across DC load is represented by figure (5.15) which is settled to around 820V.

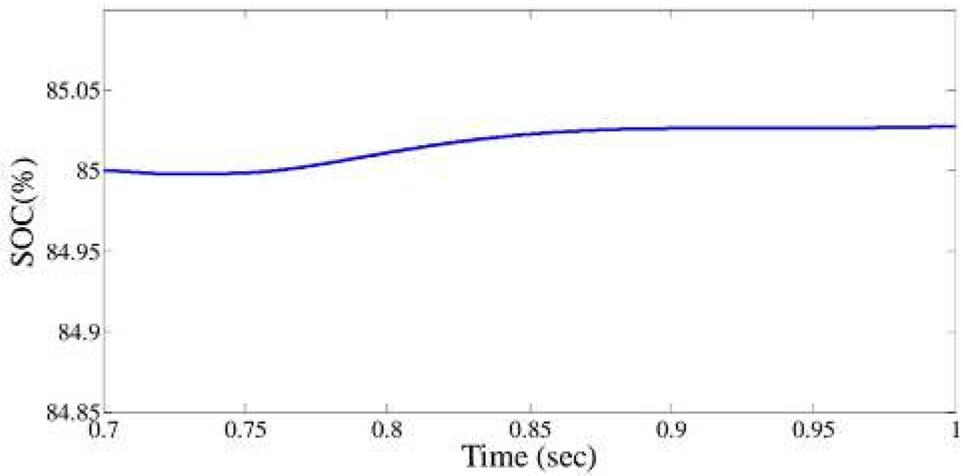


Fig.5.16. State of charge of battery

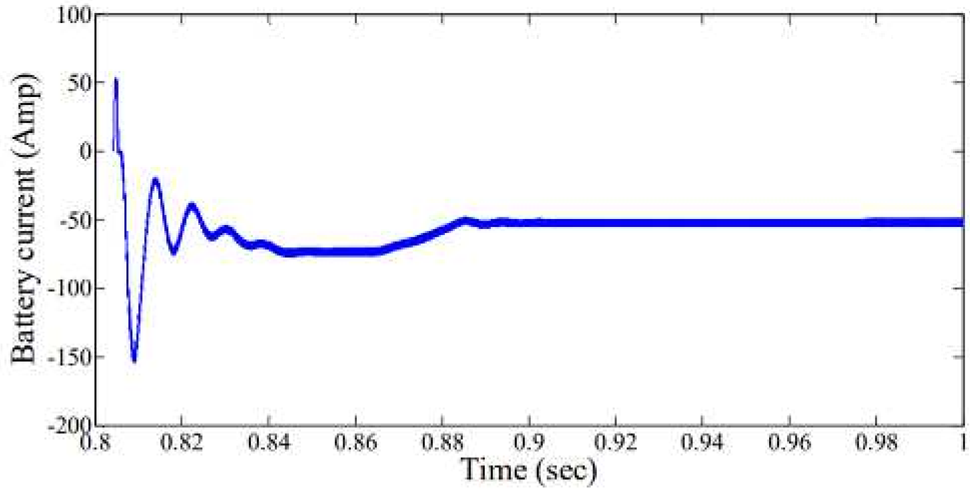


Fig.5.17. Voltage of battery

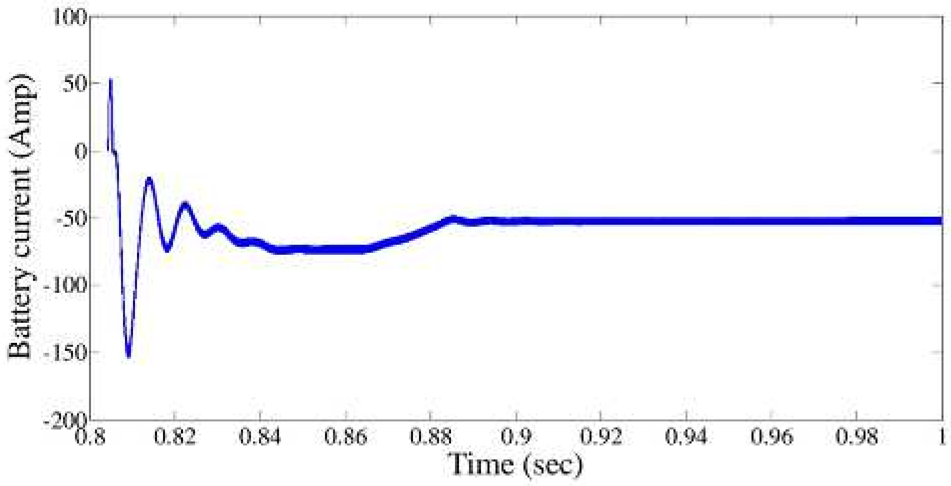


Fig.5.18. Current of battery

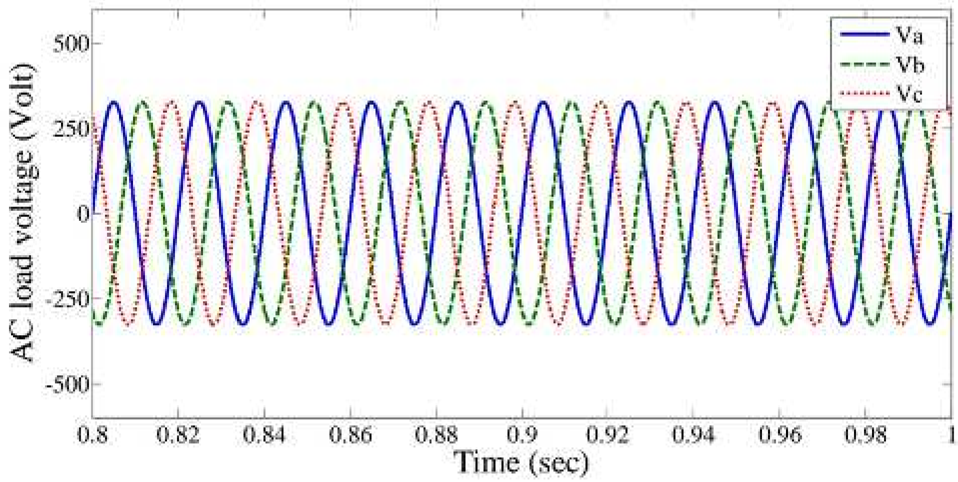


Fig.5.19. Output voltage across AC load

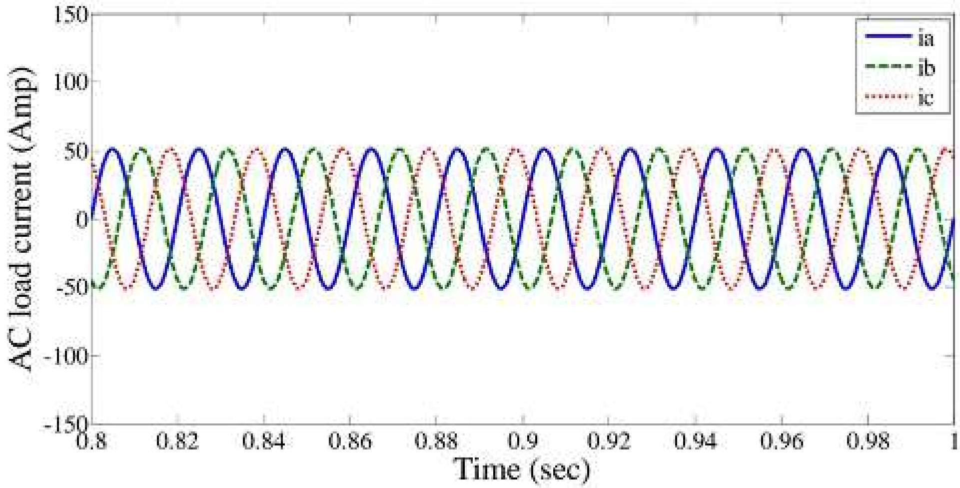


Fig.5.20. Output current across AC load

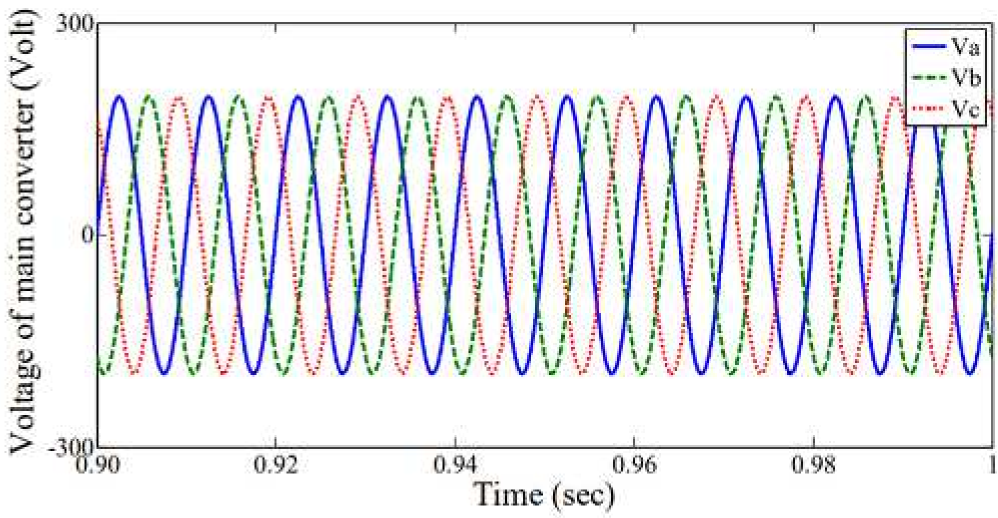


Fig.5.21. AC side voltage of the main converter

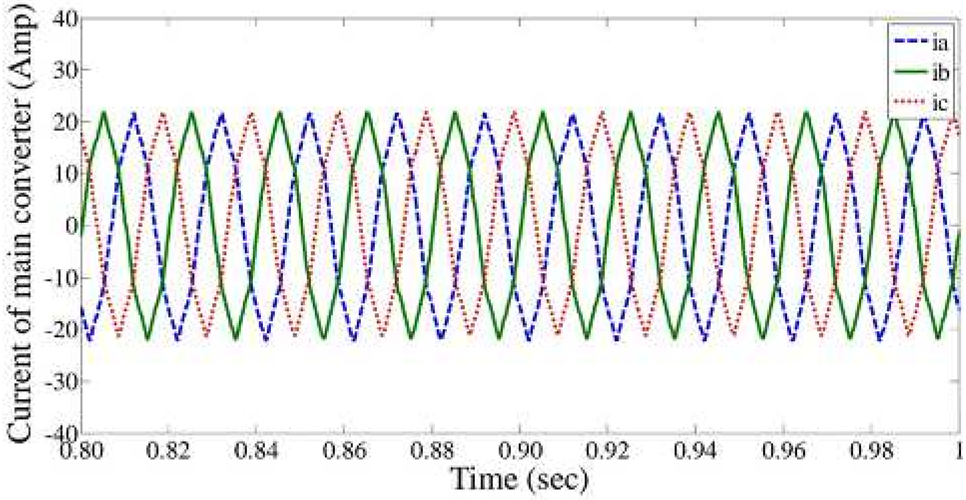


Fig.5.22. AC side current of the main converter

The battery characteristics are shown in the figures (5.16) - (5.18). The state of charge of battery is set at 85% whereas the battery current varies between -50 to 50A and the value of battery voltage is nearly 163.5. The output characteristics of AC load voltage and current are represented by the figures (5.19) and (5.20). Phase to phase voltage value of AC load is 300V and current value is 50A.Figure (5.21) and (5.22) shows the voltage and current responses at the AC side of the main converter when the solar radiation value varies between 950-1300 W/sq.m with a fixed DC load of 25 kW.

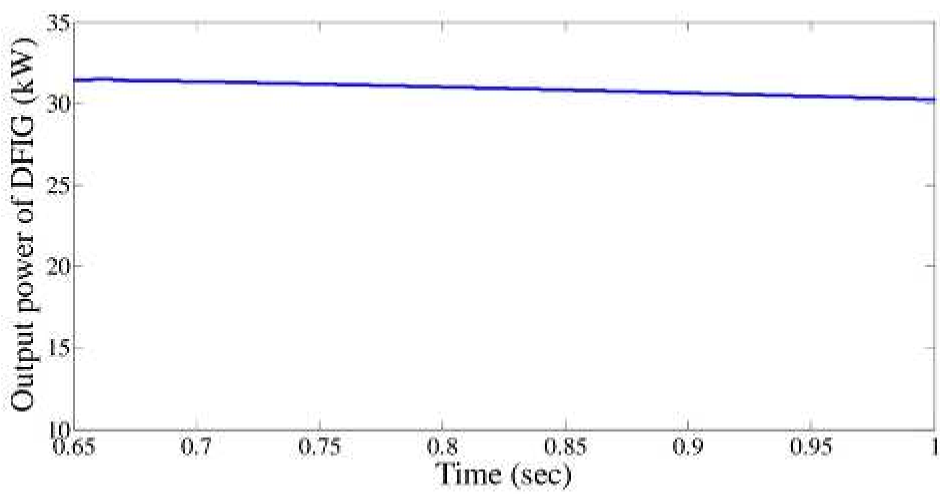


Fig.5.23. Output power of DFIG

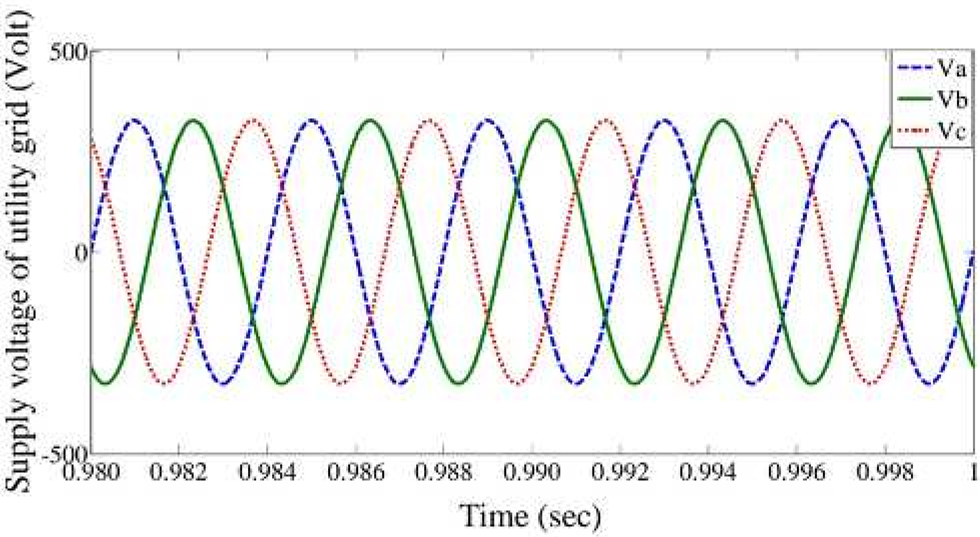


Fig.5.24. Three phase supply voltage of utility grid

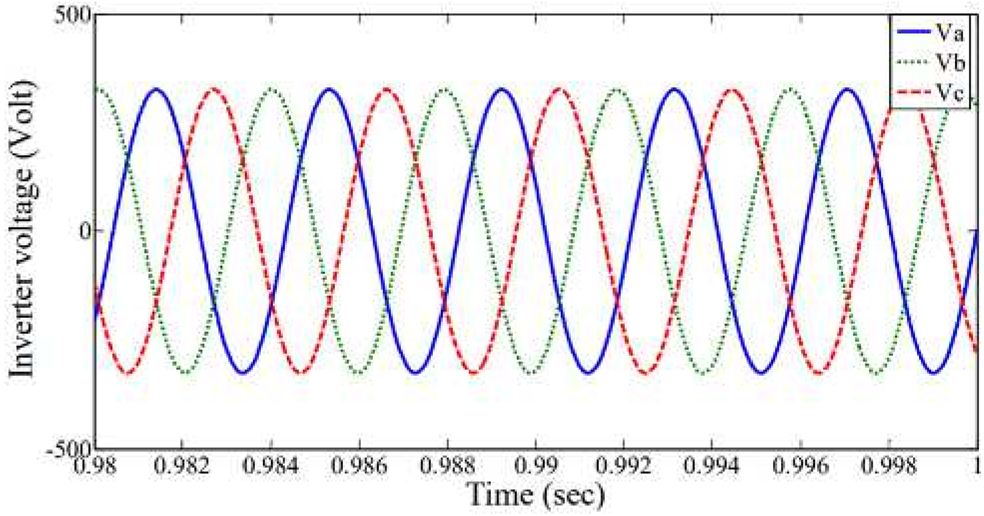


Fig.5.25. Three phase PWM inverter voltage

Figure (5.23) shows the response of the DFIG. power output which becomes a stable value 32kW due to mechanical inertia. Figure (5.24) and (5.25) represents the three-phase supply voltage to the utility grid and three phase PWM inverter output voltage respectively. In this chapter simulation results are discussed briefly. Also various characteristics of PV array, doubly fed induction generator, battery and converters are studied in this chapter and the waveforms are traced.

CONCLUSION & FUTURE SCOPE

Conclusion

The modeling of hybrid microgrid for power system configuration is done in MATLAB/SIMULINK environment. The present work mainly includes the grid tied mode of operation of hybrid grid. The models are developed for all the converters to maintain stable system under various loads and resource conditions and also the control mechanism are studied. MPPT algorithm is used to harness maximum power from DC sources and to coordinate the power exchange between DC and AC grid. Although the hybrid grid can diminish the processes of DC/AC and AC/DC conversions in an individual AC or DC grid, there are many practical problems for the implementation of the hybrid grid based on the current AC dominated infrastructure. The efficiency of the total system depends on the diminution of conversion losses and the increase for an extra DC link. The hybrid grid can provide a reliable, high quality and more efficient power to consumer. The hybrid grid may be feasible for small isolated industrial plants with both PV systems and wind turbine generator as the major power supply.

Future Scope

- The modeling and control can be done for the islanded mode of operation.
- The control mechanism can be developed for a microgrid containing unbalanced and nonlinear loads.

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