International Journal of LNCT
Volume-2 Issue-9 December-2018
ISSN: (Online):2456-9895

Power Enhancement in Hybrid PV Wind System Using Power Buffer Control

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Abstract -Solar and wind energy system is one of the most prominent sources of energy. The utilization of solar and wind energy system has become increasingly popular due to modular and environment friendly nature. Solar and wind energy system works normally in standalone or grid connected mode, but the efficiency of these sources is less due to the stochastic nature of solar and wind resources. The hybrid renewable energy sources with grid integration overcome this drawback of being unpredictable in nature. The use of active dynamic buffers is a method for mitigating the effects of constant power loads is. These devices act as an interface that decouples the dynamics of the load from the system. In this paper we have designed a hybrid Solar Wind Energy System using MALAB/SIMULINK environment to enhance the output by reducing Total harmonic Distortion in the output voltage waveform by employing suitable power buffer. The active Power output with power buffer came approximately 8000 volt ampere and is highly stable whereas the active power output from the inverter without buffer is varying between 5000 volt amperes. More smooth and stable active power output from the inverter has been achieved with power buffer in solar wind hybrid system. It was concluded that the stability and safety of the power grid based on the hybrid system is improved when the power through the designed hybrid system with power buffer is fed to the grid system.

Keywords: Power Buffer, Active Power, THD, Stability

1. Introduction

Electricity is the important factor for industrialization, urbanization, financial growth of any country [1]. There are different types of conventional and unconventional energy sources used to generate electricity. Solar and wind power plants are one of the most important sources of energy. The use of solar and wind systems has become increasingly popular due to its modular and ecological nature [2].

The solar wind field has experienced significant growth over the last two decades, taking advantage of the use of autonomous systems for interactive wind systems [3]. Solar and wind turbines generally operate in standalone or network mode. However, the efficiency of these sources is lower due to the stochastic nature of solar and wind resources. Hybrid renewable energy sources associated with a network outweigh this disadvantage, which is unpredictable by nature.

The Hybrid Renewable Energy System (HRES) is a combination of renewable and conventional energy sources. It can also combine two or more renewable energy sources operating in stand-alone or network mode. HRES, which combines the main solar and wind energy resources, operates in two modes: simultaneous and sequential. In simultaneous mode, solar and wind power plants produce energy at the same time as they produce electricity in sequential mode.

1.1 Hybrid power and methodology

The general Hybrid power system mainly consists of three stages:

a) Power Generation Stage

b) Converter / Controller Stage

c) Distribution Stage

1.2 Solar Energy

Energy is essentially the radiant energy emitted by the sun, another term called solar energy. Solar energy is a form of radiant light and heat used by many technologies, including solar thermal power stations, photovoltaic power plants, solar thermal power stations and power plants. Solar energy is a very important source of renewable energy.

Its technology is classified as passive solar and active solar. It mainly depends on how they capture and distribute solar energy or convert it into solar energy. Active solar technologies include concentrated solar energy and solar water heating in photovoltaic systems. Passive solar techniques include the alignment of a building with the sun, the selection of materials with a favorable thermal mass or light scattering properties and the design of spaces in which air naturally circulates.

Solar energy, which is widely available, makes it a very attractive source of energy. The development of solar energy is convenient and clean solutions will have long-term benefits. In the use of solar radiation many technologies are developed, such as solar power plants, photovoltaic, solar cookers, solar heating and solar cells. In solar power stations, solar power systems use lenses or mirrors and a pointing system to focus most of the sunlight on a small beam. Photovoltaic transforms light with the photoelectric effect into electrical or electrical energy.

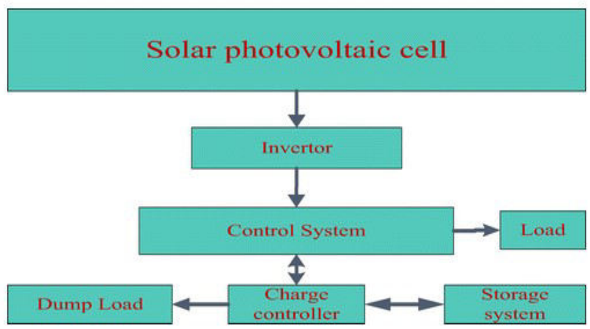

Figure 1.1. Architecture of PV hybrid system.

The term solar cell indicates when to capture the energy of sunlight and the term photovoltaic cell is used if the light source is not specified [9]. In general, solar cells are present in solar panels. When the solar energy of solar cells is turned on, the current is generated by the separation of electrons and excited holes.

2.Literature review

Khare V et al.[1] this article is to present the main limits in the development of renewable energy in India in a coherent and integrated way. There are restrictions that hinder the solar and wind system in India. However, India has provided the sun and a sufficient balanced wind speed available. Therefore, it is in the Indian scenario, a great opportunity for the development of solar and wind energy, as well as sufficient space for the future, renewable sources such as "grid parity".

Elhadidy MA et al [2] In this study were wind speeds per hour of solar radiation measurements at the Sonnenstrahlungs- and Dhahran weather station (26 ° 32'N, 50 ° 13'E) in Saudi Arabia performed influences important parameters like the photovoltaic (PV) -Arrayfläche, the number of wind machines and the capacity of conversion batteries of hybrid systems (solar wind + + diesel) storage, while an annual specific charge of 41,500 kWh is satisfactory. Average mean wind speeds in Dhahran are from 4.1 to 6.4 m / s. Daily daily solar radiation values for Dhahran are from 3.6 to 7.96 kWh / m2. Parametric analysis shows that two 10 kW wind machines in combination with a three-day battery depot and use 30 instead of photovoltaic systems, the diesel accounting system for about 23% of the load request. With the removal of the battery, however, the diesel system must provide about 48% of the load.

Nema, S. et al. [3]In this work, the study of Simulink photovoltaic cells / PV modules / photovoltaic generators based on Simulink Lab is performed and presented. The simulation model uses the basic equations of the circuit for photovoltaic solar cells as a function of their behavior as a diode, and the study of global behavior is performed under different conditions such as solar radiation, temperature, the various parameters of the series model standard and shunt resistance. The study is useful for describing the theory and complexity of photovoltaic cells / modules and can be used to examine the effects of different topologies and control techniques on the performance of different types of photovoltaic systems. What is based on the Matlab / Simulink study is based on the importance of finding the maximum power point for a given module / array. An experimental verification is performed in the laboratory by a developed PC data acquisition system, which is also briefly discussed.

Elhadidy MA et al.[4] In this study, the average hourly wind and solar energy data collected for the period 1986-1997 at the Dhahran solar and meteorological station (26 ° 32 'N - 50 ° 13' E), in Saudi Arabia, were analyzed to determine the potential for using hybrid energy conversion systems (wind + solar) that meet the load requirements of a typical commercial building (with 620,000 kWh). Average mean wind speeds in Dhahran are from 4.1 to 6.4 m / s. The average daily values of solar radiation for Dhahran range from 3.6 kWh / m2 to 7.96 kWh / m2. The hybrid systems considered in this analysis consist of various combinations of commercial wind energy conversion systems (WECS) of 10 kW, photovoltaic panels (photovoltaic panels) integrated by battery accumulation and diesel support. The study shows that the 30 WECS diesel backup system with 10 kW and 150 m2 of PV and 3 days of battery storage must cover 17% of the required load.

3. OBJECTIVE

• Design a hybrid Solar Wind Energy System using MALAB/SIMULINK environment

• To enhance the output by reducing Total harmonic Distortion in the output voltage waveform by employing suitable power buffer.

• To design power buffers for hybrid Wind/Solar system to damp out voltage fluctuations and improve micro grid's stability. To design a control to manage energy-impedance profiles of power buffers across the grid.

• The stability and safety of the power grid based on the hybrid system need to be improved when the power through the designed hybrid system with power buffer is fed to the grid system.

4. METHODOLOGY

4.1 Methodology

The model has been developed in MALAB/SIMULINK environment. It is a matrix / matrix matrix language with control flow instructions, functions, data structures, inputs / outputs and object-oriented programming functions. It has the following main features:

• High level language for scientific and technical computer science

• Desktop environment for exploring, designing and solving iterative problems

• Graphs to display data and tools to create customized graphs

• Applications for curve adaptation, data classification, signal analysis, control optimization and many other tasks

• Complementary toolboxes for various technical and scientific applications

• Tools to create custom applications for the user interface

Modeling a DC hybrid network system takes place, with the possibility of using solar or wind resources based on availability, which makes the system more reliable. The two resources have been connected to the load through a DC bus which is being fed by the either sources. As shown in fig. 1 basic architecture of the system has been modeled to meet the requirements.

Modeling of various parts of the system has been discussed further. The modeled PV system with MPPT technique for its optimum operation, AC grid with its modeled bidirectional converter, PMSG (permanent magnet synchronous generator) connected with the wind turbine, and DC load has been shown in fig 1.

This chapter discusses the basic modeling structures of solar energy system, power buffers and Wind energy system.

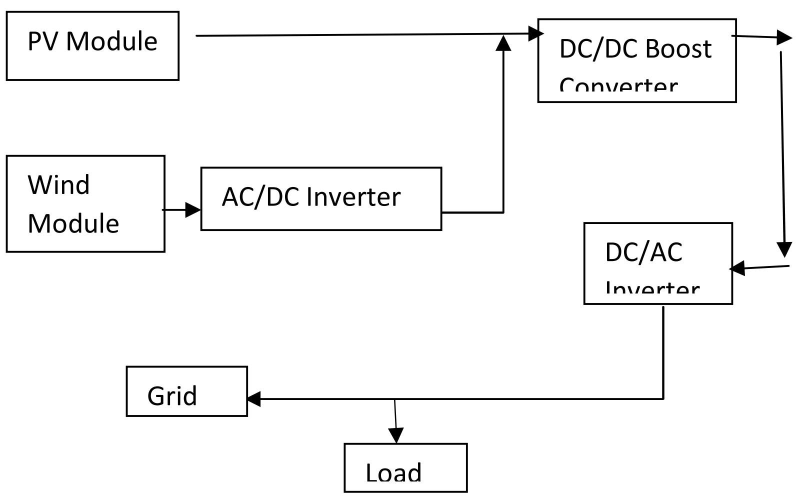

Figure 4.1: Hybrid energy system topology

4.2 PV Module modelling:

PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I.

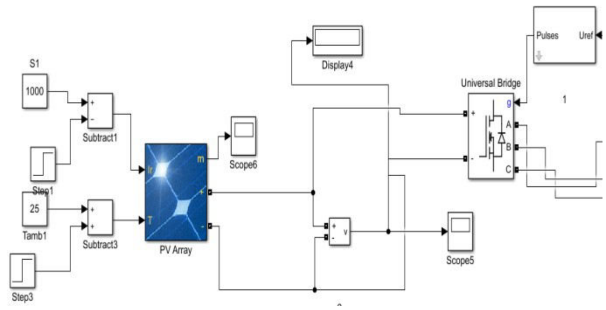

Figure 4.2 Modeled solar system

A cell series resistance (Rs) is connected in series with parallel combination of cellphotocurrent (I_{ph}),exponential diode (D), and shunt resistance (R_{sh}) , I pv and Vpv are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_s)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I_{ph}- Solar-induced current

I_s - Diode saturation current

q - Electron charge ($1.6e^{-19}$C)

K - Boltzmann constant ($1.38e^{-23}$J/K)

n - Ideality factor (1~2)

T - Temperature ^{0}K

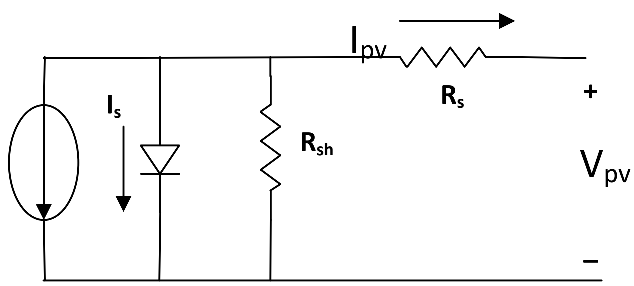

Figure 4.3 Equivalent circuit of solar pv cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000}$$

Where:

I_{SC}Short-circuit current of cell at STC

k_iCellshort-circuit current/temperature coefficient(A/K)

I_r Irradiance in w/m 2

T_C ,T_r Cell working and reference temperature at STC

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve as shown in the Fig 4.4.

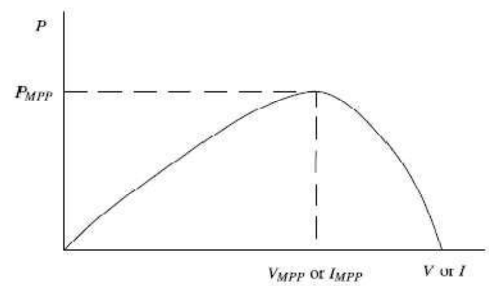

Figure 4.4 Characteristic PV array power curve

The P&O algorithm will track the maximum power to supply the DCMGs system. The assumptions for model derivation are that the ideal current source can be presented as the PVs behavior. In addition, all power converters are operated under the continuous conduction mode (CCM) and the harmonics are also ignored.

4.3 wind energy system modelling

Model of wind turbine with PMSG Wind turbines cannot fully capture wind energy. The components of wind turbine have been modelled by the following equations [8-10].

Output aerodynamic power of the wind-turbine is expressed as:

$$P_{Turbine} = \frac{1}{2}\rho A C_p(\lambda, \beta) v^3$$

Where, ρ is the air density (typically 1.225 kg/m3), A is the area swept by the rotor blades (in m2),*CP*is the coefficient of power conversion and *v* is the wind speed (in m/s).

The tip-speed ratio is defined as:

$$\lambda = \frac{\omega_m R}{v}$$

Where$\omega_m$and R are the rotor angular velocity (in rad/sec) and rotor radium (in m), respectively. The wind turbine mechanical torque output m T given as:

$$T_m = \frac{1}{2}\rho A C_p(\lambda, \beta) v^3 \frac{1}{\omega_m}$$

The power coefficient is a nonlinear function of the tip speed ratio λ and the blade pitch angle β (in degrees). Then Power output is given by

$$P_{Turbine} = \frac{1}{2}\rho A C_{p_{max}} v^3$$

A generic equation is used to model the power coefficient $C_P$based on the modeling turbinecharacteristics described in [2], [7-9] and [11] as:

$$C_p = \frac{1}{2}\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right) e^{-\left(\frac{21}{\lambda_i}\right)}$$

For each wind speed, there exists a specific point in the wind generator power characteristic, MPPT, where the output power is maximized. Thus, the control of the WECSload results in a variable-speed operation of the turbine rotor,so the maximum power is extracted continuously fromthe wind.

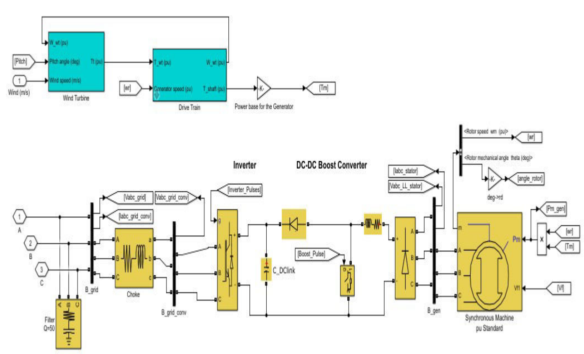

Figure 4.5 modeled Wind system

This mechanism uses the variable torque output $w_m$and tries to optimize the output current and voltage waveform to its maximum value.

4.4 Power Buffer Modeling

The buffer is located between the load and the connection point to the distribution network. The inclusion of the supply buffer in the load structure adds a degree of control freedom to improve the transient response of the system.

The interaction of force buffers affects the dynamic response of the entire microarray. The dynamic model of the entire micro-network is derived taking into account the exchange of information and the collective action of the buffers, as well as the effect of the transmission / distribution network.

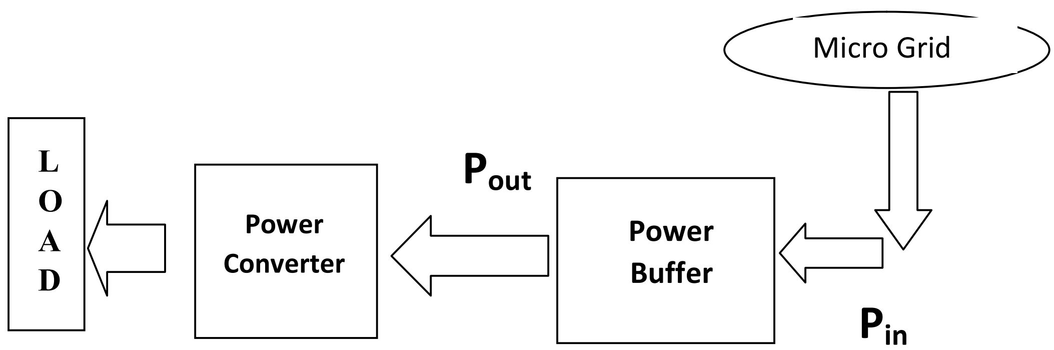

Fig. 4.6 Power buffer operation during a step change in power demand

A power buffer is connected in series with a load driven by the power electronics and forms the instantaneous power profile taken from the distribution network, as shown in FIG.

The final load here refers to the inverter and its load. The active load refers to the serial connection of a power buffer. and one last accusation. In figure 1, the final load suddenly changes load Pout to tt1. To meet the demand for excess energy, the energy storage device slowly increases the input voltage (pin). There will be a gap between the forces delivered and requested.

The buffer uses its stored energy and to compensate for this inadequacy. At the instant t2, the input power is equal to the load request and the buffer mode ends. Then the controller activates energy recovery.

At this point, d. H. T2, t3, the buffer absorbs additional energy from the micro-array to restore it. At time t3, the buffer recovers its initial energy level and ends the energy recovery mode.

For t3, the input power in the buffer memory is equal to the load power, i. H. Pin Pout and stored energy and remain constant until the next load change. The buffer range rt1; t2s is significantly shorter than the recovery interval rt2; T3S.

5. RESULTS AND DISCUSSION

5.1 Implementation Details

This chapter comprises with an analytical and numerical description of proposed algorithm for sentiment analysis of a power buffer which is simulated to obtain the performance of the proposed algorithm.

In order to evaluate the performance of proposed algorithm scheme, the proposed algorithm is simulated in following configuration:

Pentium Core I5-2430M CPU @ 2.40 GHz

4GB RAM

64-bit Operating System

Matlab Platform

5.2 Simulation Environment

MATLAB stands for MATrixLABoratory, which is a programming package exclusively designed for speedy and effortless logical calculations and Input/output. It has factually hundreds of inbuilt functions for a large form of computations and plenty of toolboxes designed for specific analysis disciplines, as well as statistics, optimization, solution of partial differential equations, information analysis.

In this research work MATLAB platform is used to show the implementation or simulation of implemented algorithm performance.Measurement toolboxes are used and some inbuilt functions for generating graphs are used. Simulation results and comparison of the performance of implemented model with some existing ones are calculated by MATLAB functions.

5.3 Modelling of Solar System

The solar panel has been modelled with PV arrays having 10 cells connected in each series with 40 parallel branches that together give out the DC output from the system. The variable illumination of 1000 lux is provided along with varying temperature of 25^0 C .This output is then merged with the DC output from the wind energy system and further sent to the inverter for its AC conversion. The DC output wavefrom have been illustrated in the fig. below.

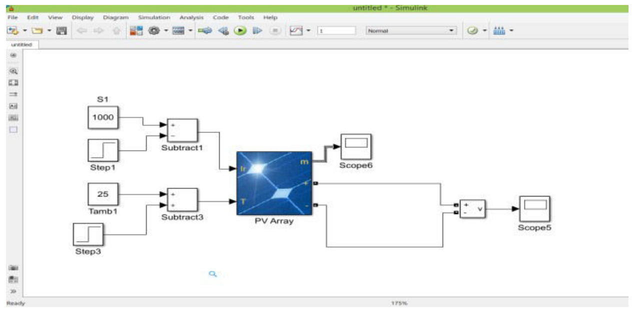

Figure 5.1 Modelled Solar System in MATLAB/SIMULINK

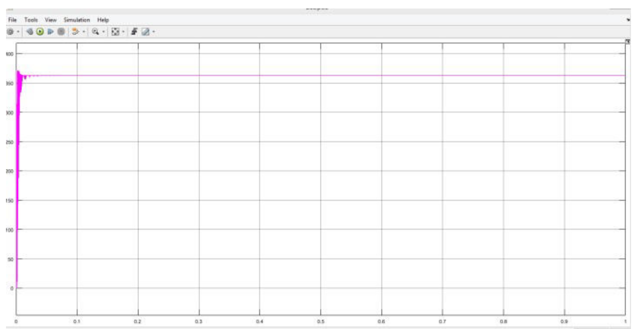

Figure 5.2 DC output from the solar system

5.4 Modelling of Wind System:

Modelling of wind energy system has been illustrated in the figure below. It consists of a turbine and drive train that has been modelled to depict the movemnet of wind turbine due to wind. The turbine mechanical output seves as an inpdfut to the synchronous machine that would there by produce a three phase AC output. This output is converted into DC to damp out the variations due to changes in the frequency arising duce varioations in the wind speed.

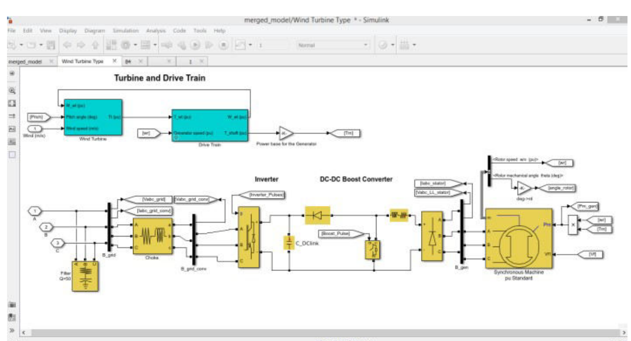

Figure 5.3 Modelled Wind Energy system

The figure below converts the AC output of the synchronous machine to DC. This DC output waveform is then merged with the DC output of the solar system to be then furter conversion through the inverter and supplying to the grid system.

The conversion takes place through a bridge of selected power electronics devices. Series RC snubber circuits are connected in parallel with each switch device. The snubber resistance is kept to be 1x 10^5 ohms and the R_{on} is kept to be $1x10^{-3}$ ohms. The power electronic device MOSFETS/diodes are used for the conversion each pair connected in bridge circuit. The bridge circuit is having three arms of the MOSFETS devices to perform the conversion.

The AC ouput is being fed to the grid through a three-phase transformer built with three single-phase units (no coupling between phases). The transformer R L parameters are obtained from no-load excitation tests and short-circuit tests in positive- and zero-sequence.

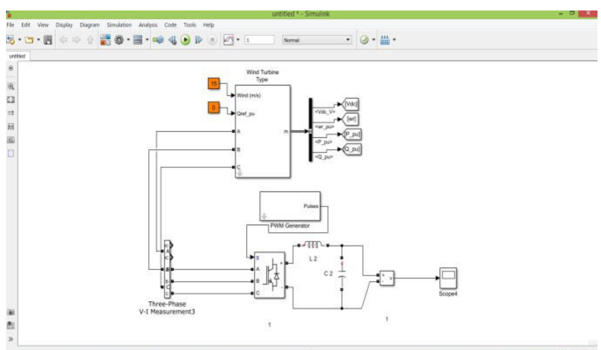

Figure 5.4 AC to DC Conversion system of Wind Output

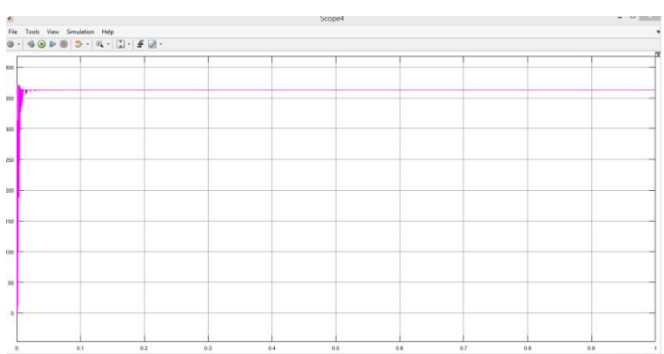

Figure 5.5 DC output from wind energy system

5.5 Scenario 1

5.5.1 Modelling of Hybrid power system without power buffer disconnected from grid

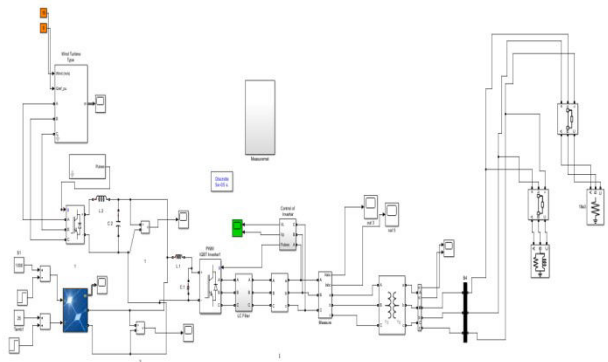

Figure 5.6 Hybrid power system without power buffer disconnected from grid

The system has been modeled with hybrid solar and wind energy without using power buffer before the converter and disconnected from the grid directly feeding the loads.

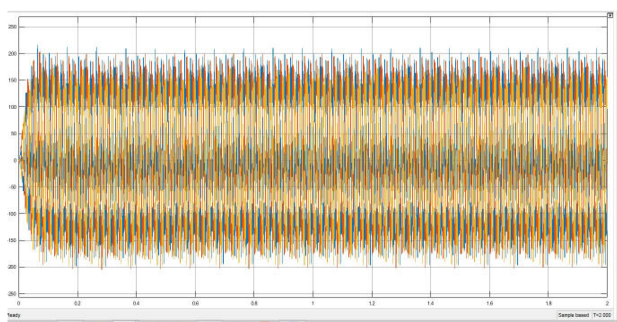

Figure 5.7 Voltage output from the inverter in system without power buffer

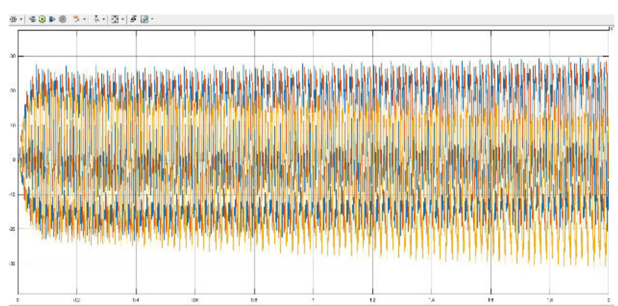

Figure 5.8 Current output from the inverter in system without power buffer

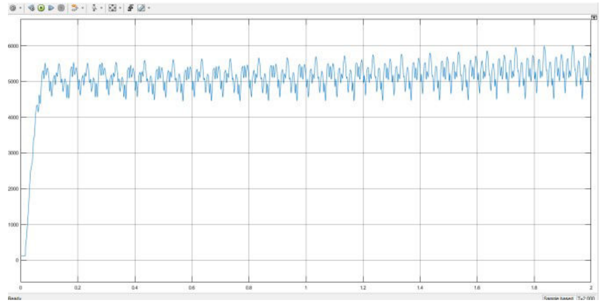

Figure 5.9 Active Power (RMS) Output from the inverter in system without power buffer

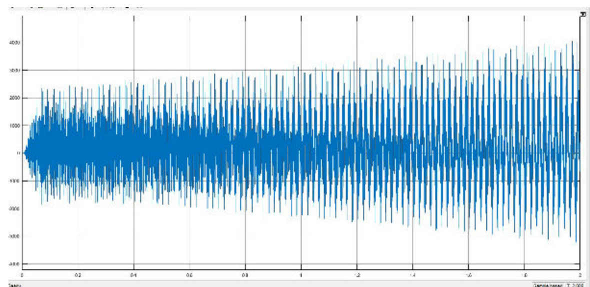

Figure 5.10 Reactive Power (RMS) Output from the inverter in system without power buffer

The above waveform shows the voltage and the current output from the converter along with the RMS value of active power and reactive power that would be later said to the Transformer to be further integrated with the Grid. It can be seen that that is power from the inverter is varying between approximately 5000 VA which is the RMS value for the active power coming from the inverter. It is also observed that the output waveform of the voltage from the inverter is highly distorted when we are not using power buffer in the system.

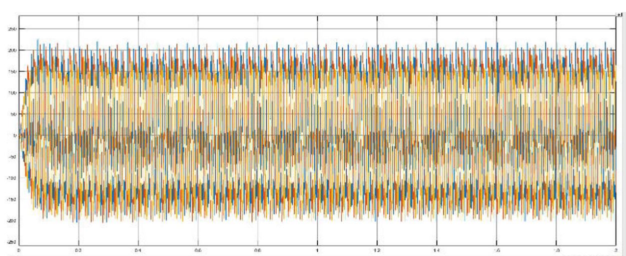

Figure 5.11 Phase to Ground Voltage Output From the transformer fed to the loa

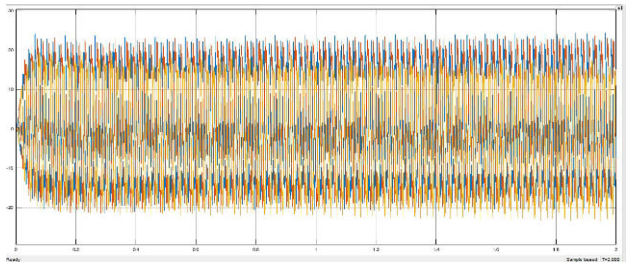

Figure 5.12 Current Output From the transformer feeding loads.

The graph above further describes the voltage output coming from the Transformer that is feeding the load because the system in this case is not integrated with the grid. The phase to phase voltage output from the Transformer is approximately 420 volts and when we see the Phase to ground voltage output from the Transformer it is coming to be 220 volts approximately.

5.5.2 Modelling of Hybrid power system without power buffer connected to the grid

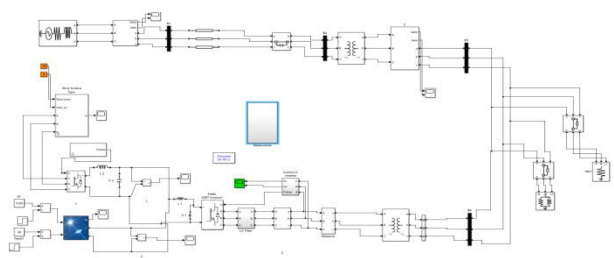

Figure 5.13 Modeled Hybrid power system without power buffer connected to the grid

The system in this case is modelled with hybrid wind and solar energy without using power buffer what is also integrated with the grid. Further the voltage current, active power and reactive power waveforms have been analysed.

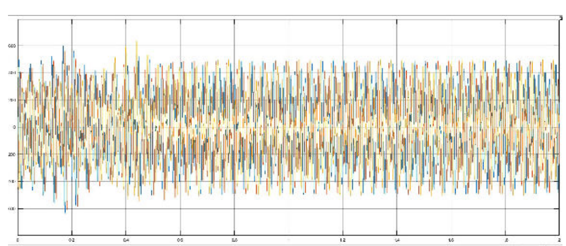

Figure 5.14 Voltage Output from the inverter in system without power buffer connected to grid

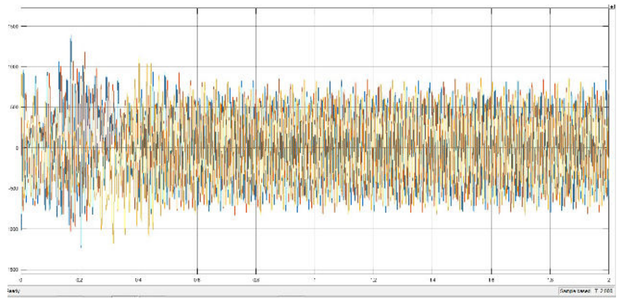

Figure 5.15 Current Output from the inverter in system without power buffer connected to grid

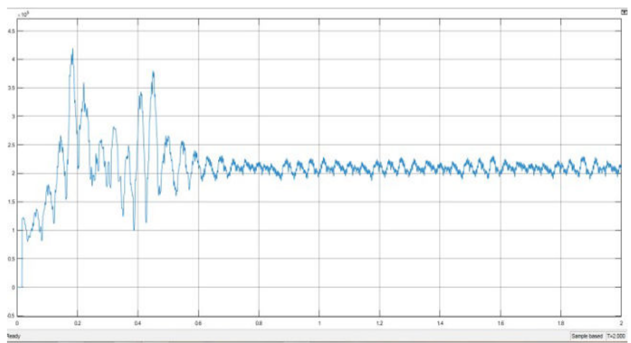

Figure 5.16 Active Power (RMS) Output from the inverter in system without power buffer connected to grid

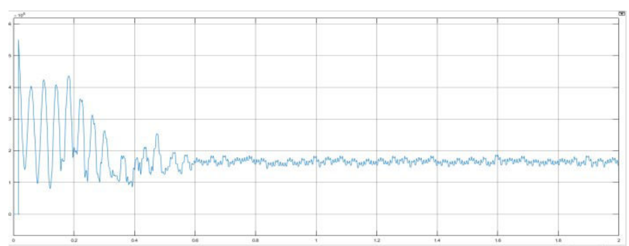

Figure 5.17 Reactive Power (RMS) Output from the inverter in system without power buffer connected to grid

The voltage output from the inverter in this case is also highly distorted and is coming to be approximately 410 volts with variation in current output the graph above also shows The RMS value of active power and reactive power being fed to the Transformer. The active power is approximately 20KVA

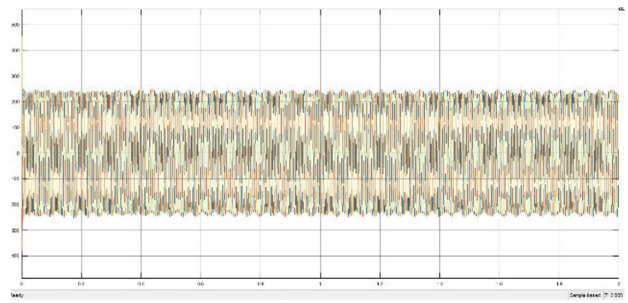

Figure 5.18 Phase to Ground Voltage Output From the transformer connected to grid feeding the load

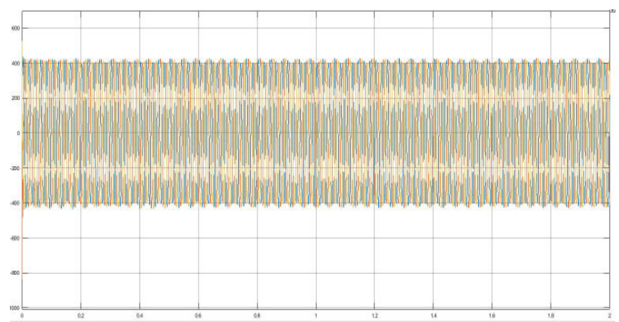

Figure 5.19 Phase to Phase Voltage Output From the transformer connected to grid feeding the load

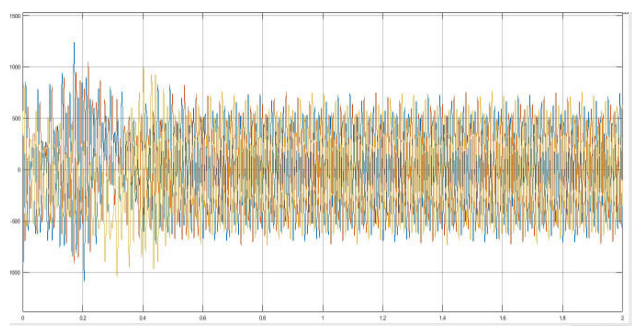

Figure 5.20 Current Output From the transformer connected to grid feeding the load

The graph above shows the phase to phase voltage output from the Transformer that is being fed to the grid which is coming to be approximately 410 volts and phase to ground voltage is coming to be 250 volts approximately. Two loads are also being connected to the Grid via a circuit breaker.

5.6 Scenario 2

5.6.1 The system modeling with power buffer disconnected from the grid

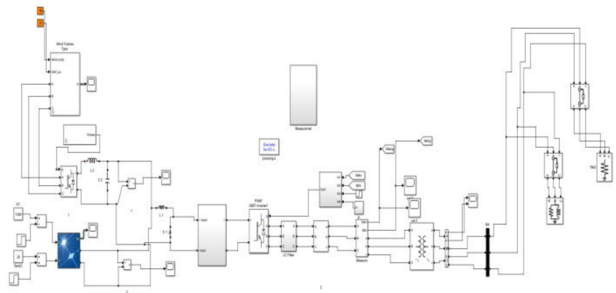

Figure 5.21 Hybrid power system with power buffer disconnected from the grid

In the system, output from the Solar wind energy system is first passed through the power buffer before it is being fat to the inverter for inversion. The system is directly feeding the load instead of being connected to the grid.

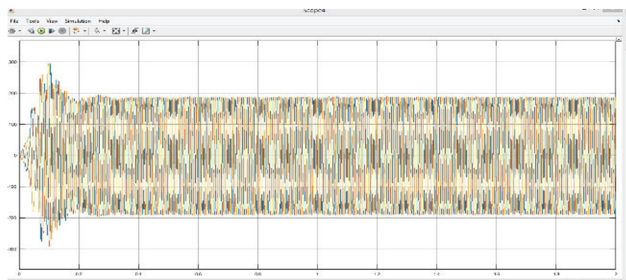

Figure 5.22 Voltage Output from the inverter in the system with power buffer

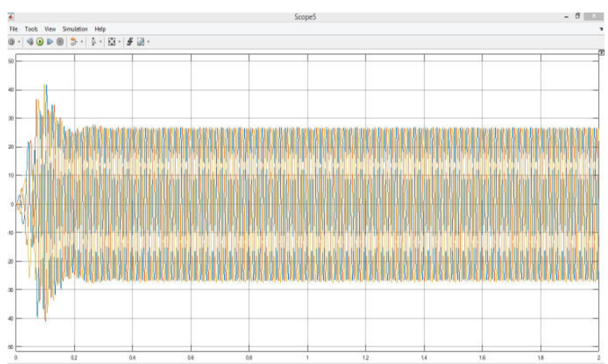

Figure 5.23 Current Output from the inverter in the system with power buffer

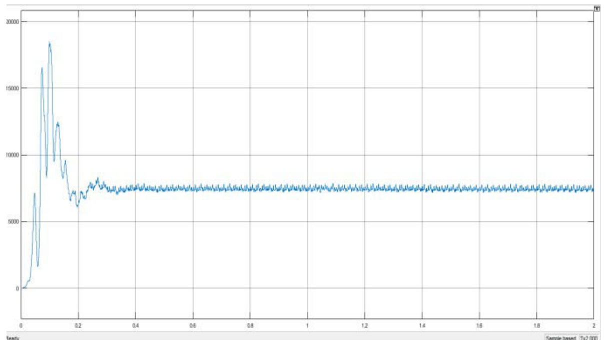

Figure 5.24 Active Power (RMS) Output from the inverter in the system with power buffer

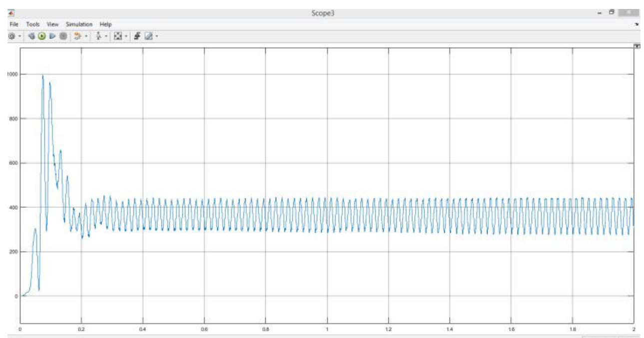

Figure 5.25 Reactive Power (RMS) Output from the inverter in the system with power buffer

The above waveforms shows the voltage output, current output, active power output, and reactive power output from the inverter which will be further passed through the Transformer and fed to the Load. It is concluded that the voltage output from the inverter is highly smooth and is coming to be approximately 200 volts. The distortion while using the power buffer has been considerably reduced.

Also The RMS value of the active power output from the inverter is coming to be approximately 8000 volt ampere

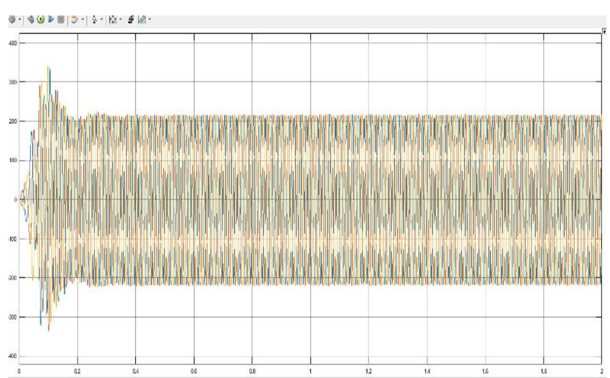

Figure 5.26 Phase to Ground Voltage Output From the transformer

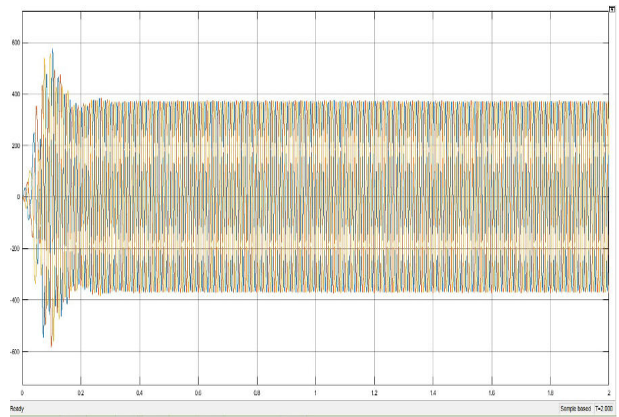

Figure 5.27 Phase to Phase Voltage Output From the transformer

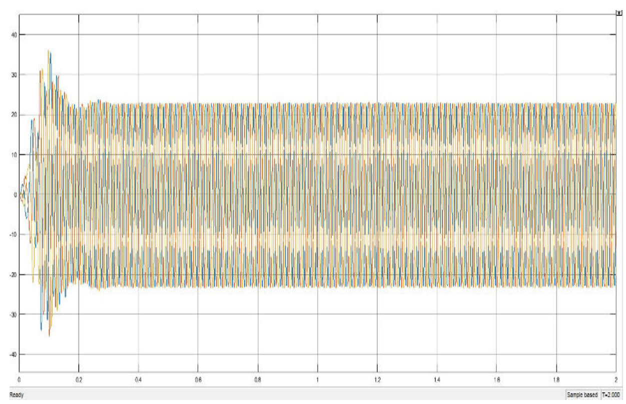

Figure 5.28 Current Output From the transformer

The above graphs are the phase to phase voltage output waveforms from the Transformer which is approximately 410 volts and phase to ground voltage is coming to be approximately 230 volts with current varying according to the Load.

5.6.2 The system modeling with power buffer connected to the grid

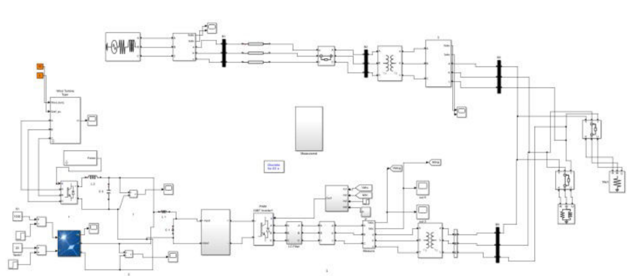

Figure 5.29 The system modeled with power buffer connected to the grid

The system in case 4 is modelled with the hybrid system along with power buffer and after passing through the Transformer it is further integrated with the Grid.

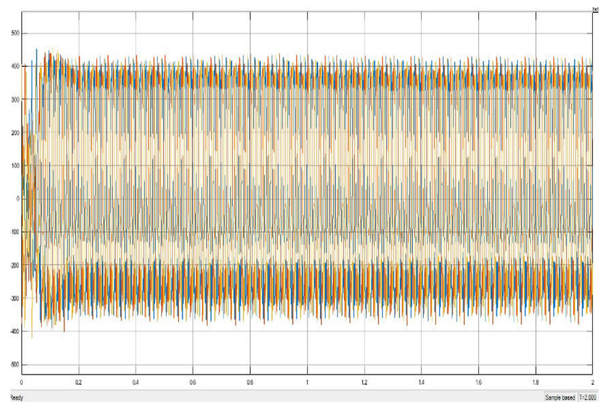

Figure 5.30 Voltage Output from the inverter in the system with power buffer connected to grid

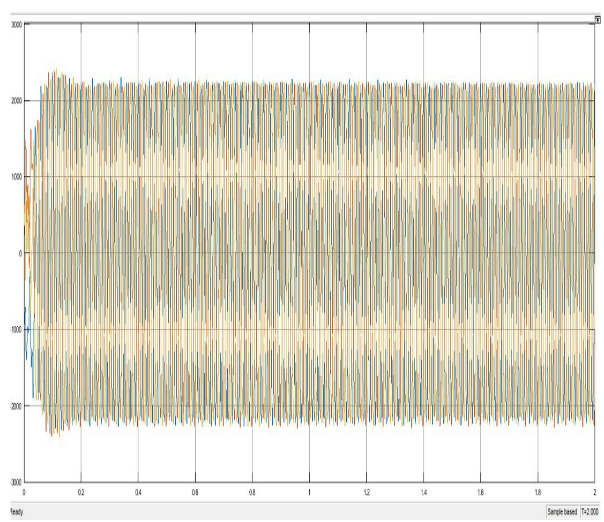

Figure 5.31 Current Output from the inverter in the system with power buffer connected to grid

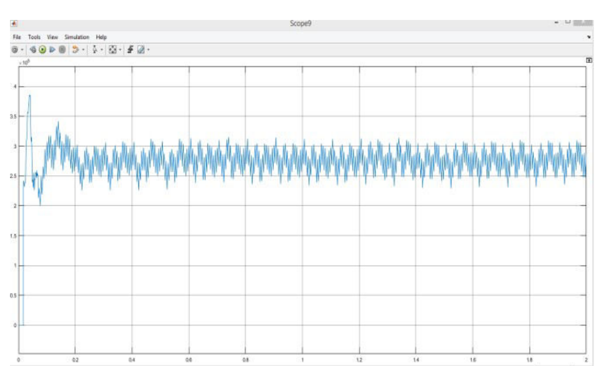

Figure 5.32 Active Power (RMS) Output from the inverter in the system with power buffer connected to grid

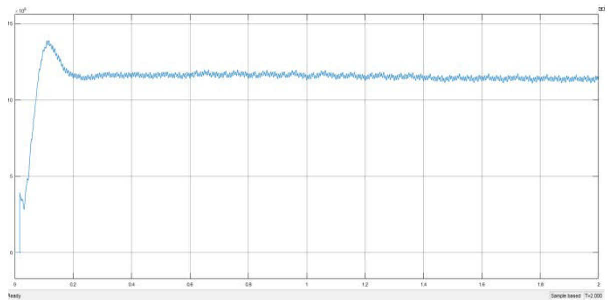

Figure 5.33 Reactive Power (RMS) Output from the inverter in the system with power buffer connected to grid

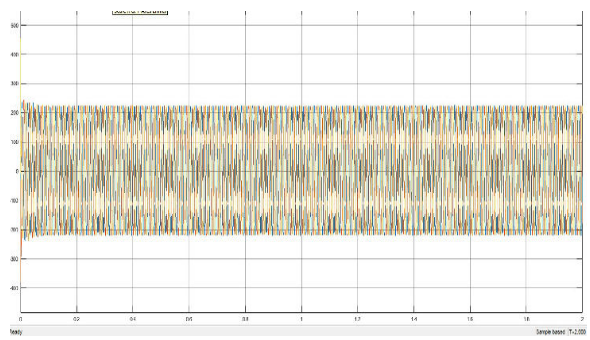

Figure 5.34 Phase to Ground Voltage Output From the transformer Feeding the grid

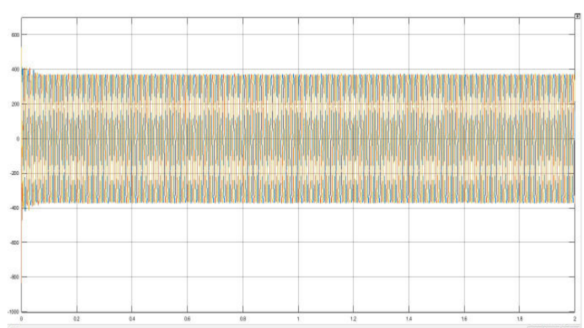

Figure 5.35 Phase to Phase Voltage Output From the transformer feeding the grid

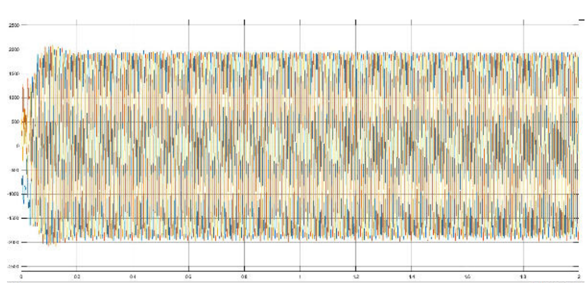

Figure 5.36 Current Output From the transformer Feeding the grid

The above graphs are the phase to phase voltage output waveforms from the Transformer which is approximately 410 volts and phase to ground voltage is coming to be approximately 230 volts with current varying according to the Load

6. VALIDATION

This graph shows that while employing power buffer in the grid system the output has been enhanced to a good level. The power being delivered to the grid has been increased. This is because employing the buffer system gradually increases the voltage output of the system with minimum amount of current being fed into the grid.

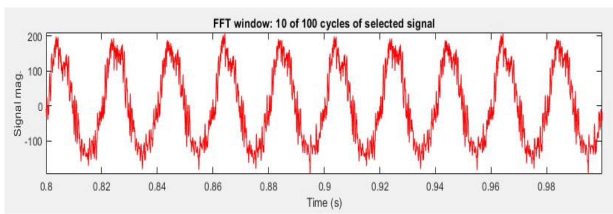

Figure 6.1 FFT analysis of the voltage output from the inverter in the system without power buffer not connected to the grid

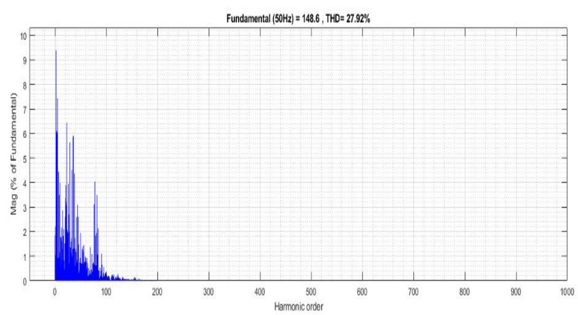

Figure 6.2 THD% of the voltage output from the inverter in the system without power buffer no connected to the grid

Fourier transform of the voltage output from the inverter in the system without power buffer has been carried out for 10 cycles which is shown in figure. It is visible that the output waveform is highly distorted. The total harmonic distortion percentage in the voltage waveform has been calculated to be 27. 92%.

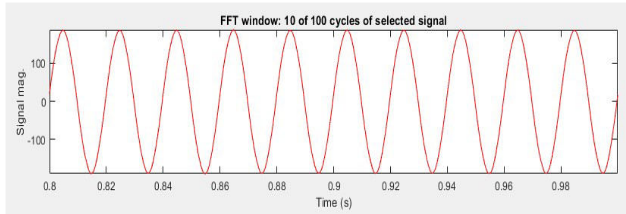

Figure 6.3 FFT analysis of the voltage output from the inverter in the system with power buffer not connected to the grid

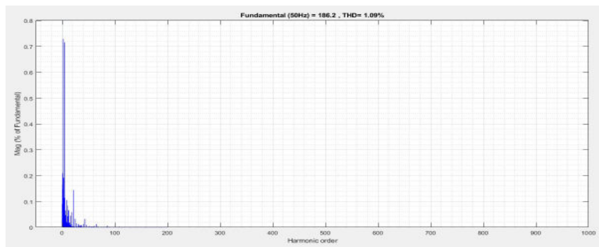

Figure 6.4 THD% of the voltage output from the inverter in the system without power buffer no connected to the grid

Fourier transform of the voltage output from the inverter in the system without power buffer has been carried out for 10 cycles which is shown in figure. It is visible that the output waveform is highly distorted. The total harmonic distortion percentage in the voltage waveform has been calculated to be 1.09%.

It can be concluded that while we are employing power buffer the voltage output waveform is smooth and its distortion level has been considerably reduced from 27.9% to 1.09%

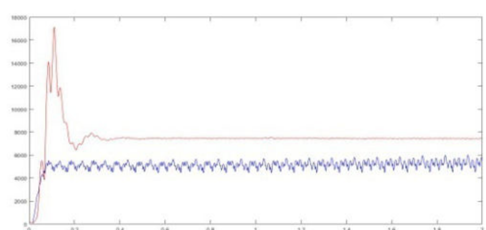

Figure 6.5 Comparative Graph of active power output from the inverter in case of system without power buffer and with power buffer not integrated with the grid

The comparative graph has been drawn between the active power outputs also. It can be seen from the above graph that the active power output from the inverter in the system where we are using power buffer is more as compared to the system in which the power buffer is not used this concludes that the inverter produces more stable and more active power to be fed to the load if we are using power buffer.

The active Power output with power buffer is approximately 8000 volt ampere and is highly stable whereas the active power output from the inverter without buffer is wearing between 5000 volt amperes.

This concludes the work that the usage of power buffer would enhance the power output into the grid and there by the load connected to the grid system. The power buffer is used to enhance the voltage on the DC side of the system which results in further improvement in the grid power supplied by the system.

This would make the system more reliable for heavy load conditions as well.

REFERENCES

[1] Khare V, Nema S, Baredar P. Status of solar–wind renewable energy in India. Renew Sustain Energy Rev 2013;27:1–10.

[2] Elhadidy MA, Shaahid SM. Parametric study of hybrid (windþsolarþdiesel) power generating systems. Renew Energy 2000;21:129–39.

[3] Nema S, Nema RK, Agnihotri G. Matlab/Simulink based study of photovoltaic cells/modules/array and their experimental verification. Int J Energy Environ 2010;1:487–500.

[4] Elhadidy MA, Shaahid SM. Promoting applications of hybrid power systems in hot regions. Renew Energy 2004;29:517–28.

[5] Notton G, Muselli M, Louche A. Autonomous hybrid photovoltaic power plant using a back-up generator: a case study in a Mediterranean Island. Renew Energy 1996;7:371–91.

[6] Karaki SH, Chedid RB, Ramadan R. Probabilistic performance assessment of autonomous solar–wind energy conversion systems. IEEE Trans Energy Convers 1999;14:766–72.

[7] T. H. Rini and M. A. Razzak, "Voltage and power regulation in a solarwind hybrid energy system," 2015 IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE), Dhaka, 2015, pp. 231-234.