Challenges in Integrating Renewable Sources into a Utility Grid

Teki Vamsee Krishna, Manoj Kumar Maharana, Chinmoy Kumar Panigrahi

***Abstract:** In India, Electrical Power System is adapted to handle both constant loads and variable loads, also power is generated in two types; one is due to fossil fuels, and another one is due to renewable energy sources. However, renewable energy sources are playing a vital role in the production of clean energy and also useful for the reduction in greenhouse emission. Nevertheless, when there is any additional change in the generation side concerning to input supply, which is due to the uncertainty of nature, can create new challenges for the system operators and utility centers. It is not an easy task for the utility centres and supply operators to integrate variable renewable energy sources with the utility grid. This paper explores an overview of some operational techniques and solutions, which are helpful for high penetration of renewable energy sources such as solar and wind energy. It also explores operation, control management and challenges due to renewable energy when they integrated with the utility grid. By interfacing of renewable energy sources with a utility grid with proper management and control can provide bi-directional communication between suppliers and consumers smartly. The aim of integrating large scale renewable sources from transmission and distribution network into an existing system is to reduce the power quality issues, demand response, forecasting, peak demand, and improve network security, fast scheduling and dispatch, aiming towards smart grid technology for electrical power systems.*

***Keywords:** Renewable Energy Sources, Utility Grid, Integration, Electrical Power System, Grid Management and Control, Energy Management System.*

I. INTRODUCTION

Present immense use of electrical energy consumption day by day has kept a problem like a mismatch in the supply and demand. With increasing demand, energy generation has to be met with conventional energy sources like thermal-power, hydro-electric, nuclear, oil, etc, is not a feasible solution for energy generation in the upcoming years. Which they can drain quickly and also generation due to these fossil fuels can lead to an increase in a global warming effect. So today the world is concentrating on increasing the utilisation of renewable energy sources to fulfil the load demand and also to preserve our limited natural resources for the future generation requirements. So that the effect of supply and demand ratio can be decreased and renewable energy can be utilised optimally. Considering India's energy sources profile for electric energy generation with the help of conventional sources like thermal energy, nuclear energy, hydroelectric energy, oil has a governing situation. In India, the primary energy generation is with Coal constitutes about 56.1% of 203,154.5 MW, followed by large Hydro about 12.5% of 45,399.2 MW, Gas about 6.9% of 24,937.22 MW, Nuclear about 1.9% of 6,780 MW, Diesel about 0.1% of 509.71 MW and renewable energy sources including small Hydro is about 22.5% of 81,339.38 MW. The total installed capacity in India is 362.12 GW [11]. India has to make use of renewable energy for generating a large capacity of energy in all possible manner so that it can reduce the utilisation of fossil fuel-based generation. Present in world, India is one, which installed wind energy about 45.2% of total non-conventional energy sources of generation of about 36,368 MW and solar energy about 36.7% of 29,549 MW of capacity [12]. The world mainly depends on fossil fuel-based energy generation are about 80%. The demand for energy is expected to increase gradually to 50% for the following decades, which created anxiety to our natural energy resources which are going to drain out fastly. So utilising renewable energy resources in a useful manner can reduce the energy crisis and also reduce carbon dioxide emission which is due burning of fossil fuels. Based on energy generated from the renewable energy sources, they may categorise by capacities such as large scale generation and small scale generation. Small scale renewable energy has a capacity ranging from 10 – 15 MW, and large scale renewable energy has a capacity ranging from 100 – 1000 MW of power. These renewable energy sources such as solar energy and wind energy can integrate into the electrical power system either through a transmission network or distribution network. Small scale energy souces can integrate directly to the distribution network, whereas large scale energy sources are integrated with the transmission network of the utility grid shown in fig.1. However, integration of renewable energy sources with utility grid is a challenging task and also have many issues, especially when we are integrating large scale renewable energy sources with the utility grid. The issues and difficulties forced with integration like system transient stability, system operation and management, grid network issues, market redesign issues, placement of renewable energy sources, energy storage preservation issues and protection etc. however utilisation of large scale renewable energy sources can reduce the global warming up to 20% and increases the share of renewable energy in the market about 20%. Which increases the opportunity for small scale generation and improved efficiency. Integration of renewable energy with a utility grid requires the system operational management in the field of transmission and distribution network. In present electrical power system, energy management system playing a vital role in the field of automation and management at transmission and distribution network and

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demand-side management is used to reduce the problem due to mismatch in the supply and demand. However, the main issues regarding integration are reliability, safety of operation and power quality issues, which affects both the transmission and distribution network.

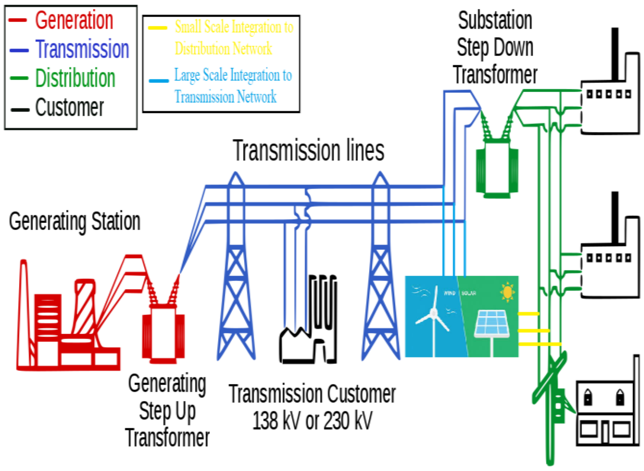

Fig.1. Integration of Renewable Energy Sources

II. LITERATURE SURVEY

Nowadays in the electrical power system, the primary concern is regarding energy saving which is very important due to the increase in the population and different types of loads has posted a problem of mismatch in supply and demand. To reduce the mismatch in demand and supply problem, we are just increasing our power generation by utilising the massive amount of fossil fuels in the nature like coal, oil, nuclear and gas etc., which leads to other problem like greenhouse gas emission. When renewable energy sources are coming into the electrical power system scenario, playing a prominent role in the production of clean energy and also useful for the reduction in the greenhouse emission which is caused by utilising a bulk amount of fossil fuels for the generation to reduce the supply and demand problem. The penetrations of large-scale renewables, particularly in the area of solar and wind energies as primary sources due to their availability in nature are high. However, there are certain limitations as these sources are based on the geological condition. Penetrating these sources reduces the greenhouse effect; increases the opportunity for small-scale generating units and also increase the share of energy in the market to 20% and finally, the overall efficiency can be improved. With integrating renewables to utility grid it requires its operational management and control of energy in the field of transmission and distribution network, but there are specific issues considered with integration like reliability, safety and power quality, affects the transmission and distribution network which cannot be neglected by the electrical power system. The nature of these renewables is in non-uniform, which is a big problem to penetrate these sources with the utility grid. Due to change in the geographical conditions, the output of renewable sources has fluctuations and which leads to the variation in the grid voltage and frequency. The authors designed active generators and used super-capacitors to reduce the fluctuations and to balance the variations which are coming from PV generators and the primary frequency control [1]. Previously the frequency control is done by using synchronous generators which are replaced now by power electronic converters. These power electronic converters are used for regulation, has a similar function of dynamic response provided by virtual synchronous generators. Hybrid energy storage (Battery and Ultra-capacitor) are used to achieve a frequency response by their power management [2]. However, due to the change in geographical conditions as these renewable sources are based on the natural condition. They can cause dangerous power quality problems in the electrical power system at the point of common coupling like power outages, surges & fluctuations. For reducing this kind of problems, some optimisation algorithms, voltage control techniques and a battery storage system should be used. The authors have implemented a two battery model to reduce problem regarding the issues and to charge and discharge the battery model for electrical peak shaving [3]. The penetration of renewables does not mean that it always used to reduce the peak demand at the time of mismatch between generation and consumption. For overcome this problem, an adaptive power flow control method is proposed to reduce the peak grid demand and also to increase the utilisation of renewables for mismatch problem [4]. With an increase in the load demand, the mismatch problem was raised in the electrical power system between the generation and consumption. In Smart grid to optimise the demand response, a game-theoretical model has been proposed with demand-side management which can effectively optimise resource utilisation [5]. The main objective of demand-side management scheme is to reduce the mismatch problem and to bring the final load duration curve (peak demand curve) as closely as possible to the standard load duration curve. Demand-side management is in right field to optimise the issue regarding peak demand. For making this, two parallel approaches are used at the time of peak demand situations by using and promoting energy-efficient technologies and developing strategies for controlling the aggregated power demand [6]. As there are sufficient amount of large power plants which are feeding into the grid and trying to maintain the generation and consumption balanced at overall time duration. It is the portfolio to improve the system energy at the side of consumption and improves energy efficiency in a better way [7]. However, there are particular challenges to generating companies and stakeholders to integrate. For successful integration some essential points to be noted which was addressed by the authors like system operation and balance, its transient stability, grid infrastructure issues, internal issues, market redesign etc., [8].

III. ISSUES CONCERNED WHEN RENEWABLES ARE INTEGRATED TO GRID NETWORK SYSTEM

There are certain benefits available when we are utilising renewable energy, having very low or negligible greenhouse gas emission, which is the crucial aspect of an overall change in the environmental weather condition globally. Mainly in the power sector, these renewable energy-based power generation reduces the effect of greenhouse gas emission, caused due to the production of power generation by combustion of fossil fuels. However, in India, after renewable energy generation hydro-power generation also taken a leap about 14.6% over the entire production period, to share its generation to many regions and contributed to reducing the emission of CO_2 in total power generation, fig.2 shows the present power scenario of India [11].

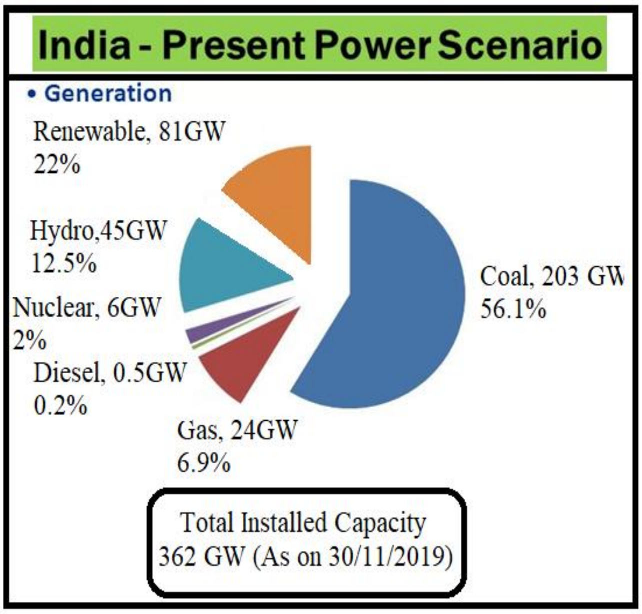

Fig.2. India Power Scenario

The use of fossil fuels makes a rise in several pollutant gases; causes a change in the quality of atmospheric air and harmful impact on human and all existing ones. By combustion of fossil fuels for power generation releases most important pollutant gases like SO_2 and NO_x, SO_2 is the primary pollutant gas, released from the thermal power plant by burning of coal, due to these pollutant gases there will change in the ecological conditions. As increasing in the renewable energy technology and innovations to generate electric power, not only reduces pollutants like SO_2 and NO_x but also it requires very less amount of water used for maintenance purpose like cleaning the solar panels. Renewable sources like solar and wind power do not require water for the production of electrical energy; even these do not require a large amount of water for cooling purposes also as generally used in thermal power plants.

A. Integration Challenges

Integration of massive amount of renewable energy resources with utility grid has different challenges, which results in the electrical power system objectives to reduce a large amount of carbon emission. Power generation with the help of renewable resources has certain limits and it is a difficult task to share the generated power to a utility grid. Some of the challenges faced during the integration of renewable resources to the utility grid are shown in fig.3.

In the electrical power system, the main issue is due to the mismatch between generation and demand. So to maintain the generation and demand, according to demand response in the real-time is one of the significant challenges with the variable renewable energy sources and also it is more economical for energy storage for large scale integration. In an electrical power system, some new techniques in planning and risk management have to be adapted for making an accurate decision due to uncertainty in renewable energy. Integration of large scale renewable energy into the transmission network and small scale renewable energy to the distribution network. These distributed energy sources and energy storage devices are integrated at the point of distribution level makes the uncertainty in the line loading. Nowadays electrical power system is becoming a smart network, which increases its functional operation, efficiency and flexibility. Design of power system protection has to be adopted for the new operating condition because of some issues in distribution network with small scale integration, due to its uncertainty in the generation, which results in the transformer and line loading.

However, electrical power system operators are planning to have particular planning and management for the variable renewable energy resources and load demand response. Centralised operators and distributed operators have full control over these system planning for making the correct decision to provide stable and reliable power to the consumers. Nevertheless, when integrating the renewable resources with the utility grid, some fundamental power quality issues have to be met. The power quality issues like voltage or current deviation, frequency variation, harmonics, transients etc. When we are integrating a large amount of solar and wind energy, some technical issues are arising mainly in the field of power electronic interface at the high-level power. However, in small scale integration, microgrid and its energy management are used for the bidirectional power supply and also it provides the system operational control and regulation. In the electrical power system, power quality is one of the significant issues to ensure system stability, reliability and efficiency. If the system power quality is poor, it may lead to dangerous effects like equipment failure. A small variation in the output power may lead to change in its magnitude, which causes large fluctuations in the output power.

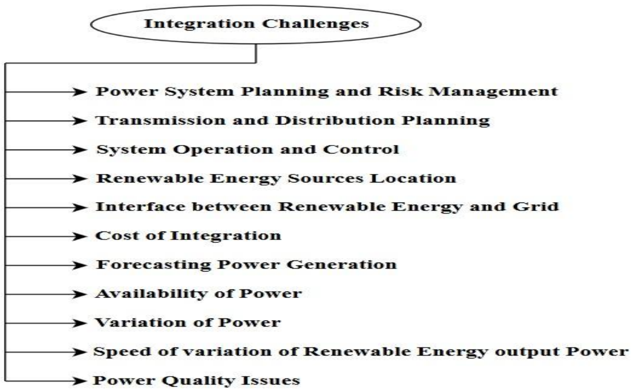

Fig.3. Integration Challenges

B. Issues Regarding Grid Integration

The transmission network of India is in two-level structure, the interconnections between the regions are operated by Power Grid Corporation of India, and whereas the connection between states is operated by State transmission Corporations. These networks (Transmission or Distribution networks) are providing a delay to connect the electric power generated by renewable energy. At present, all regions networks synchronised as a single unit, but these traditional grid networks can occur a problem due to variation in wind power, creates an issue in maintaining generation and consumption mismatch. In India maximum wind farms are located far away from the load dispatch centers. Due to weak-in traditional networks, transmission and distribution networks are not capable of transferring the power generated from wind energy to the distribution centers or load centers. It is one of the critical issues which are addressed in the literature and for the future development of wind energy in the country.

When interconnecting a new system to a traditional grid network, the primary issue of grid transient stability should be considered. Wind farms have to face new challenges like their systems reliability, safety, and efficiency when the power flow management are changed in the conventional networks of an interconnected system. Due to geographical conditions, the power generated from wind energy is static nature, so the main objective is developing an interconnection standard with either transmission or distribution network so that grid has to support the change occurred due to the geographical condition without affecting the system power quality problems.

C. Techniques and Requirements to Integrate Renewable sources into a Utility Grid

Renewable energy sources can be integrated into the utility grid at the point of transmission side or distribution side based on its amount of power generation (Large-scale or Small-scale). Wind energy systems are of a large-scale generation of renewable energy, we can integrate directly to the transmission network, but whereas small-scale renewable energy generation is interconnected to the medium or low voltage distribution networks. However, before integrating into the utility grid, renewable energy sources should be designed and analysed in an aspect such that it can be interconnected to both the types of networks and have to face different issues concerned in it.

D. Integration and their Issues with Small Scale Renewable Energy Generation

Renewable sources like solar, small wind energy, small hydro-power plants, biomass, and biogas are considered as small-scale resources for electrical power generation due to their nature, and their capacity ranges between kilowatts (KW) to megawatts (MW). With this distribution generation units (DG) also comes under small-scale generation, includes both conventional and non-conventional energy sources are connected to a primary or secondary side of the distribution network of a utility grid. To interface these small-scale generating units to utility grid, some power electronic converters are required, without power electronic converters, small-scale renewable sources like solar PV panels cannot be integrated directly to utility grid, but coming to wind energy system they can be connected directly to grid through induction generator and also with power electronic interface to avoid transients occurs at time of starting period. Before renewable sources coming into the picture distribution network consists of a single voltage source on its distribution feeder. Utility grid has to take precise measurements during interfacing with renewable sources to get safe and reliable operation of the system. An IEEE P1547 standard is used for small-scale renewable energy generation to interface with the utility grid as a standard technical requirement.

E. Integration and their Issues with Large Scale Renewable Energy Generation

Wind farms, large hydro-power plants, geothermal energy and steam turbines operated with biomass energy are considered as large-scale renewable energy generation having the capacity in megawatts (MW), and usually connected directly to transmission network of a utility grid. Compared to small-scale generation, the large-scale generation has different types of issues, due to variation in speed of generator and change in the wind speed. The development of wind power in India is increasing, having an installed capacity of 34,046 MW [12], and occupied the fourth largest wind power generation in the world. Other countries like China, United States, Germany and Spain have reached thousands of megawatts and still increasing their wind energy capacity. The output fluctuations occurred due to wind farms requires some techniques like spinning reverse and standby capacity. Due to short circuit occurs in transmission network results in disconnection of large wind farms from the system due to voltage dips causes a stability problem in the power system network. During the fault conditions, power transferred between wind energy systems to the network is reduced, which results in an amount of reactive power drawn from the system is increased. By using FACTS devices to compensate for the reactive power, the performance of the wind energy system will increase.

F. Requirements to Integrate Renewable sources to Utility Grid

As renewable energies are based on the geographical condition, the output power coming from sources are fluctuated due to variation in nature and change in the speed of the generator. So before connecting to the grid through either distribution network or transmission network, there are some requirements before going to integrate such as voltage and frequency regulation. When we are using more than two sources such as wind and solar as a hybrid system, the main issue is regarding unbalancing in terminal voltage when combing two sources at point of common coupling, and in case of hydro, geothermal or wind system frequency variation (both primary and secondary) is essential issues due to variation of nature and speed. Unbalance in the terminal voltage, which causes a change in reactive power similarly due to the variation in frequency there will effect on active power. So to maintain active and reactive power regularly, voltage and frequency droop control methods and some optimisation techniques should be implemented.

IV. PROPOSED METHODOLOGY

Microgrids may have more than one distributed generating units (DG), which can operate either in standalone mode or grid integrated mode, causes issues and create challenge to operators when operated in these two modes. Microgrid consists of Solar PV system, Wind energy system with a battery energy storage system which is integrated to utility grid through DC/DC buck/boost converter which is used to extract maximum power from the renewable energy sources, which interfaced with point of common coupling (PCC) through DC/AC power converter circuit. Local loads are connected at PCC, as the microgrid can operated any mode. Wireless droop controller is used mostly for load sharing and for maintaining constant dc bus link voltage. Other type of controller master-slave droop controller (Wired droop controller), has a drawback that when more than two converters operated parallel, the primary converter (acts as master) used to control the dc bus link voltage and transmits the reference signal to the other converter (slave converter). If the primary converter fails, the total system is going to be shutdown. Whereas in the voltage droop control, each converter is interfaced to common point and each converter respond individually and calculates how much energy has to be supplied or consume and maintains the output voltage of DC bus link voltage at its nominal value. Voltage droop control regulates the inverter output voltage and frequency when sharing active power and reactive power. Droop control is the origin which is widely used in complex power generated and transferred through transmission lines.

V. SIMULATION RESULTS AND DISCUSSION

In this paper, a hybrid model based on wind and solar PV system was designed in Simulink. The parameters are listed in table.1. As part of the integration of solar and wind to a utility grid, we mainly concentrated to maintain the dc bus link voltage when two or more energy sources are interconnected with each other. As the renewable energy are dependent of geographical conditions, with varying the solar irradiance and wind speed the output will fluctuate, to extract maximum power from these sources DC/DC converter are using with certain MPPT technology. But when interconnecting two sources the voltage at the dc bus link is going fluctuate. Here the energy sources are modelled with 500V (both solar and wind) which are shown in fig.4 and 5.

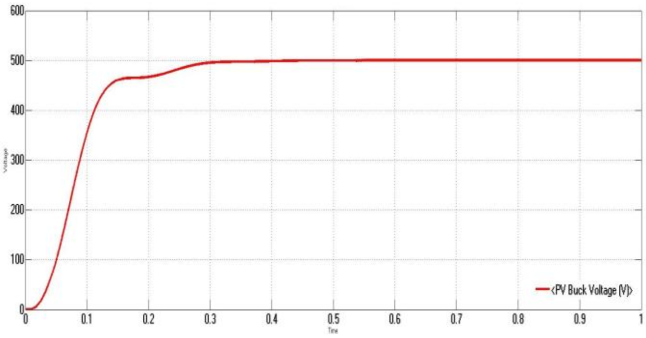

Fig.5. Output Wind Turbine (DC) Voltage

Simulation Result Parameters		
Parameters	**Symbol**	**Output Ratings**
Specification of the Solar Photovoltaic Module		
Maximum PV Power	P_{PV}	14KW
Maximum PV Voltage	V_{PV}	500V
Maximum PV Current	I_{PV}	28A
Open Circuit Voltage	V_{OC}	32.9V of each cell (Total 360 Cells in one Module)
Short Circuit Current	I_{SC}	8.21A (Single Module)
Specification of Wind Turbine		
Maximum Power	P_{WT}	14KW
Maximum Voltage	V_{WT}	500V
Maximum Current	I_{WT}	28A
Specification of BESS (Lead-acid Battery)		
Battery Voltage	V_{Bat}	200V
Battery Rated Capacity	C^{r}_{Ah}	40Ah
Maximum Battery Capacity	C^{max}_{Ah}	41.66Ah
Fully Charged Voltage	V_{ch}	217.76V
Discharge Current	I_{dch}	8A
Other System Specification		
DC-Link Bus Voltage	V_{dc}	500V
Connected Load-1	P_{L1}	3KW
Connected Load-2	P_{L2}	3KW

Table.1.System Parameters Specifications

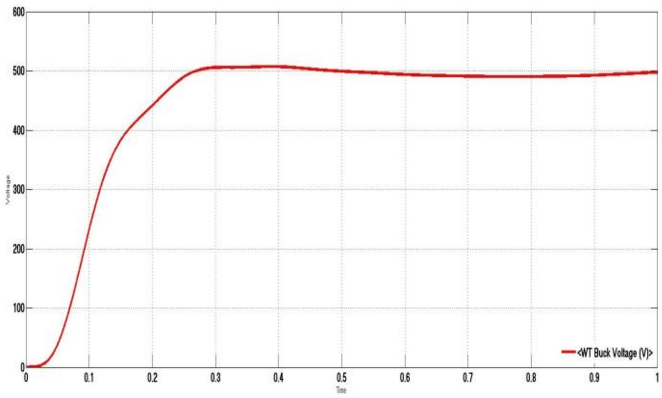

Fig.5. Output Wind Turbine (DC) Voltage

The objective is to provide constant voltage to the dc bus from renewable sources. The power balance is also done by maintaining dc bus link voltage constant but when interconnecting two or more sources or change in the nature the output voltage of each source fluctuates. Fig.6 shows the dc bus link voltage when both wind-solar are interconnected to each other.

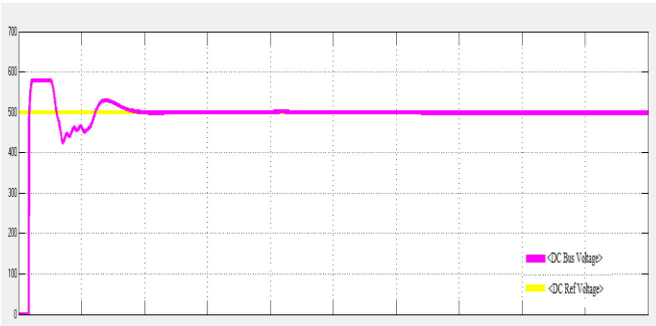

Fig.6. DC Bus link Voltage

With maintaining the dc bus link voltage at constant, the operation of microgrid under grid-connected mode with a constant load with different solar irradiation and wind speed is shown in fig.7 to 9.

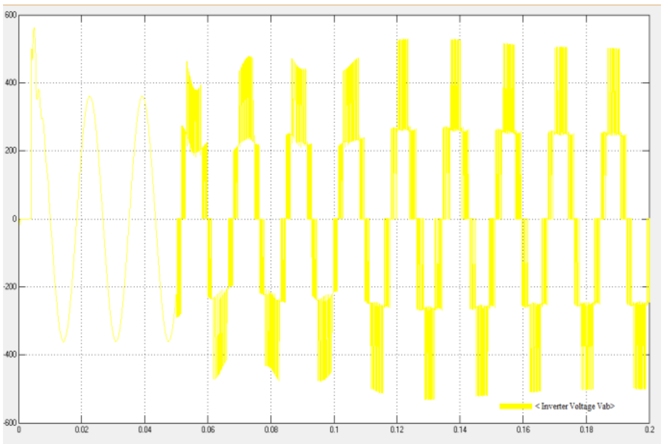

Fig.7: Inverter Vab line Voltage

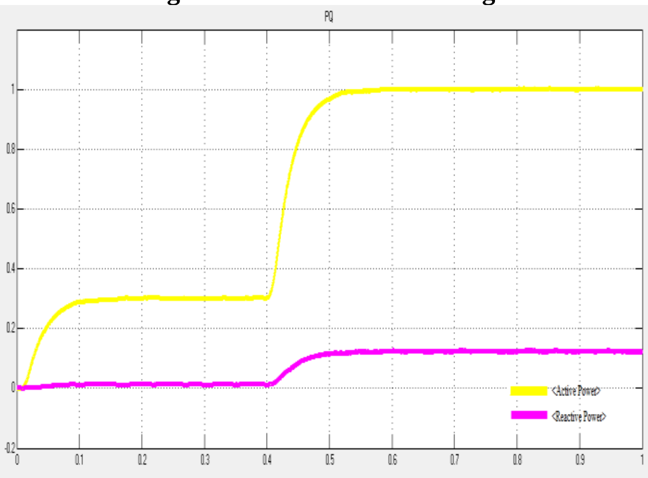

Fig.8: Active and Reactive Power

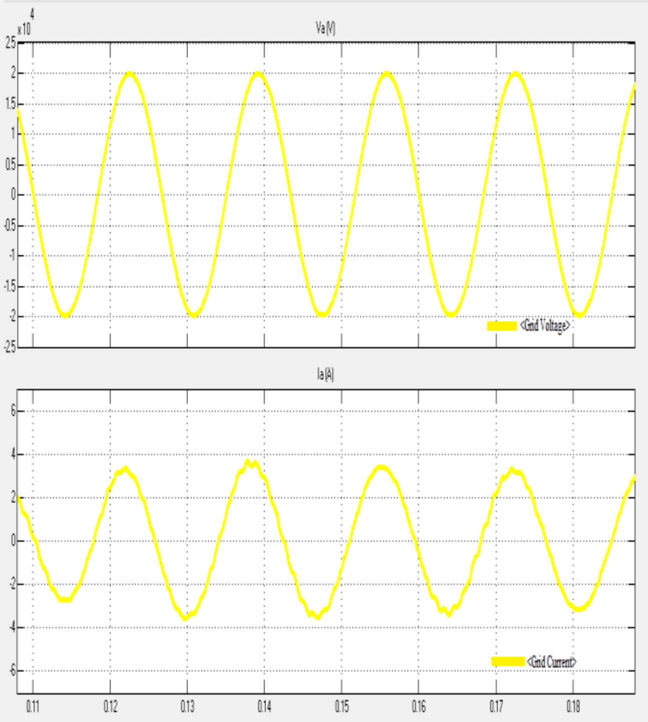

Fig.9: Grid Voltage and Current

VI. CONCLUSION

The utilisation of renewable energy resources in electrical power generation impacts in the reduction of global warming and carbon emission. However, these renewable resources have some difficulties to integrate with the utility grid, which results in some technical challenges like grid integration issues, power quality issues, output power variation, energy storage location etc. In this paper, some technical challenges are addressed which are associated due to the integration of variable renewable energy to the utility grid. In the electrical power system, all the utility grid has its own optimal solution for integration of renewable energy sources. An energy management system is used for achieving large scale integration of renewable energy with its continuous change in power generation characteristics to maintain reliable service to the consumers.

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