Thesis

THE TECHNICAL & ECONOMICAL ANALYSIS OF GRID CONNECTED HYBRID SOLAR PHOTOVOLTAIC (PV) & WIND TURBINE SYTEM FOR IMPROVING POWER QUALITY.

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ABSTRACT

Renewable Energy Resources are best practices possible today to stand against increasingly risk of climate changes and global warming of the world and the most important sources of such types of resources of energies can be Wind and Solar energies whichare most the efficient relatively. These clean power resources are used as in Distributed Generation (DGs) units technology to be defined as newer sources of power, which are in direct relation with the use of micro and smaller in capacity power generatingunits that are installed in distribution part of each power combined system or all the possible locations that loads and energyconsumers are concentrated. Hybrid systems are of different states. One of the practices possible to provide these hybrids iscombination of grid connected wind turbines and solar photovoltaic generators that together each could sit instead of the other onein a grid connection state when one of them cannot generate the required electricity for consumption by load properly. Moreover,Solar cells can generate the electricity required in the day while wind turbines can compensate the needs in the night by wind energy. The proposed architecture consists of Hybrid PV Solar and wind grid connected energy system for improve power quality by reducing Total Harmonic Distortion(THD). In solar PV system MPPT technique is applied to maximize power output, a boost converter is employed to raise DC voltage and its output is fed to a three phase PWM inverter for converting DC voltage to AC at 50Hz frequency. In wind energy conversion system Permanent Magnet Synchronous Generator (PMSG) is driven by two masse drive train based wind turbine with zero pitch angles. Simulation study of the proposed system is carried out with MATLAB Simulink and simulation results are provided. Also An advisable Hybrid Solar Pv and Wind Grid Connected system is Proposed in a suitable place in our country regarding to resource and cost analysis with the help of Homer software.

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Chapter 1 : Introduction

The Government of Bangladesh has issued its Vision and Policy Statement in February 2008, to bring the entire country under electricity service by the year 2020 [1]. Presently, more than 40% of the total population do not have access to electricity [2]. The installed electricity generation capacity of the country is about 10,445MWin 2014 [3]. At present, electricity demand growth in Bangladesh is about 10% annually which is expected to increase in the coming years.Due to gas shortage and inadequate addition of new generation plants in the past few years, demand of electricity has outpaced generation capacity resulting in persistent load-shedding [4]. Present electricity generation scenario in Bangladesh is shown in Figure 1. As the figure shows, 65%of total generated electricity comes from gas. Each year millions of tons of greenhouse gases (GHGs) are being emitted from fossil fuel based power plants. Although the per capita CO_2 emission of Bangladesh is very low compared to developed countries [5], a report showed that the CO_2 emission has increased from 0.1374 tons/capita in 1990 to 0.2667 tons/capita in 2007 [6]. Annual energy shortage and greenhouse gas emission, the two pressing problems, can be solved by installing renewable energy system (RES) such as solar, wind, biogas, and hydro. The increasing demand for conventional energy sources like coal, natural gas and oil is forcing people towards the research and development of renewable energy sources or non-conventional energy sources. Many renewable energy sources like wind, solar etc are now well developed, cost effective and largely used. The present share of renewable energy in Bangladesh isonly 1% [7].This is due to the high initial cost compared to fossil fuel based system. But renewable energy based options become economically viablewhen environmental cost, health hazard, and lower operating cost are taken into consideration These energy sources are environment friendly. Hybrid energy system is the combination of two or more renewable energy sources like wind, solar, hydro etc .These provide a clean and eco-friendly energy. These hybrid systems can be standalone or can be grid connected.

The grid connected hybrid system are more reliable todeliver continuous power to the grid because if there is any shortage of power or fault in the renewable energy sources then the loads are directly connected to the grid. The hybrid power system consist of two Renewable energy sources which are solar energy and wind energy that are used as a input sources . A wind turbine converts mechanical energy into electrical energy and it produces ac output voltage and this ac output voltage is converted to dc by the help of ac to dc converter or rectifier. A PV cell converts the light energy into electrical energy and produces dc output voltage. The reliability to deliver continuous supply to load is more for grid connected hybrid wind and PV system. if there occurs any problem with the energy sources then the loads are connected to the grid.

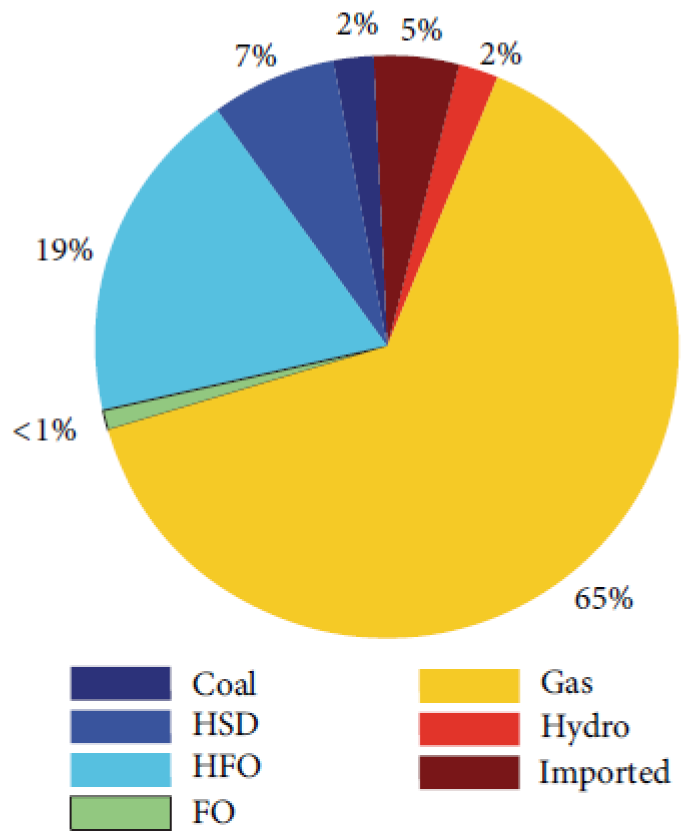


FIGURE 1: Present electricity generation scenario in Bangladesh.

1.1 Objectievs

1)The main objective of this paper is to model a grid connected Solar and Wind hybrid power system for improving Power quality . This system requires the use of power electronics (Mosfet,IGBT ,Diodes) .The extensive use of power electronics based equipment and non-linear loads at PCC generate harmonic currents and volatges, which may deteriorate the quality of power.For improving power quality Total Harmonic Distortion of Volatge and Current is kept very much low before grid connection .

2) An advisable Hybrid Solar Pv and Wind Grid Connected system is Proposed in a suitable place in our country regarding to resource and cost analysis with the help of Homer software.

1.2 Improtance of This Study and Work :

Due to the fact that solar and wind power is intermittent and unpredictable in nature, higher penetration of their types inexisting power system could cause and create high technical challenges especially to weak grids or stand-alone systemswithout proper and enough storage capacity. By integrating the two renewable resources into an optimum combination, the impact of the variable nature of solar and wind resources can be partially resolved and the overall system becomes more reliable and economical to run. This paper provides a review of challenges and opportunities / solutions of hybrid solar PV and wind energy integration systems. Voltage and frequency fluctuation, and harmonics are major power quality issues for both grid-connected and stand-alone systems with bigger impact in case of weak grid. This can be resolved to a large extent by having proper design, advanced fast response control facilities, and good optimization of the hybrid systems. The paper gives a review of the main research work reported in the literature with regard to optimal sizing design, power electronics topologies and control.

The combination of wind and solar has the advantage that the two sources complement each other because the peak operating times for each system occur at different times of the day and year. The power generation of such a hybrid system is more constant and fluctuates less than each of the two component subsystems.[8]

1.3 The Background Of Hybrid Solar And Wind System :

Solar hybrid power systems are hybrid power systems that combine solar power from a photovoltaic system with another power generating energy source.A common type is a photovoltaic diesel hybrid system,combining photovoltaics (PV) and diesel generators, or diesel gensets, as PV has hardly any marginal cost and is treated with priority on the grid. The diesel gensets are used to constantly fill in the gap between the present load and the actual generated power by the PV system.As solar energy is fluctuating, and the generation capacity of the diesel genesets is limited to a certain range, it is often a viable option to include battery storage in order to optimize solar's contribution to the overall generation of the hybrid system.The best business cases for diesel reduction with solar and wind energy can normally be found in remote locations because these sites are often not connected to the grid and transport of diesel over long distances is expensive. Many of these applications can be found in the mining sector and on islands. [9]

Many countries with an average wind speed in the range of 5–10 m/s and average solar insolation level in the range of 3–6 KWh/m^2 are pursuing the option of wind and PV system to minimize their dependence on fossil-based non-renewable fuels . In general, the variation of solar and wind energy does not match the time distribution of the demand. Thus, power generation system dictates the association of battery bank storage facilities to overcome/smoothen the time distribution-mismatch between the load and renewable (solar PV and wind) energy generation (A drawback common to wind and solar system is their unpredictable nature and dependence on weather and climatic change. Both of these (if used independently) would have to be oversized to make them completely reliable, resulting in an even higher total cost. However, a merging of solar and wind energy into a hybrid generating system can attenuate their individual fluctuation increase overall energy output, and reduce energy storage requirement significantly.[3]It has been shown that because of this arrangement, the overall expense for the autonomous renewable system may be reduced drastically . Nowadays, the integration of PV and wind system with battery storage and diesel backup system is becoming a viable, cost-effective approach for remote area electrification. Wind and solar systems are expandable, additional capacity may be added as the need arises. Moreover, the combination of wind and solar PV system shrinks the battery bank requirement and further reduces diesel consumption. The prospects of derivation of power from hybrid energy systems are proving to be very promising worldwide The use of hybrid energy systems also reduces combustion of fossil fuels and consequent CO_2 emission which is the principle cause of greenhouse effect/global warming. The global warming is an international environmental concern which has become a decisive factor in energy planning. In wake of this problem and as a remedial measure, strong support is expected from renewables such as solar and winds . The smart grid readying is associate optimum resolution to the present-day power sector issues like environmental pollution caused by typical power generation, grid losses, as well as poor reliableness and accessibility of power in rural areas . The PV–wind hybrid energy system using battery bank and a diesel generator as a back-up can be provided to electrify the remotely located communities (that need an independent source of electrical power) where it is uneconomical to extend the conventional utility grid. All possible advantages of a hybrid energy system can be achieved only when the system is designed and operated appropriately .[10]

In 2015, a case-study conducted in seven countries concluded that in all cases generating costs can be reduced by hybridising mini-grids and isolated grids. However, financing costs for diesel-powered electricity grids with solar photovoltaics are crucial and largely depend on the ownership structure of the power plant. While cost reductions for state-owned utilities can be significant, the study also identified short-term economic benefits to be insignificant or even negative for non-public utilities, such as independent power producers, given historical costs at the time of the study. [12]. The intermittent / non-dispatchable solar PV at the prevailing low tariffs clubbed with Pumped-heat electricity storage can offer cheapest dispatchable power round the clock on demand.

1.4 Technical Resources :

1.4.1SOLAR ENERGY :Solar energy is energy from the Sun. It is renewable, inexhaustible and environmental pollution free.. Solar charged battery systems provide power supply for complete 24hours a day irrespective of bad weather. Moreso, power failures or power fluctuations due to service part of repair as the case may be is nonexistent.

1.4.2Solar Systems :

There are two types of solar systems; those that convert solar energy to D.C power, and those that convert solar energy to heat.

1.4.2.1 **Solar-generated Electricity – Photovoltaic :**

The Solar-generated electricity is called Photovoltaic (or PV). Photovoltaics are solar cells that convert sunlight to D.C electricity. These solar cells in PV module are made from semiconductor materials. When light energy strikes the cell, electrons are emitted. The electrical conductor attached to the positive and negative scales of the material allow the electrons to be captured in the form of a D.C current. The generated electricity can be used to power a load or can be stored in a battery. Photovoltaic system is classified into two major types: the off-grid (stand alone) systems and inter-tied system. The off-grid (stand alone) system are mostly used where there is no utility grid service. It is very economical in providing electricity at remote locations especially rural banking, hospital and ICT in rural environments. PV systems generally can be much cheaper than installing power lines and step-down transformers especially to remote areas. Solar modules produce electricity devoid of pollution, without odour, combustion, noise and vibration. Hence, unwanted nuisance is completely eliminated. Also, unlike the other power supply systems which require professional training for installation expertise, there are no moving parts or special repairs that require such expertise.

1.4.2.2 **Basic Components of Solar Power**

The major components include P.V modules, battery and inverter. The most efficient way to determine the capacities of these components is to estimate the load to be supplied. The size of the battery bank required will depend on the storage required, the maximum discharge rate, and the minimum temperature at which the batteries will be used . When designing a solar power system, all of these factors are to be taken into consideration when battery size is to be chosen. Lead-acid batteries are the most common in P.V systems because their initial cost is lower and also they are readily available nearly everywhere in the world. Deep cycle batteries are designed to be repeatedly discharged as much as 80 percent of their capacity and so they are a good choice for power systems. Figure 2 is a schematic diagram of a typical Photovoltaic System.

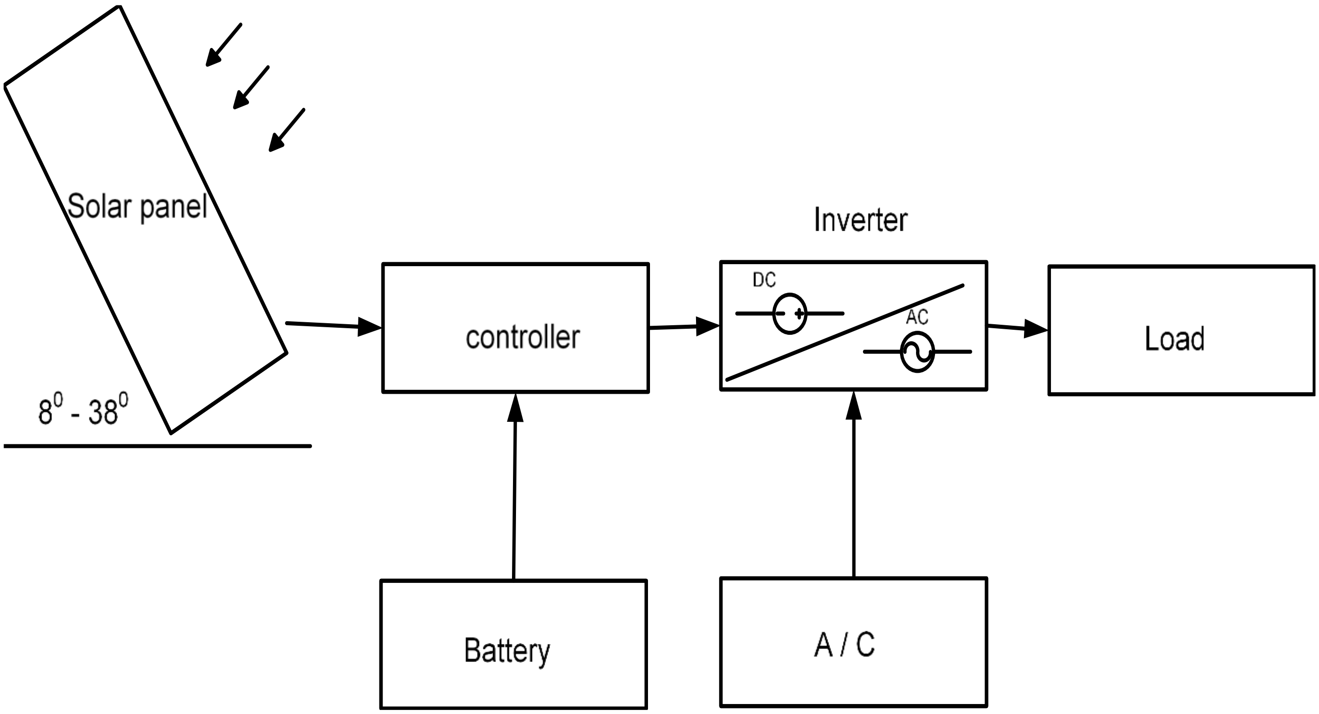


Fig 2: Photovoltaic System

1.4.3 Photovoltaic (P.V) Solar Module: The photovoltaic cell is also referred to as photocell or solar cell. The common photocell is made of silicon, which is one of the most abundant elements on earth, being a primary constituent of sand. A Solar Module is made up of several solar cells designed in weather proof unit. The solar cell is a diode that allows incident light to be absorbed and consequently converted to electricity. The assembling of several modules will give rise to arrays of solar panels whose forms are electrically and physically connected together. To determine the size of PV modules, the required energy consumption must be estimated. Therefore, the PV module size in Wp is calculated as:

Daily energy Consumption / Isolation *efficiency

Where Isolation is in KWh/m2/day and the energy consumption is in watts or kilowatts.

1.4.4 :Batteries and Batteries Sizes of the Solar System

As mentioned above, the batteries in use for solar systems are the storage batteries, otherwise deep cycle motive type. Various storage are available for use in photovoltaic power system, The batteries are meant to provide backups and when the radiance are low especially in the night hours and cloudy weather. The battery to be used:

(a)must be able to withstand several charge and discharge cycle

(b)must be low self-discharge rate

(c)must be able to operate with the specified limits.

The battery capacities are dependent on several factors which includes age and temperature.

Batteries are rated in Ampere-hour (Ah) and the sizing depends on the required energy consumption. If the average value of the battery is known, and the average energy consumption per hour is determined. The battery capacity is determined by the equations 2a and 2b following :

$$BC = 2*f*W/V_{batt} \quad \text{…….. …} \qquad (2a)$$

Where BC – Battery Capacity ,f – Factor for reserve,W – Daily energy

,Vbatt – System DC voltage ,The Ah rating of the battery is calculated as

Daily energy Consumption (KW) /Battery rating in (Amp-hr) at a specified voltage ……..(2b).

Charging Electronics (Controllers)

The need for Charging Controllers is very important so that overcharging of the batteries can be prevented and controlled.. The controllers to be used required the following features[11]:

•Prevent feedback from the batteries to PV modules • It should have also a connector for DC loads

•It should have a work mode indicator.

1.4.5 : Solar Inverters

The Solar inverters are electrical device meant to perform the operation of converting D.C from array or battery to single or three phase A.C signals. For P.V Solar Systems, the inverters are incorporated with some inbuilt protective devices. These include:

•Automatic switch off if the array output is too high or too low.

•Automatic re-start

•Protecting scheme to take care of short circuit and overloading. Generally the inverter to be used that would produce the quality output must have the following features:

•Overload protections

•Miniature Circuit Breaker Trip Indicator(MCB)

•Low - battery protection

•Constant and trickle charging system

•Load status indicator

1.4.6 : WIND POWER

Wind Power is energy extracted from the wind, passing through a machine known as the windmill. Electrical energy can be generated from the wind energy. This is done by using the energy from wind to run a windmill, which in turn drives a generator to produce electricity . The windmill in this case is usually called a wind turbine. This turbine transforms the wind energy to mechanical energy, which in a generator is converted to electrical power. An integration of wind generator, wind turbine, aero generators is known as a wind energy conversion system (WECS).

1.4.6.1 Component of a wind energy system

Modern wind energy systems consist of the following components:

- A tower on which the wind turbine is mounted;
- A rotor that is turned by the wind;
- The nacelle which houses the equipment, including the generator that converts the mechanical energy in the spinning rotor into electricity. The tower supporting the rotor and generator must be strong. Rotor blades need to be light and strong in order to be aerodynamically efficient and to withstand prolonged used in high winds. In addition to these, the wind speed data, air density, air temperature need to be known amongst others.

1.4.7 : Wind Turbine

A wind turbine is a machine for converting the kinetic energy in wind into mechanical energy. Wind turbines can be separated into two basic types based on the axis about which the turbine rotates.Turbines that rotate around a horizontal axis are more common. Vertical-axis turbines are less frequently used .Wind turbines can also be classified by the location in which they are used as Onshore, Offshore, and aerial wind turbines.

1.4.8 :PMSG Genarearator connected with wind Turbine Rotor :

A permanent magnet synchronous generator is a generator where the excitation field is provided by a permanent magnet instead of a coil. The term synchronous refers here to the fact that the rotor and magnetic field rotate with the same speed, because the magnetic field is generated through a shaft mounted permanent magnet mechanism and current is induced into the stationary armature. It acts to control the effective rotor resistance of the generator to optimize the power output as the wind speed changes. In the case of the PMSG, the power converter connects the generator to the grid and is used to convert the frequency of the generator (which varies with the wind speed) to the grid frequency.

1.4.9 :Rectifier, Converter and LC Filter :

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification, since it "straightens" the direction of current. It is used as a converter in wind turbine to convert ac to dc current .

A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission.

Low pass filters are used in a wide number of applications. Particularly in radio frequency applications, low pass filters are made in their LC form using inductors and capacitors. Typically they may be used to filter out unwanted signals that may be present in a band above the wanted pass band. In this way, this form of filter only accepts signals below the cut-off frequency.

1.5 Hybrid Pv and Wind Grid Connected Technique :

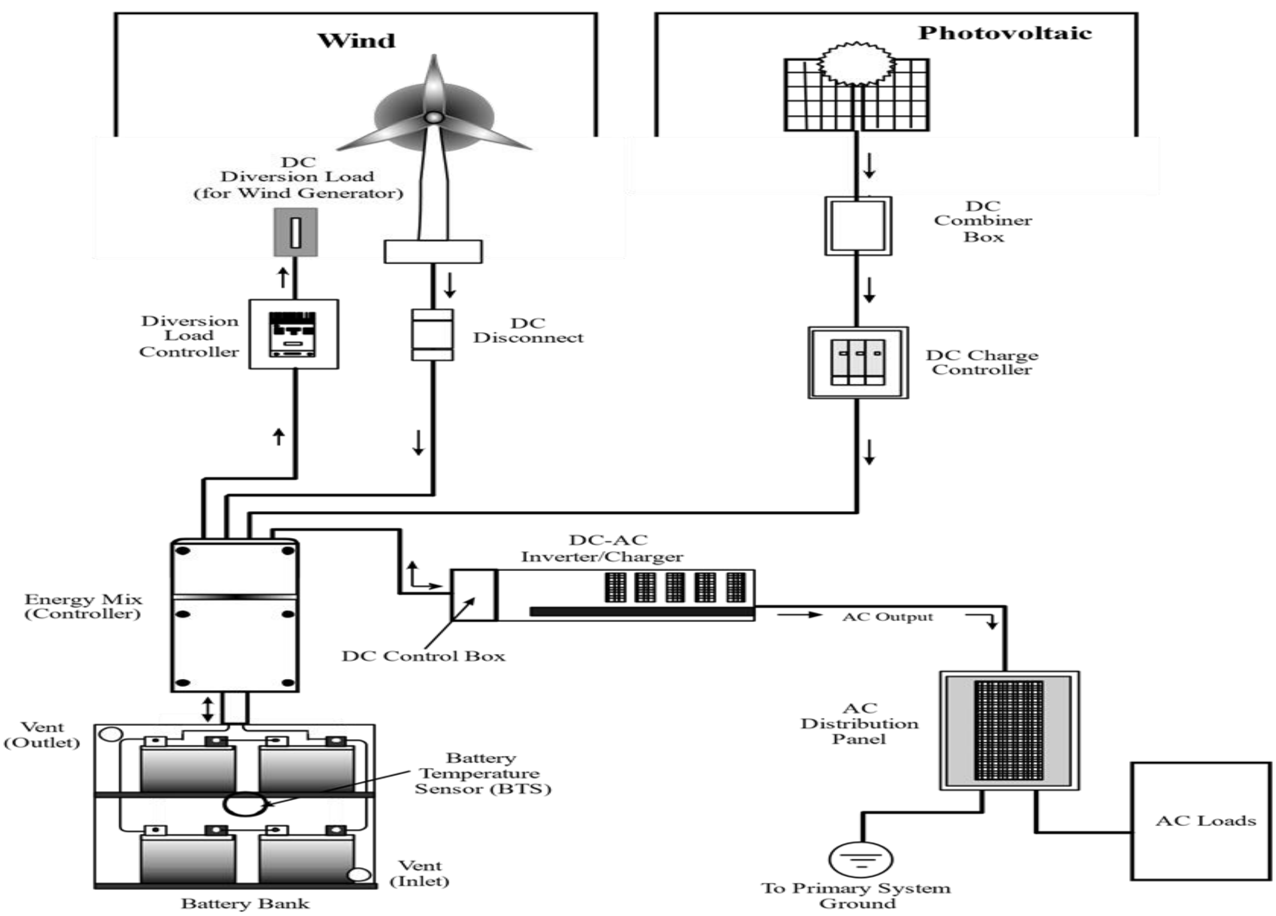


Fig 3: **A simple schematic diagram of Hybrid (Renewable) Solar – Wind Power Source**

1.6 MPPT Algorithom Control System :

MPPT or Maximum Power Point Tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called maximum power point (or peak power voltage).

Wind energy conversion systems have been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a directconsequence of using fossil fuel and nuclear energy sources.

Wind energy, even though abundant, varies continually as wind speed changes throughout the day. The amount of power output from a wind energy conversion system (WECS) depends upon the accuracy with which the peak power points are tracked by the maximum power point tracking (MPPT) controller of the WECS control system irrespective of the type of generator used.

1.7 Present and Futue Scope : According to many renewable energy experts, a small "hybrid" electric system that combines home wind electric and home solar (photovoltaic or PV) technologies offers several advantages over either single system.In Our Country , wind speeds are low in October To March and the sun shines brightest from January to june and the irradance is maxium at this months.So we can get maxium pv power from January to June .The peak operating months for wind is from May to Ausgust. The combination of this system gives a optimum average power in every month throughout a year. Total electrical energy installed capacity is 12229 MW (2016) [13] and total installed wind energy is 1.9 MW. Wind energy potential in Bangladesh is over 20,000 MW [14], the wind speed being < 7 m/sec. In Bangladesh, research in the field of wind energy began only a few years ago, which had shown that some southern districts of Bangladesh have a very good potential of wind energy[8]In Bangladesh first-ever generation of electricity from wind is at Muhuri Dam, Feni having a capacity of 0.9 MW (225 KW, 4 Turbines) and another one at Kutubia Island (20 KW, 50 turbines) with a capacity of 1 MW [15]. Vesta Company of Denmark will invest 100 MW wind power plant which will be made in Patuakhali. This will be the largest wind power plant of Bangladesh[10].On the other hand, the values of solar radiation intensity greater than 200W/m2 were observed in the months February to October in Sylhet, March to October in almost all regions of Dhaka, April to September in Khulna, Northern Areas and Chittagong regions while March to October. For 10 h a day, average solar radiation intensity ranges from 1500W/m2/day to 2750W/m2/day in Bangladesh especially in Chittagong, and Cox's Bazar regions throughout the year. In an area of 100 m2, 45MW to 83MWpower per month may be generated in the above mentioned regions.So,Hybrid pv and wind grid connected system in costal area about 170km will be benifitical and a advisable model is simulated through MATLAB and Homer software with cost efficiency.

Chapter 2 :LITERATURE REVIEW

In This Chapter , A of Hybrid Solar Pv and Grid Connected system for improve power quality is evaluated and compared with respect to classified previous works .Their Advantages and disadvatages are outlined. A number of papers published in IEEE journals and conferences were reviewed literature discussed about power quality and reliability in renewable energygeneration, various forecasting aspects concerning harmonics reduction have been highlighted.

2.1 What is Total Harmonic Distortion and How It is created ?

Total Harmonic Distortion (THD) is a measurement of how much the voltage or current waveform is "distorted" or changed from its conventional sine wave shape. Power comes from the utility in the form of a clean sine wave. As it goes through different types of loads, the voltage and current get utilized at different rates causing distortion to be reflected back from the load onto the system.Distortion mainly occurs in multiples of the carrier frequency (50 or 60 Hz) which are referred to as harmonics. For example, the 3rd harmonic on a 50 Hz line would be 150 Hz, the 7th would be 350 Hz. THD is the cumulative percentage of distortion for all harmonic orders relative to the total power. Distortion is measured separately for the current (THDI) and voltage (THDV).

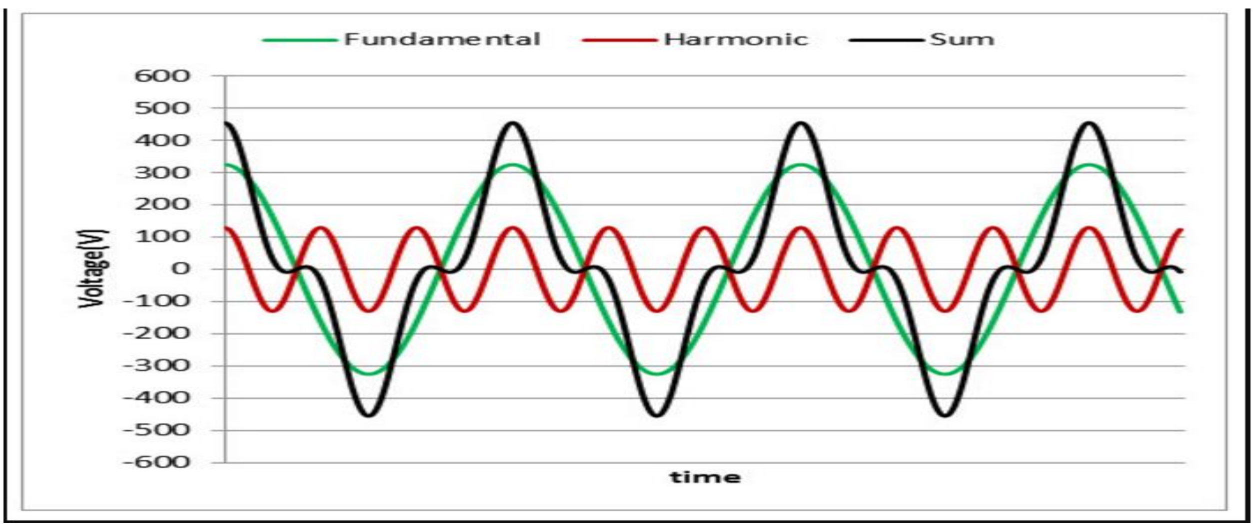


Fig : Understanding THD.

2.1.1THD CALCULATION :

Very short time harmonic values are assessed over a 3-second interval based on an aggregation of 15 consecutive 12 (10) cycle windows for 60 (50) Hz power systems. Individual frequency components are aggregated based on an rms calculation as shown in the following Equation -

$$F_{n,vs} = \sqrt[2]{\frac{1}{15}\sum_{i=1}^{15} F_{n,i}^{2}}$$

Short time harmonic values are assessed over a 10-minute interval based on an aggregation of 200 consecutive very short time values for a specific frequency component. The 200 values are aggregated based on an rms calculation as shown in the following Equation -.

$$F_{n,sh} = \sqrt[2]{\frac{1}{200}\sum_{i=1}^{200} F_{(n,vs),i}^{2}}$$

Where, F represents voltage (V) or current (I)in rms value

n represents the harmonic order

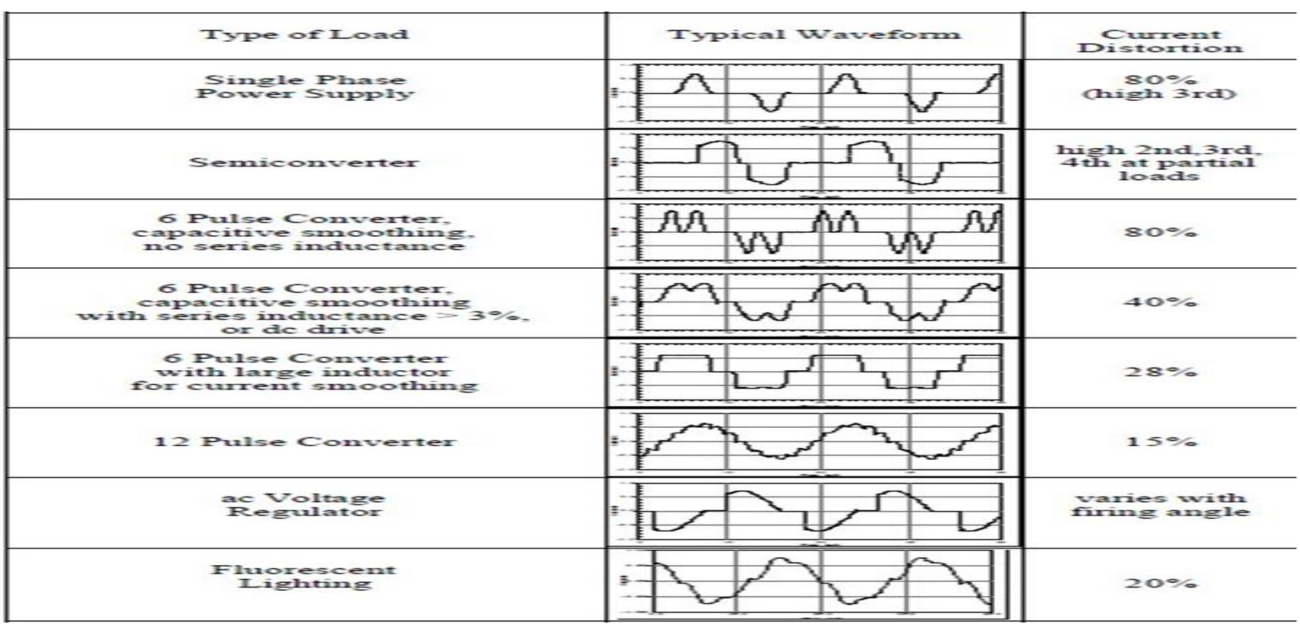
i is a simple counter ,

Subscript vs = “very short.”

Subscript sh is =“short.”

2.1.2 : **What causes harmonic distortion?**

Just about all non-linear loads create harmonics. Examples of these types of loads include non-incandescent lighting, computers, uninterruptible power supplies, telecom equipment, copy machines, battery chargers, and devices with a solid state AC to DC power converter. Distortions in current cause distortions in voltage.



Type of Load	Typical Waveform	Current Distortion
Single Phase Power Supply		80% (high 3rd)
Semiconverter		high 2nd,3rd, 4th at partial loads
6 Pulse Converter, capacitive smoothing, no series inductance		80%
6 Pulse Converter, capacitive smoothing with series inductance > 3%, or dc drive		40%
6 Pulse Converter with large inductor for current smoothing		28%
12 Pulse Converter		15%
ac Voltage Regulator		varies with firing angle
Fluorescent Lighting		20%

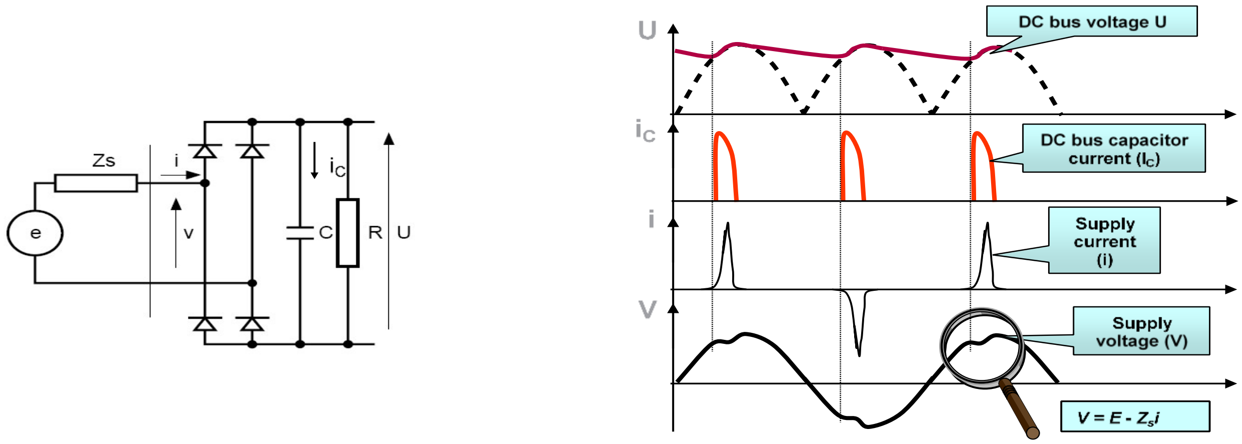


Fig: Harmonic Creation

2.1.3 Effects of Harmonics (Different Perspectives)

Engineering Perspective :

1) Nuisance tripping of circuit breaker

2) Harmonic resonance

3)Capacitor bank failure

4)Excessive heating

5)Transformer overheating

7) Skin effects on cables for higher harmonic orders

8)Motor winding burnt (dv/dt) & hunting

9)Neutral overloading (double neutral)

10) Causing EMI to sensitive signals

11)Problems to generators.

Business Perspective

1)Increased maintenance and replacement cost (OPEX)

2)Interruptions and downtimes cost

3)Reduced system capacity and thus increase CAPEX by unnecessary of expansion.

2.2 : IEEE STANDARAD OF THD LIMIT

1) IEEE STD 519-1981 **:** Title: IEEE Guide for Harmonic Control and Reactive Compensation of Static Power Converters (54 pages)**.**

2) IEEE STD 519-1992 :Title: IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power System s(101 pages).

3) IEEE STD 519-2014 : Title: IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Power System s(29 pages).

2.2.1 Harmonic Voltage and Current Limits

New limits for Low Voltage (<1kV) & Percentiles in IEEE STD 519-2014:

Table 10.2
Low-Voltage System Classification and Distortion Limits

	Special Applications*	General System	Dedicated System†
Notch Depth	10%	20%	50%
THD (Voltage)	3%	5%	10%
Notch Area (A_N)‡	16 400	22 800	36 500

NOTE: The value A_N for other than 480 V systems should be multiplied by V/480

*Special applications include hospitals and airports.
†A dedicated system is exclusively dedicated to the converter load.
‡In volt-microseconds at rated voltage and current.

Table 1—Voltage distortion limits

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
1 kV $< V \leq 69$ kV	3.0	5.0
69 kV $< V \leq 161$ kV	1.5	2.5
161 kV $< V$	1.0	1.5[a]

[a]High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Table 2—Current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{SC}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
< 20[c]	4.0	2.0	1.5	0.6	0.3	5.0
$20 < 50$	7.0	3.5	2.5	1.0	0.5	8.0
$50 < 100$	10.0	4.5	4.0	1.5	0.7	12.0
$100 < 1000$	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.
where
I_{sc} = maximum short-circuit current at PCC
I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

2.3: **Analysis of previous IEEE Papers Regarding THD for Improve Power quality** :

1)In paper [16] mainly focused on power quality issue in distribution system. For improving the power quality of renewable energy generation the new approach of multilevel inverter is beneficial as total harmonics were reduced from system. Switches used in the proposed model are less hence switching losses are less is studied in[16]. It is expected that total harmonic distortion in output voltage waveform of multilevel inverter will be reduced as the number of levels of output voltage waveforms will be increased .However to carry out research work it is first necessary to analyze the smart grid system for various kinds of loads. Hence in this paper the smart grid under study is simulated using MA TLAB SIMULINK various kinds of load (R, RL, RC and Diode) are connected and percentage of total harmonic distortion is studied in [16]. The simulations indicated that harmonics is nullified and current at unity power factor is delivered to the grid.

The efficiency and the performance of renewable energy sources can be increased by the development of the control structure of grid connected inverter.

2) In paper [17] THD comparison of five levels and seven level inverter were done. Simulations has been done using MATLAB Simulink, with developed topology and found that the developed topology provides the better amount of THD and also there is increase in the fundamental voltage magnitude which implies good performance. PV array and boost converter is modeled and its performance is analyzed. Also, the 7-level inverter is simulated with the PV array as its input and found to be good performance were noticed.

3)In Paper [18] the power electronics technology helps to integrate the renewable energy into the grid .

4) In Paper [19]simulation shows optimization of hybrid system and relocation based on load requirement, to reduced overall cost.

5) In [20] analysis of power system network that consisted of hybrid power generation, Discussed different power quality issue while interacted with diesel power generation.

6) In [21] multilevel inverter is use for improving efficiency of waveform by reducing switc

7)In [22] voltage THD is reduced by switching angle step modulation in real time based. Final results verify the performance of propose algorithm in [17].

8) In [23] model was based on multiwinding transformer to proven maximum efficiency [18] Results shows one of the top efficiency inverter. 9) In [24] recent year hybrid generation plays enormous role for encouraging quality strategy. Multilevel inverter is used to control the dc output solar power into ac power to be supplied to the grid.

2.4 :**Inspired Paper analysis :** In Paper (25) details study has been carried out for grid interconnection system using hybrid solar and wind power generation for improving power quality. Two renewable energy sources, solar and wind are used for supplying power to the grid. The energy generated from the wind is given directly to the load through pee. The solar energy generated is supplied to the load through seven level inverter at pee. SPWM technique is used to control the output of seven level inverter. The input to the driver circuit of seven level inverter is given through Pie microcontroller which requires 5V supply. The seven level inverter is used for reactive compensation at pee to avoid the voltage swell and sag due to changes taking place in the load. In the proposed paper details study has been carried out for grid interconnection system using hybrid solar and wind power generation for improving power quality.

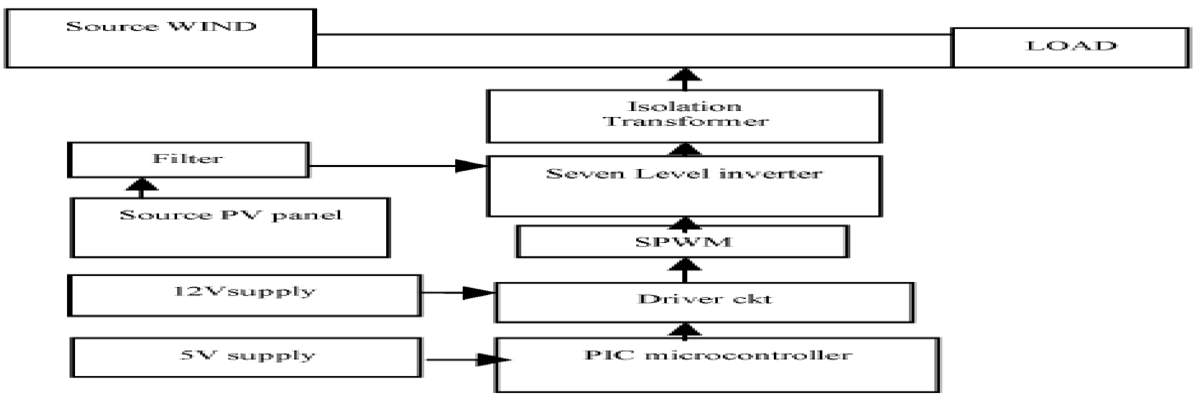


Fig: main block diagram of the simulation model of the paper[20].

The software simulation circuit of the proposed project is simulated on MATLAB using simulink the power system under study for simulation circuit. It can be concluded that:

1. The non sinusoidal source voltage, source current and load voltage became sinusoidal with the use of controller.

2. The controller reduces the reactive power delivered by PY source thus improving THD of the proposed power system. The magnitude of voltage sag and swell of line RMS voltage at PCC due to sudden change of load were also observed for the simulated power system, under study.

Sr. No.	Results of the Proposed System with and without Controller		
	Titles	Without Controller	With Controller
1	Source Voltage	Non sinusoidal	Sinusoidal
2	Source Current	Non sinusoidal	Sinusoidal
3	Load Current	Non sinusoidal	Sinusoidal
4	Voltage Sag	Not Observed	6.35Kv
5	Voltage Swell	Not Observed	6.15kv
6	% THD	17.87	4.79
7	Max.Power Transferred	Less as compared to controller	Yes

Fig :Result Of The paper[20]

3.The reduced THD of the [20] is obtained 4.79%.

In Our Proposed Model ,after simulatin in Matlab software the obtained THD is much less than this paper(25) .The further discucussion is in “Experimental And Observations Chapter .

2.5 : Our Proposed Model Improvement Structure .

1) A 30kw wind Turbine is added model with Parmanent Magnet Sinchronous Genarator(PMSG) .

2) MPPT is used for both solar pv and wind turbine.

3) Hybrid wind and Solar system is connected with 11Kv transmission line.

4) 3-Phase-Bridge Inverter is Connected which is controlled by Pulse Width Modulation(PWM) Gate pulses.

5)Low Pass(LC) Filter is added after inverting which helps much to reduce THD.

6)Pmsg Voltage and Current is first Converted from Ac to dc and added to Dc Bus whrere Dc voltage and current from Pv Panel is also added .This voltage and current is controlled by Battery/electrolyzer controller .Battery will serve when grid volage is low less than 150 volatge.

7)Real Time Data(30 Samples) of Irradance is inserted on Pv solar panel and Wind Velocity is inserted on wind Turbine

Chapter 3 : Methodology.

3.1 System Design

Full system of hybrid Pv and Wind Grid connected system is given below by schematic block diagram :

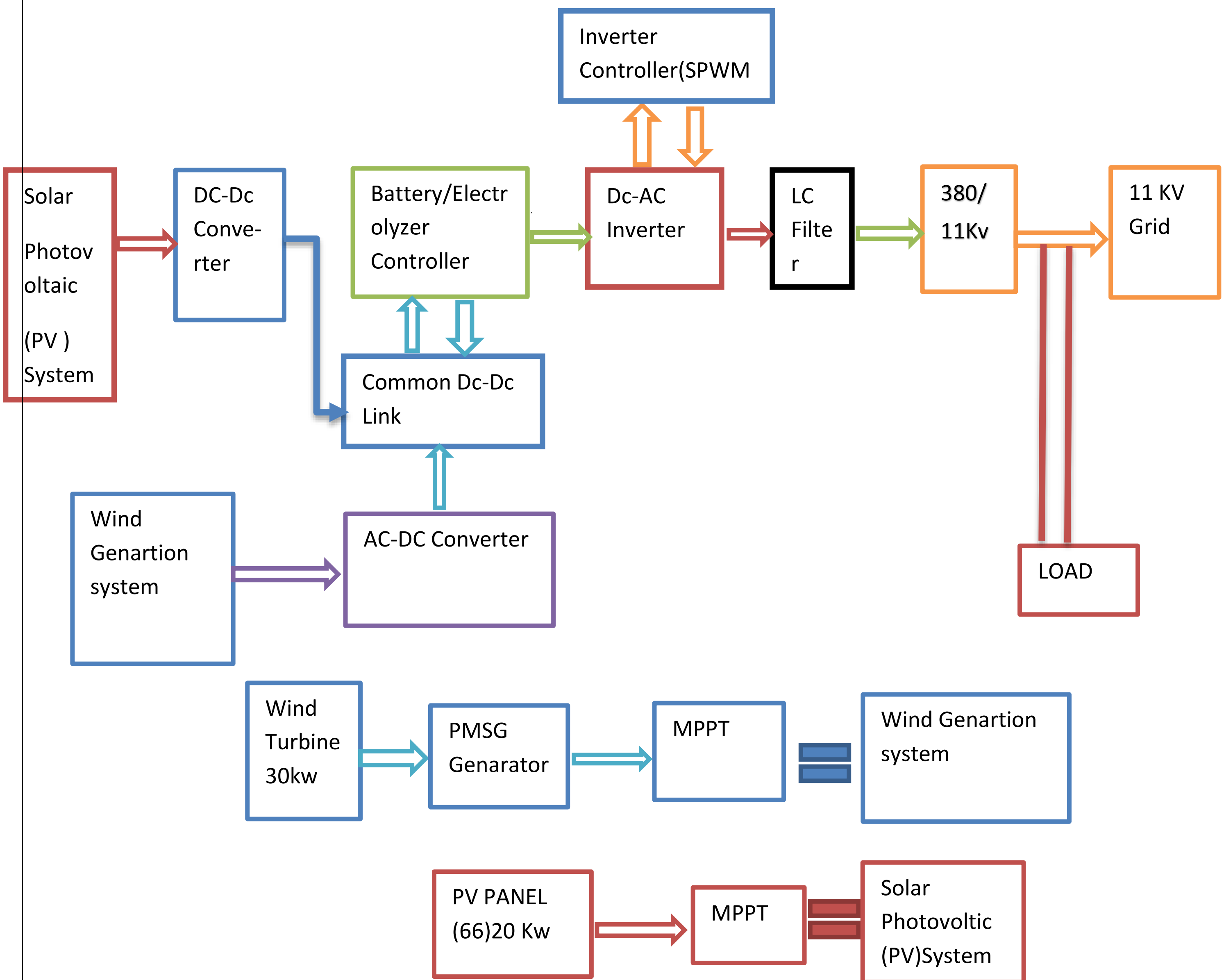


Fig : Basic Block Diagram Of Hybrid System

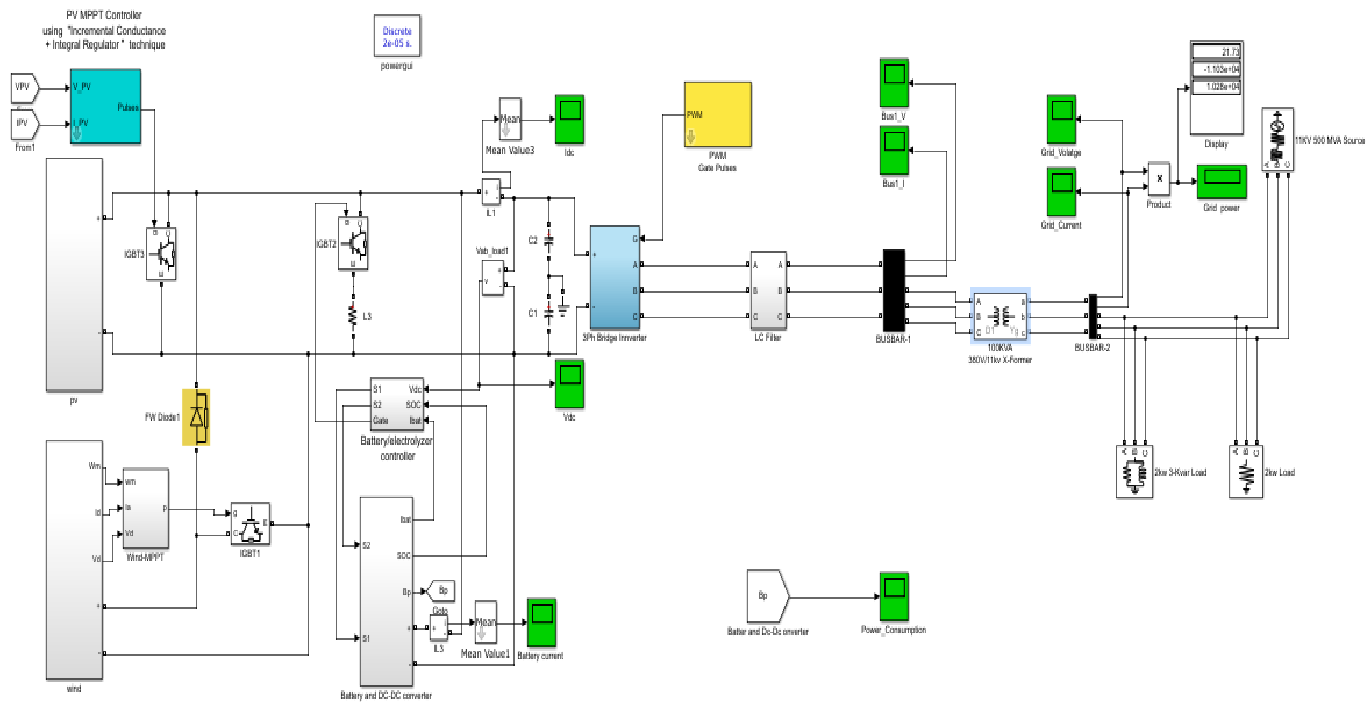


Fig : Full System Matlab Scheme.

3.1.1 Solar Pv Module Design WITH MPPT : Each Module contains 11 solar Panel.

Each Panel rated voltage=300 Watt.

Each Panel Rated Maximum Power Volage Vmpp=30.54v

Each Panel Open Circuit Voltage Voc=44v

Rated Peak Current Per Hour Ip=1.2 amp

Rated Peak Power per Hour ,Pmax=0.3kw

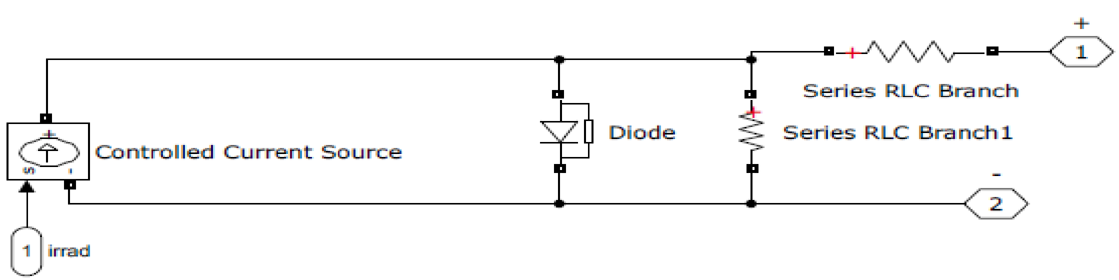


Fig :Matlab Model Of 11x300 Watt Pv Module.

R1(Serires Rlc Branch)= 0.005*11 ohm

R2(series Rlc Branch1)= 550 ohm

Diode Voltage=336Volatge.

Current Calculation At maximum Voltage for Each Solar Module , Imax=Pmax/Vmax=3000w/11x30.54=3300=9.82amp.

3.1.2 Solar Pv System Design : There is 6 Pv module in Solar Pv system :

This 6 module is connencted series with each other in 3 subsystem

Which contains each 2 pv module=22 solar pv panel.

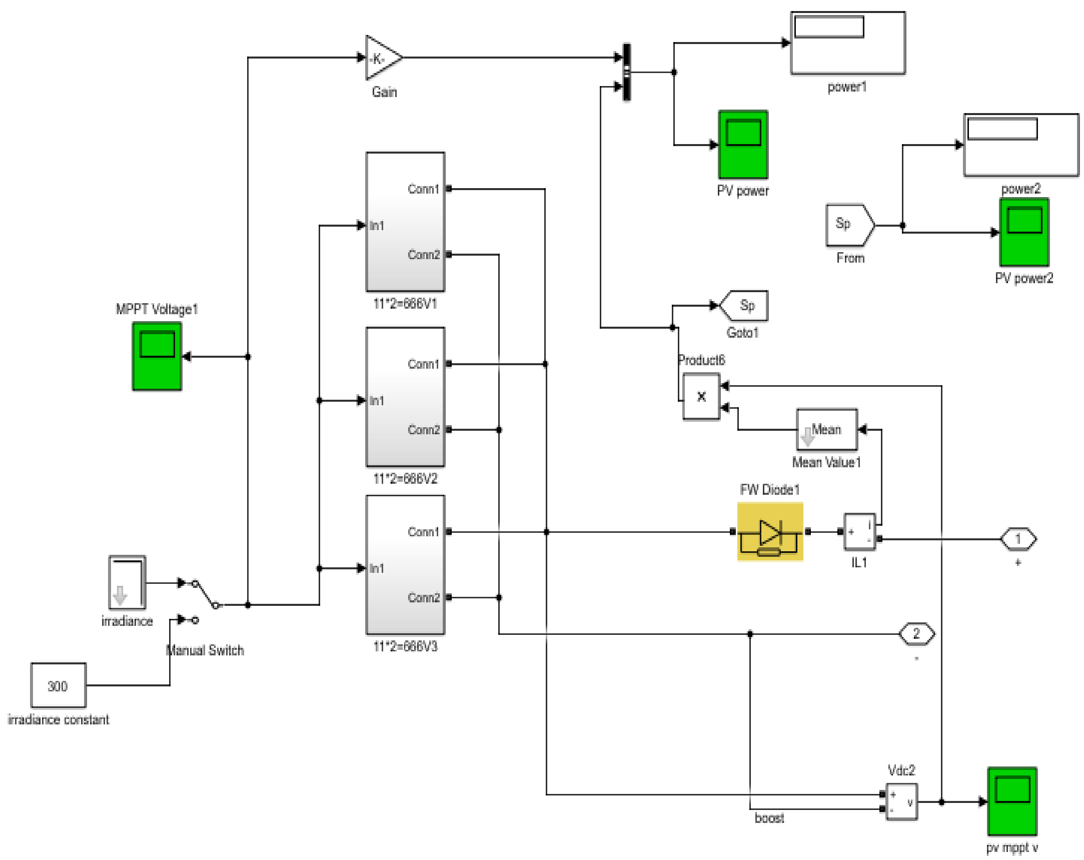


Fig : Pv Solar System (3 subsystem,6 Module,66 Panel).

MPPT CONTROLLER : Maximum power point tracking by incremental conductance method :

Maximum power point is obtained when dP/dV=0 where P= V*I

=>d(V*I)/dV = I + V*dI/dV = 0

=> dI/dV = -I/V

dI, dV = fundamental components of I and V ripples measured with a sliding time window T_MPPT

I , V = mean values of V and I measured with a sliding time window T_MPPT

The integral regulator minimizes the error (dI/dV + I/V)

Regulator output = Duty cycle correction

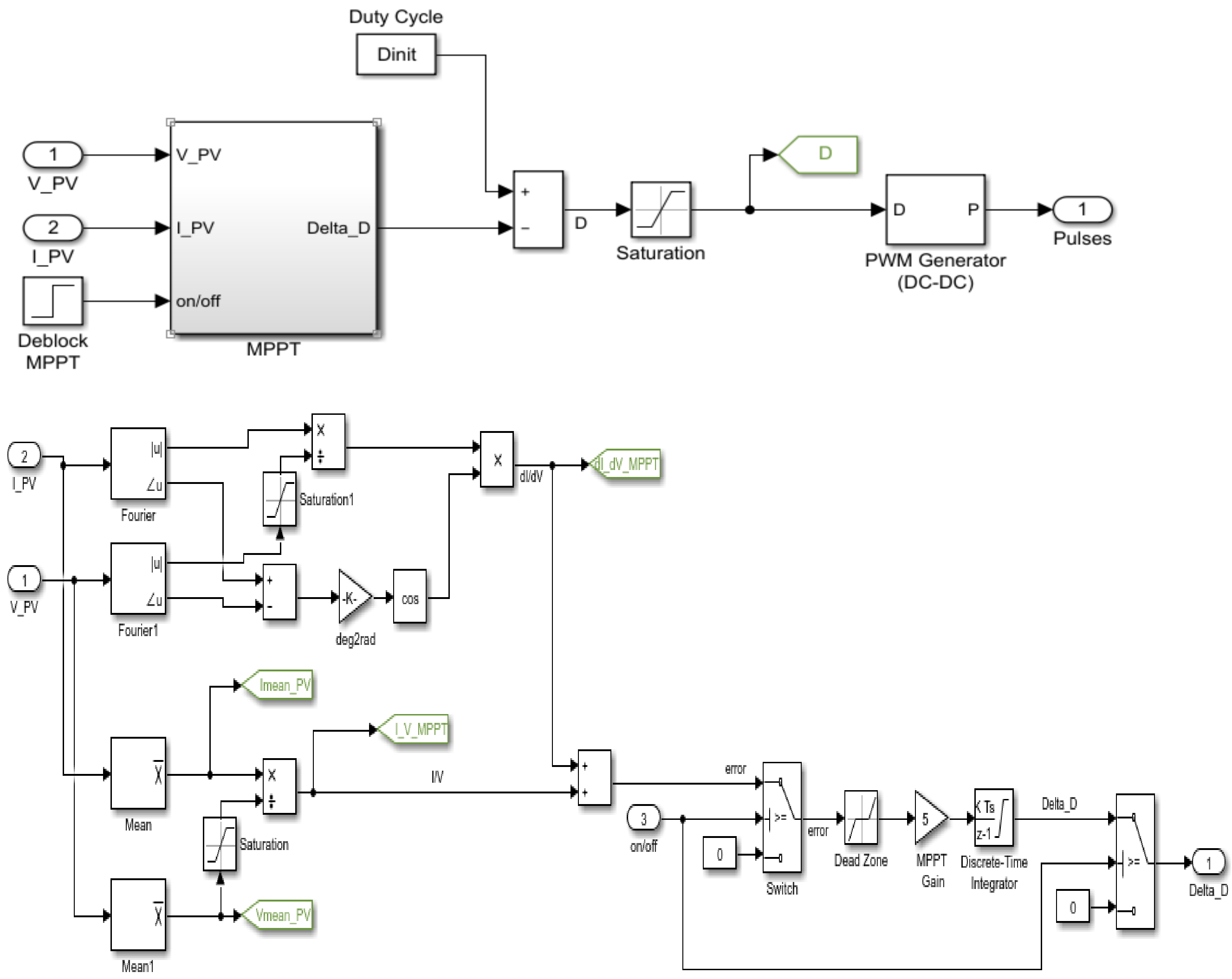


Fig : MPPT CONTROLLER Scheme (MATLAB)

3.1.3 Irradance Input : 30 Samples

Maximum Irradance=240w/m^2,

Minimum Irradance =200w/m^{2,}

Average Irradance =216 w/m$^{2.}$

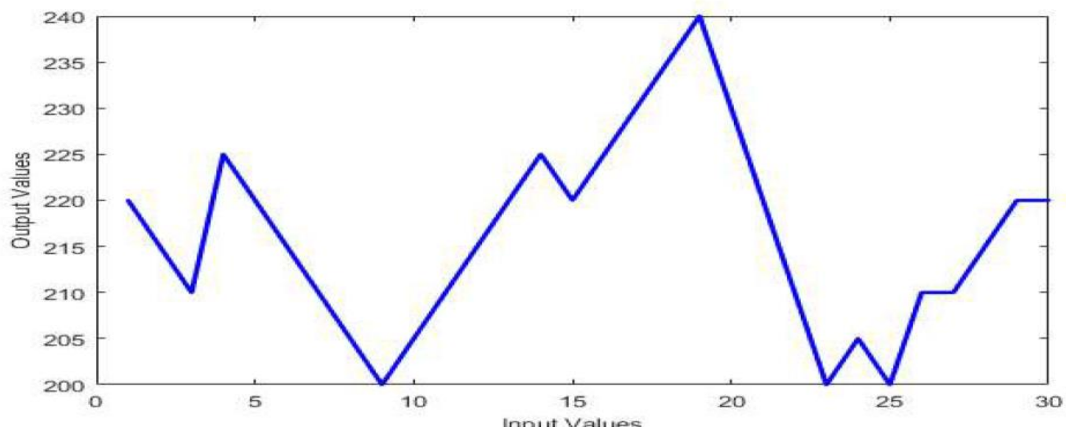


Fig : Irradance w/m^2

3.1.4 Solar Irradance In Bangladesh :

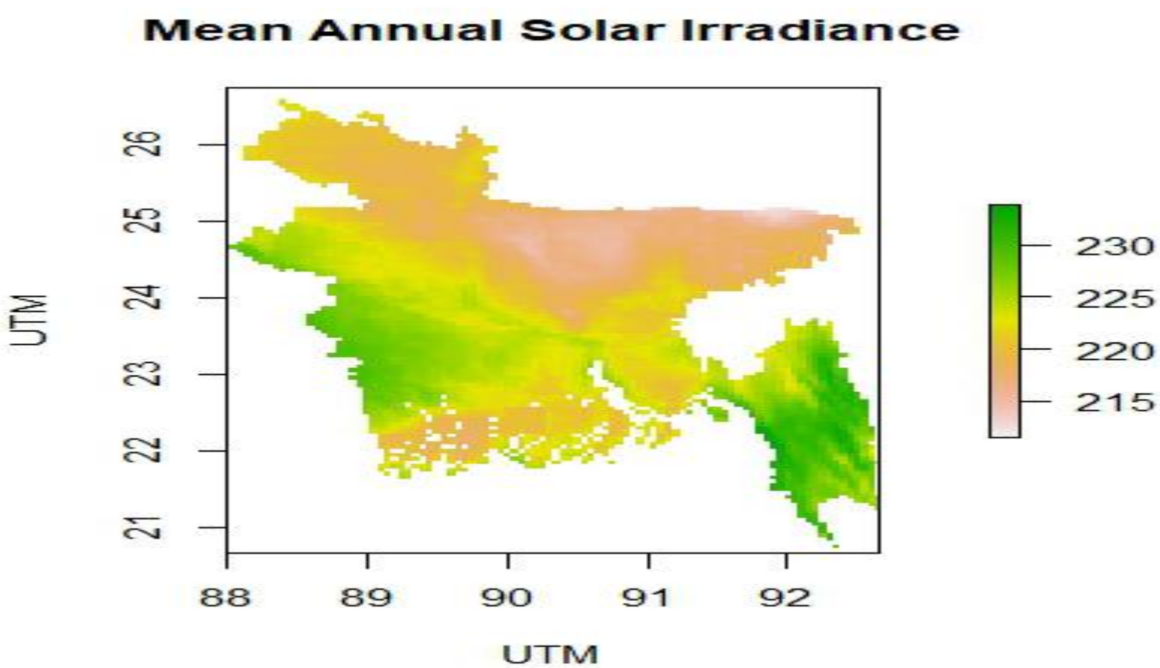


Fig : Mean Annual Solar Irradiance for Bangladesh | Data: PVGIS © European Communities, 2001-2017(26)

3.1.5 Wind Turbine Design

Blade length, ***l* = 28 m** , Wind speed, ***v* = 6 m/sec (average),**Pitch angle=**0**

Air density, **ρ = 1.20kg/m^3 (average)** ,Power Coefficient**, C_p = 0.4,** Inserting the value for blade length as the radius of the swept area into equation (8) we have: l =28m=2r

A =πr 2

=π×14^2

=615.75^2

The designed wind Turbine Prouced Power : We can then calculate the power converted from the wind into rotational energy in the turbine using equation :

When power efficiency Cp=o.4(standard value)

$$Pavail = \frac{1}{2}\rho A v 3 C p$$

$$= \frac{1}{2} \times 1.20 \times 615.75 \times 6^3 \times 0.4$$

$$= 32kwh(around)$$

When Cp= 0.2 , Pavail = ρAv3Cp

= ×1.20×615.75 ×63 ×0.2

= 16kwh(around)

Output Power depends on Wind Velocity And Wind turbine power Coefficient which is variable with Time .A 1-40 kwh Pmsg is connected with wind turbine.

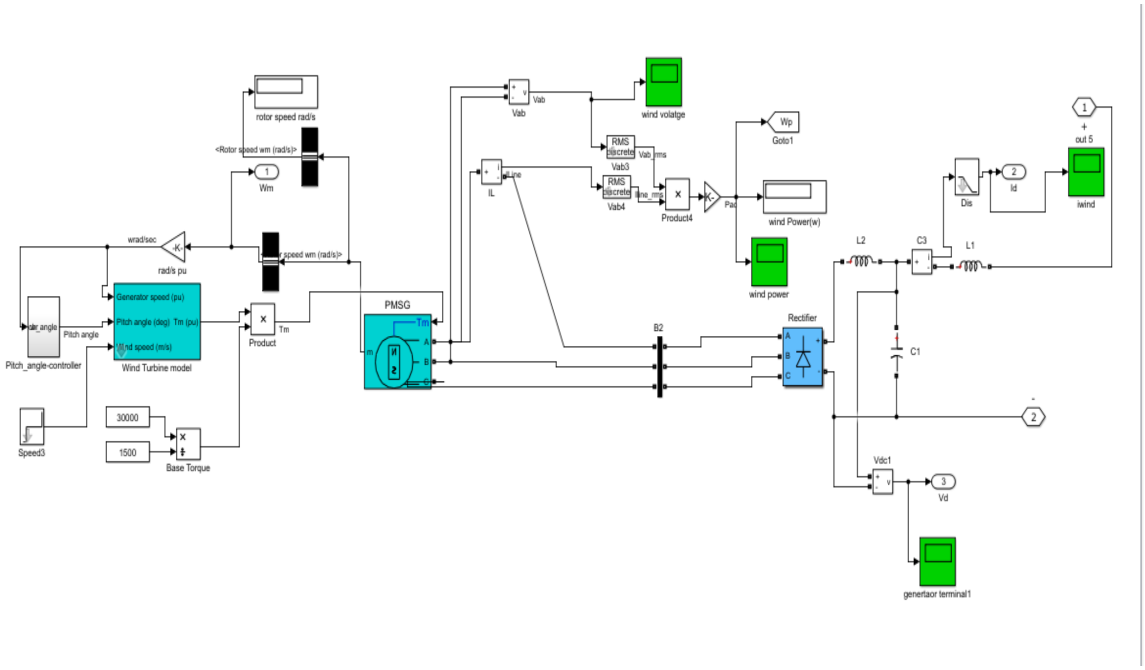


Fig: Wind Turbine scheme of Matlab.

3.1.6 Reliablity Of Design:

1) A German physicist Albert Betz concluded in 1919 that no wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy turning a rotor. To this day, this is known as the **Betz Limit** or **Betz' Law.** The theoretical maximum **power efficiency** of *any* design of wind turbine is 0.59 (i.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine). This is called the "power coefficient" and is defined as: $\boldsymbol{C_p max = 0.59}$

Also, wind turbines cannot operate at this maximum limit. The C_p value is unique to each turbine type and is a function of wind speed that the turbine is operating in. the real world limit is well below the *Betz Limit* with values of 0.35-0.45 common even in the best designed wind turbines. By the time we take into account the other factors in a complete wind turbine system - e.g. the gearbox, bearings, generator and so on - only 10-30% of the power of the wind is ever actually converted into usable electricity.

2) According to USAID-NREL research paper (27) showing wind velocity 6-6.5m/s at costal area.

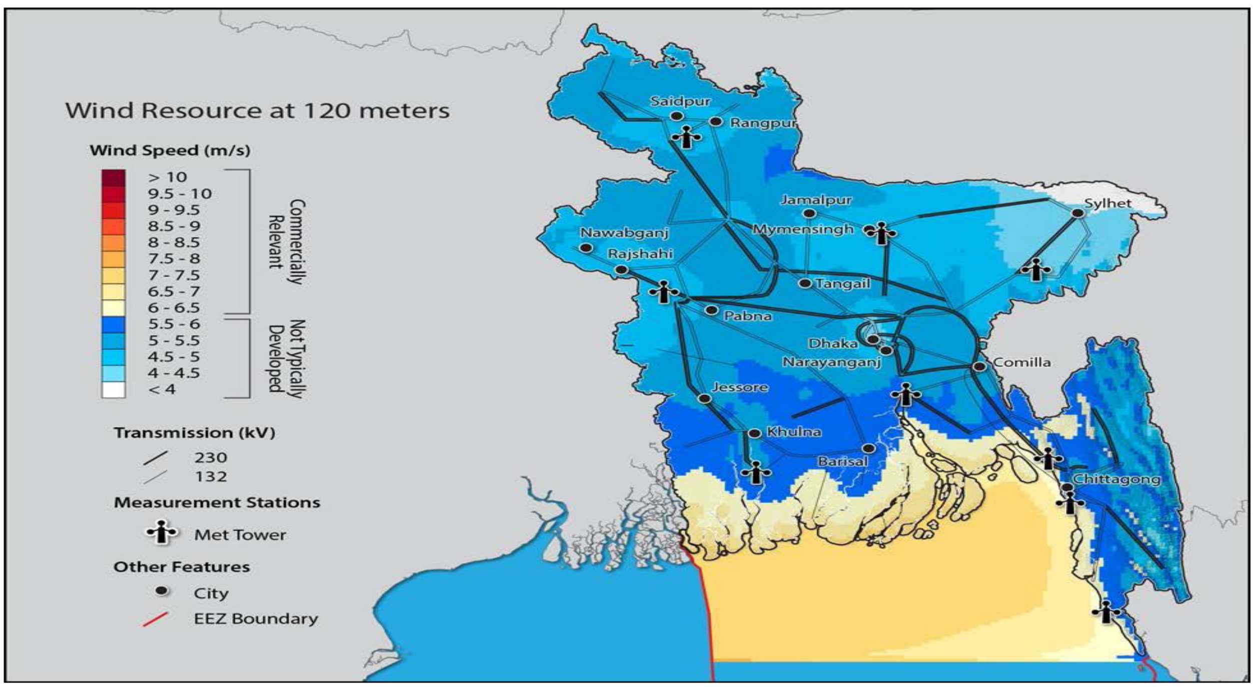


Fig : Annual Wind velocity of Bangladesh .

3) RPM=6o x V x TSR / pi x L

Here,V=velocity of wind=6 m/s ,TSR=6 for 3 blade turbine , pi=3.1416 ,L=lenth of diameter od blade=14m

RPM=60 x 6 x 6 /3.1416 x 14 = 49 . which is variavble with change of V .

4)Real Time Inserted Data OF Wind Velocity (30 Samples) :

Maximum velocity =9m/s ,Minimum Velocity =5m/s ,Average velocity=6.10m/s

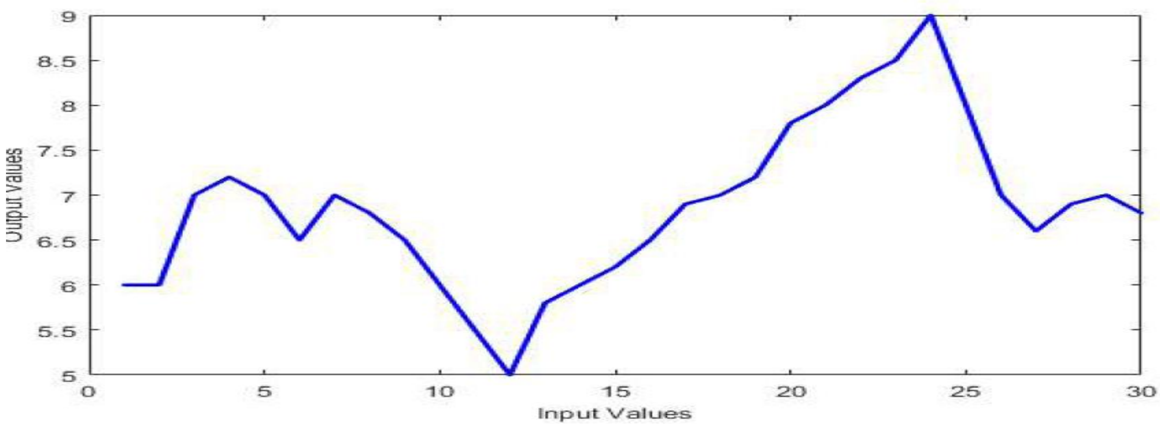


Fig : Air Velocity (m/s)

3.1.7 Inverter Design : To assemble an inverter the MOSFET and IGBT are heavily used power semiconductor devices. Power MOSFET can operate at somewhat higher frequencies (a few to several tens of kHz), but is limited to power ratings, usually 1000V, 50A. Insulated-gate bipolar transistor (IGBT) is voltage controlled power transistor that is used while voltage requirement increases and it also offers better speed than a BJT but is not quite as fast as a power MOSFET [28]. In higher switching frequencies MOSFET is superior to IGBT but higher switching operation of IGBT is feasible by employing soft switching power conversion [24]. Therefore, according to our requirements MOSFET is chosen to design the inverter The output voltage of the inverter is the sum of the voltage that is generated by each cell. The number of output voltage levels are 2n+1, where n is the number of voltage source. The switching angles can be chosen in such a way that the total harmonic distortion is minimized. An n level cascaded H-bridge multilevel inverter needs 2(n-1) switching.

Our Model Calculation : No. Of Mosfet switching =6

2(n-1)=6

n=6/2+1=4

Our Designed Inverter is 4-Level 3-ph Bridge Inverter.

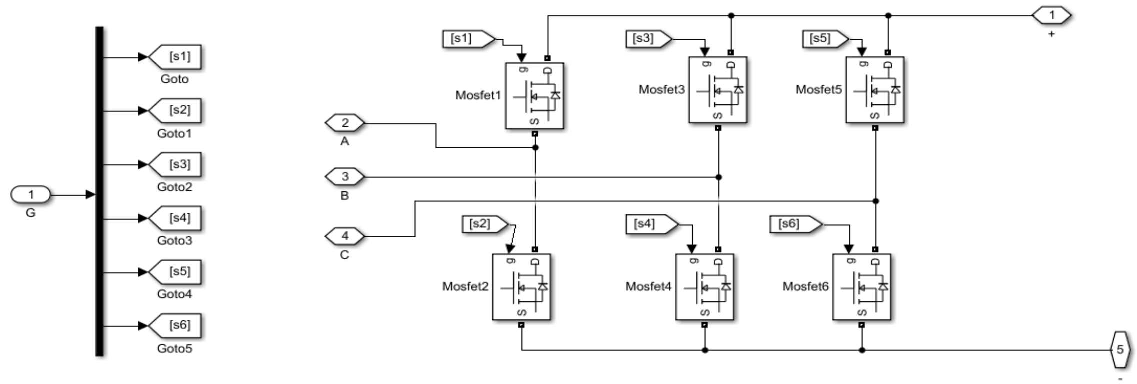


Fig: 4-level Bridge Inverter .

3.1.8 Inverter Control : The voltage source inverter that use PWM switching techniques have a DC input voltage (VDC = VS) that is usually constant in magnitude. The inverter job is to take this DC input and to give AC output, where the magnitude and frequency can be controlled. There are several techniques of Pulse Width Modulation (PWM**).**The efficiency parameters of an inverter such as switching losses and harmonic reduction are principally depended on the modulation strategies used to control the inverter. In this design the Sinusoidal Pulse Width Modulation (SPWM) technique has been used for controlling the inverter as it can be directly controlled the inverter output voltage and output frequency according to the sine functions . Sinusoidal pulse width modulation (SPWM) is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches. The PWM inverter has been the main choice in power electronic for decades, because of its circuit simplicity and rugged control scheme.

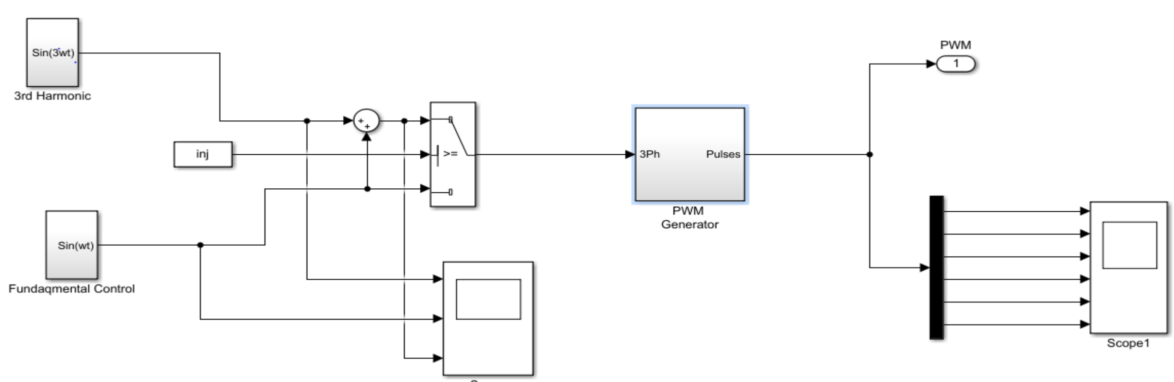


Fig : Inverter Control Design Scheme

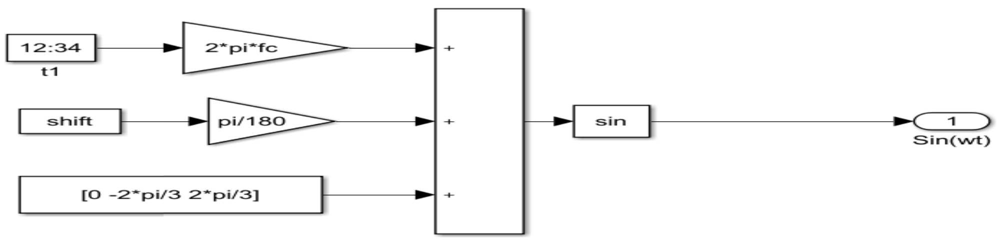


Fig : Fundamental THD control Scheme

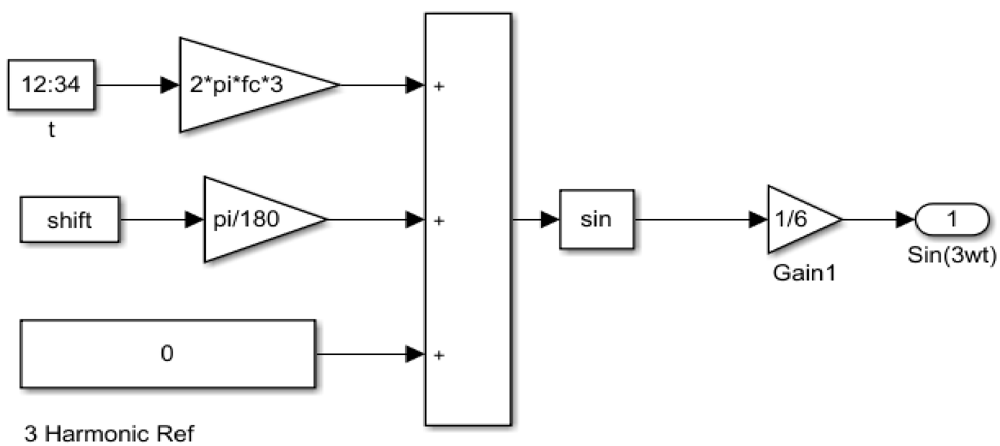


Fig : 3rd harmonic Control Scheme.

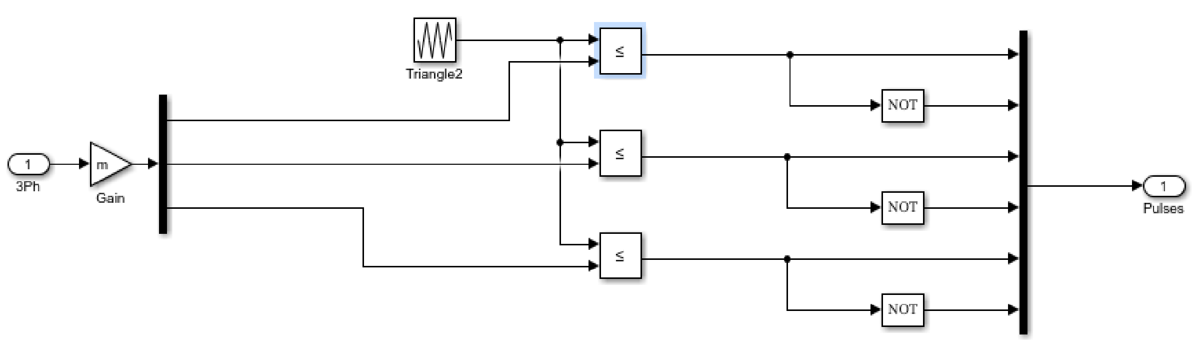


Fig : Pulse Genarator Schem

In SPWM technique three sine waves and a high frequency triangular carrier wave are used to generate PWM signal. The sinusoidal waves are called reference signal and they have 120^0 phase difference with each other. The frequency of these sinusoidal waves is chosen based on the required inverter output frequency (50/60 Hz). The carrier triangular wave is usually a high frequency (in several KHz) wave.

Pahse Difference=120^0

We control frequency ,fc=50

Carrier/switching frequency,Fs =10 khz,

modulation index, m=1 . (Maximum for PWM)

modulation index,m =M/A

where , A = the carrier amplitude. M = the modulation amplitude and is the peak change in the RF amplitude from its un-modulated value.

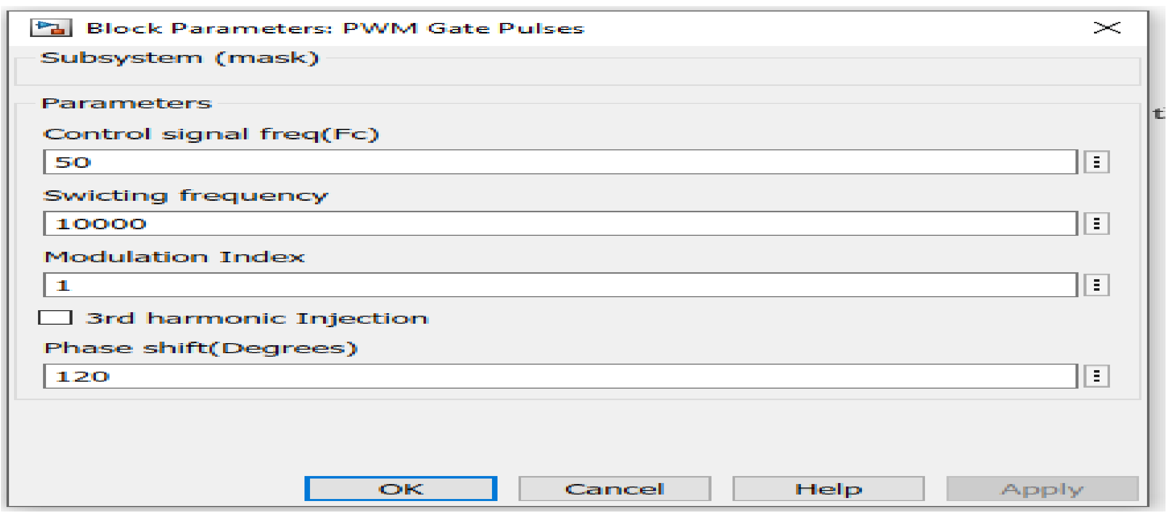


Fig : PWM generator Input value scheme.

3.1.9 Inverter Control with LC Filter Design : The outputs of an inverter contain large amount of harmonics content. The VSI generates an AC output voltage waveform composed of discrete values (high dv/dt); therefore, the load should be inductive at the harmonic frequencies in order to produce a smooth current waveform . The need for inverters in distributed generation systems and grid has clarified the significance of achieving low distortion, high quality power export via inverters. Both switching frequency effects and grid voltage distortion can lead to poor power quality. A well designed filter can attenuate switching frequency components but impacts on control bandwidth and the impedance presented to grid distortion . To the standalone load system where the loads are low voltage, the inverter is used without transformer but in case of utility grid or high voltage sensitive loads (several KV) it should be used step up transformer with the inverter. As a result, due to the noise/harmonic components the loss in the transformer will be increased and then it will be badly affected. Moreover, the core loss in the machine is also increased by the presence of harmonics in the supply voltage and current. Harmonic attenuation can be achieved by several methods such as by resonating of the loads, by an LC filter, by pulse width modulation, by sine wave synthesis, by selected harmonic reduction and by polyphase inverters . Apart from these in PWM technique, if the carrier frequency is increased, the harmonics components are reduced. A high-carrier ratio improves waveform quality by raising the order of the principle harmonics. At low fundamental frequencies, very large carrier ratios are feasible and resulting in near-sinusoidal output current waveforms account for one of the main attributes of the sine wave PWM inverter . However, there are different types of filtering circuits. RC & LC filters are the most used passive filters. They are divided into 1st order, 2nd order & 3rd order filters according to the combination of the passive components. L or C is the first. order filter, LC is the 2nd order filter and LCL is the 3rd order filter.

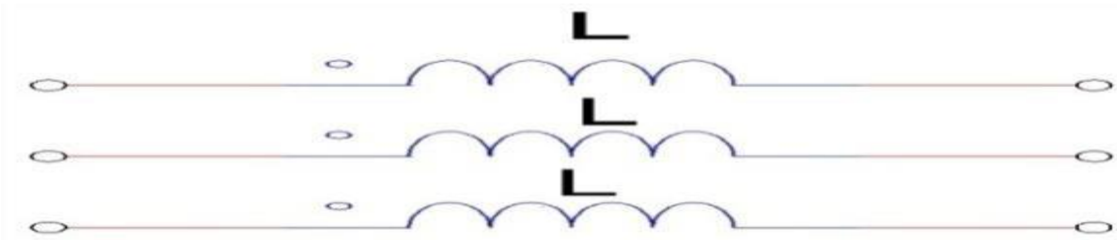


FiG :1st order Filter

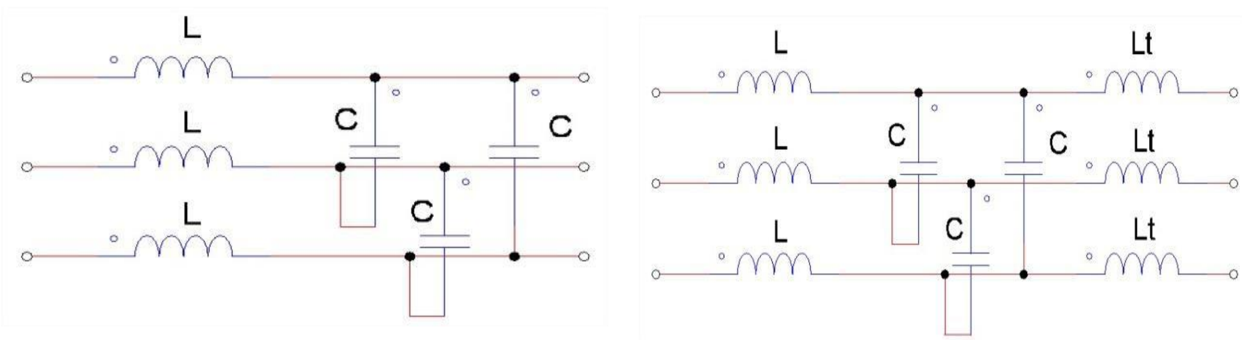


Fig : 2nd & 3rd Order Filter .

An LCL filter can achieve reduced levels of harmonic distortion with lower switching frequencies and with less overall stored energy . In this system Lt is the inductance of the transformer through which the inverter is connected to the grid. After LC filter a transformer is used and the LCL filter is formed. It eliminates all high order harmonics from the output waveform of the inverter so that the output is 50Hz, low distortion, pure sinusoidal voltage wave. The cut-off frequency of the low pass filter is selected such that, total THD is less than 5%. The calculation is done by the following equation

$$f_o = \frac{1}{2\pi}\sqrt{\frac{L + L_t}{L L_t C}}$$

Our Design Cut-off Frequency Calculation :

L=0.3mH ,Lt=0.08 H, C=0.465mF

F_o=1/2*pi*sqrt(3e-2+0.08/3*10^{-2}*0.08*4.65e-4)=50 HZ

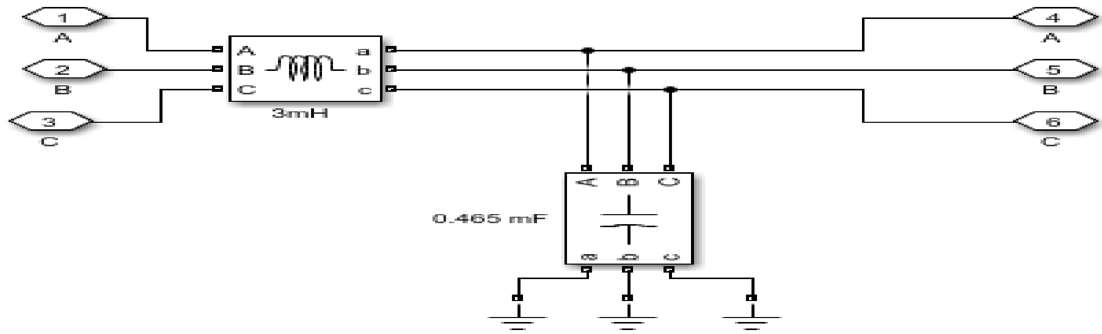


Fig : LC filter Scheme Matlab.

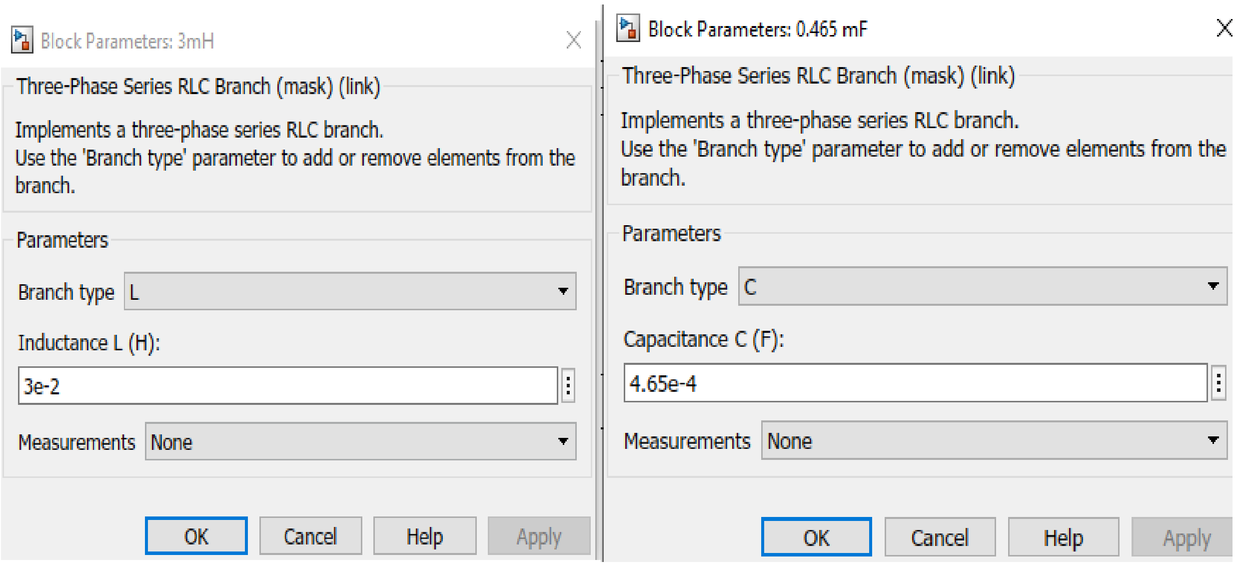


Fig : L & C Input

3.1.10 100 KVA 380/11kv (Delta-Y Connected) Step Up Transformer Input :

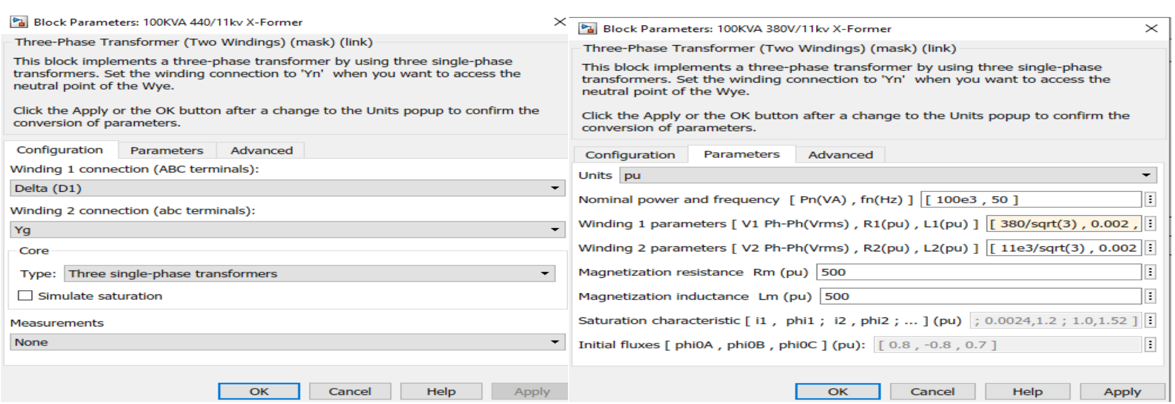


Fig : 380V/11KV X-Former Input scheme.

3.1.11 Grid Design with Load : 11kv ,500kva Three phase voltage source is inserted as 11kv Transmission line Grid power supply and two parallel 2kw active power load and 2 kw active power 3 kvar Reactive power load is added .

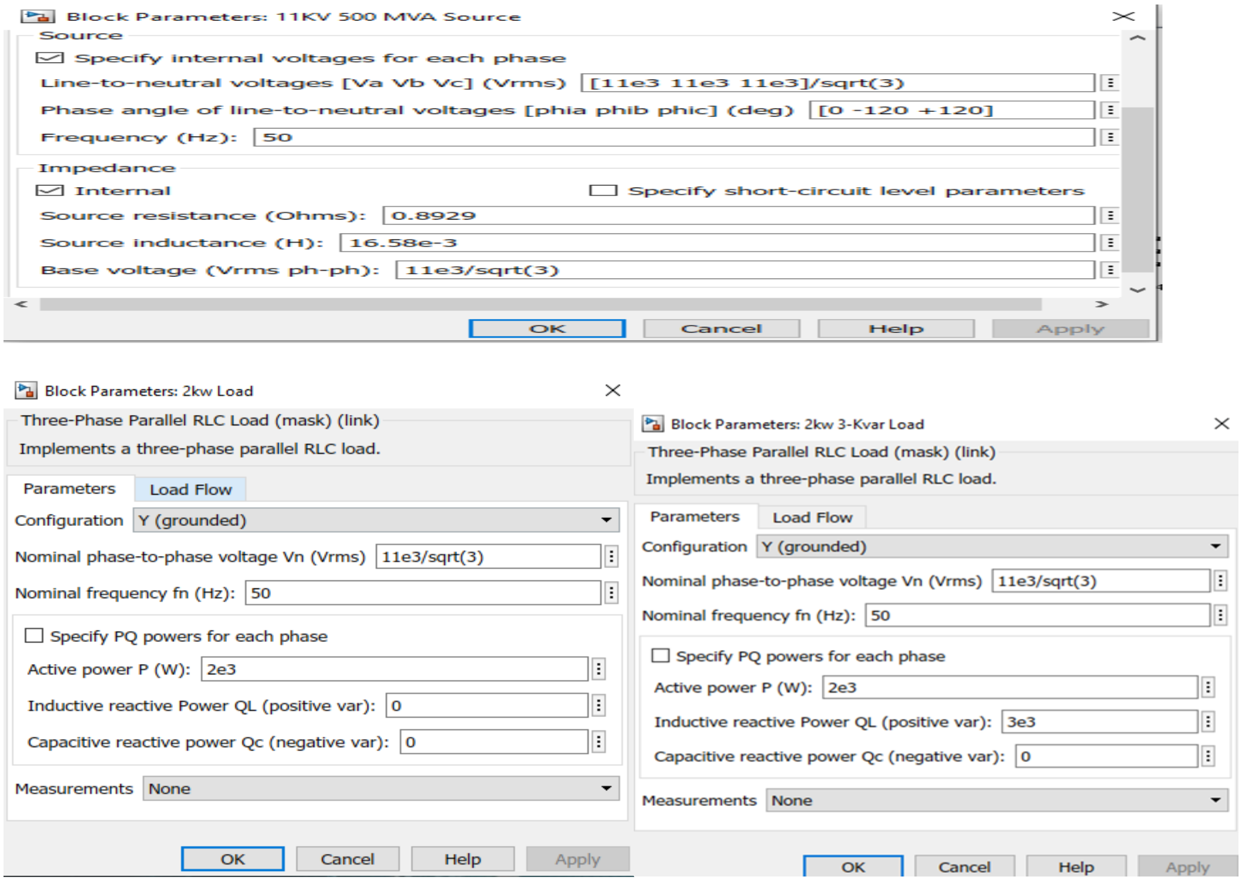


Fig : 11 kv Surce & Load INPUT Scheme.

3.1.12 BATTERY CONTROL & DESIGN :

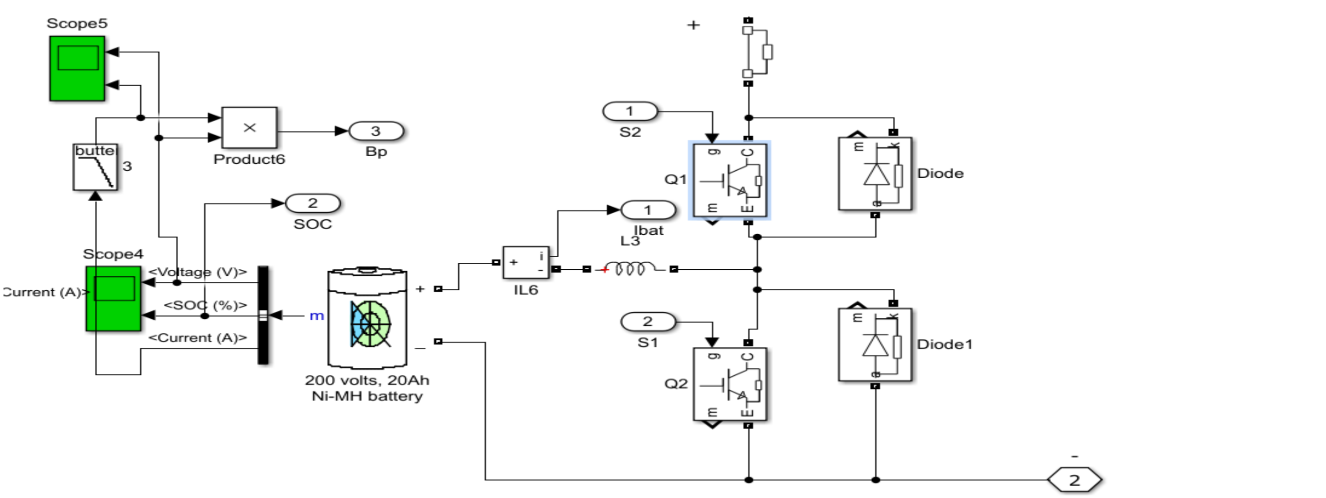
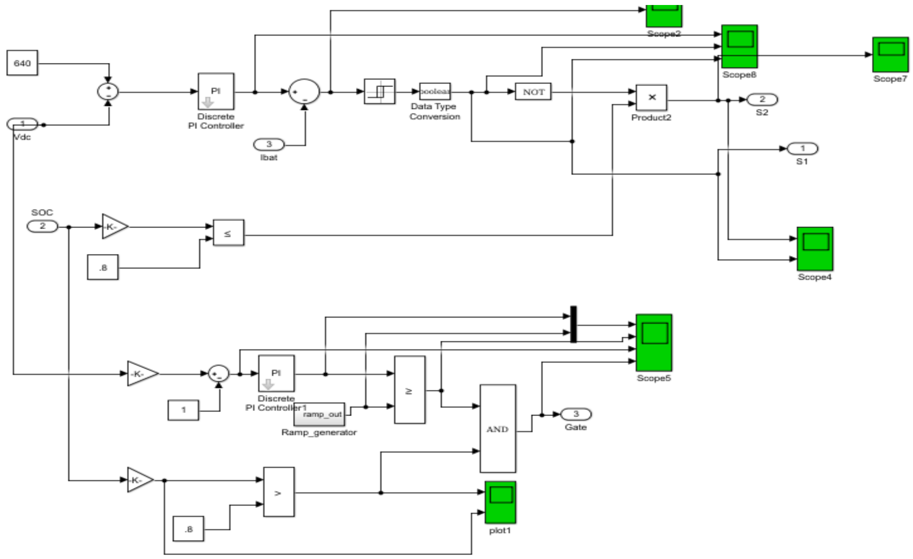


Fig : Battery connection with Dc-Dc Converter .



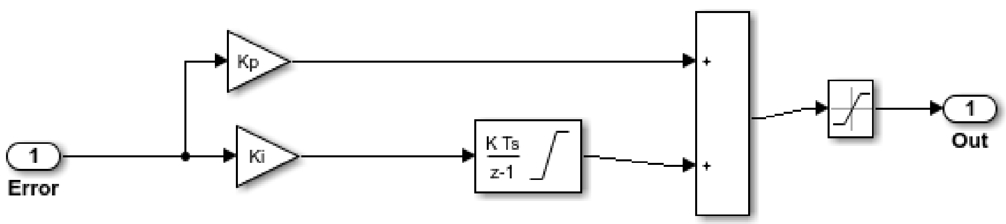


Fig : Battery Control with PI Controller.

3.1.13 Battery Function :

200 V and 20 ah battery is connected with Dc- BUS . Battery is controlled buy PI controller .when Supply Dc voltage is avobe 200 v then battery starts to charge and maximum charge gain at 236 volatge .Battery will starts to discharge below 200 Voltage ,Cut off voltage=150 v.Hishest Discharge =32.2 a At 160-120Voltage.

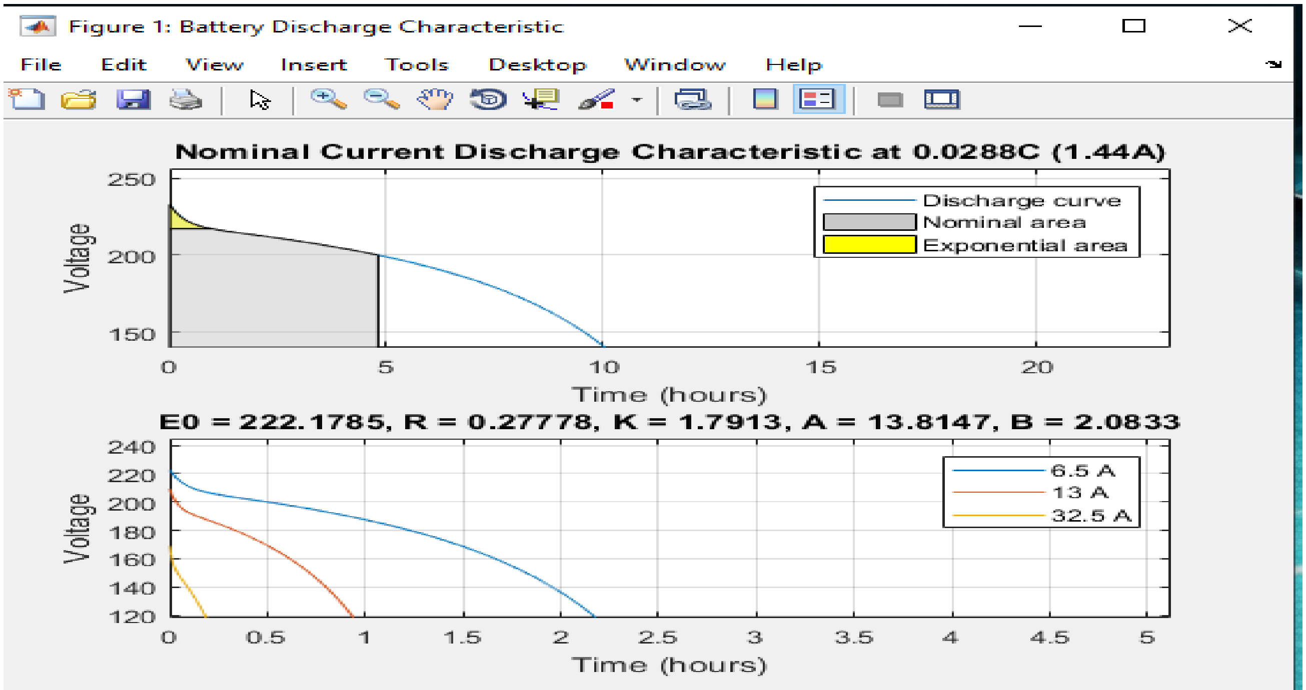


Fig : Battery discharge curve.

CHAPTER 4 : EXPERIMENTAI RESULT AND OBSERVATIONS

4.1 THD ANALYSIS : THD Analysis Of voltage and Current before the connection of Grid Via Step Up Transformer And Grid Connected using LC filter and without Filter is Compared below :

4.1.1 THD Obseravtions Result :

Busar-1 Before Grid Connected	THD % without LC Filter	THD % with LC Filter	Busar2 Grid Connected	THD % without LC Filter	THD % with LC Filter
Vph-1	32.96	0.21	Vph-1	0.55	0.02
Vph-2	31.12	0.27	Vph-2	0.38	0.02
Vph-3	31.87	0.27	Vph-3	0.54	0.02

Iph-1	5.66	2.96	Iph-1	5.68	3.13
Iph-2	4.24	3.49	Iph-2	5.66	3.85
Iph-3	4.19	3.49	Iph-3	4.19	3.36

Table 1 : THD Analysis.

This Result is collected for 50 cycle at MATLAB FFT Analysis. Here

Vph= Voltage Phase Number. , Iph= Current Phasee Number

4.1.2The Matlab figure of THD analysis is given below :

Busar-1 Before Grid Connected Voltage and Current THD % without LC Filter Figures :

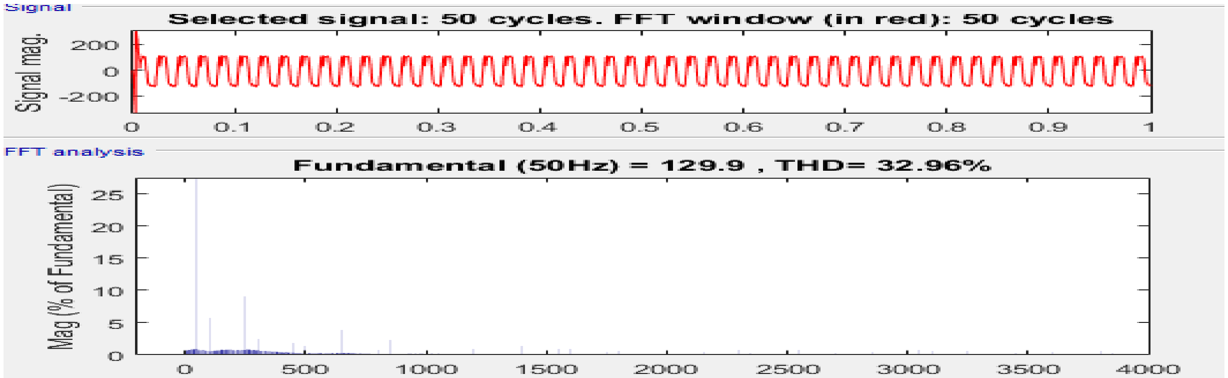


Fig : BusBar-1 Vph1

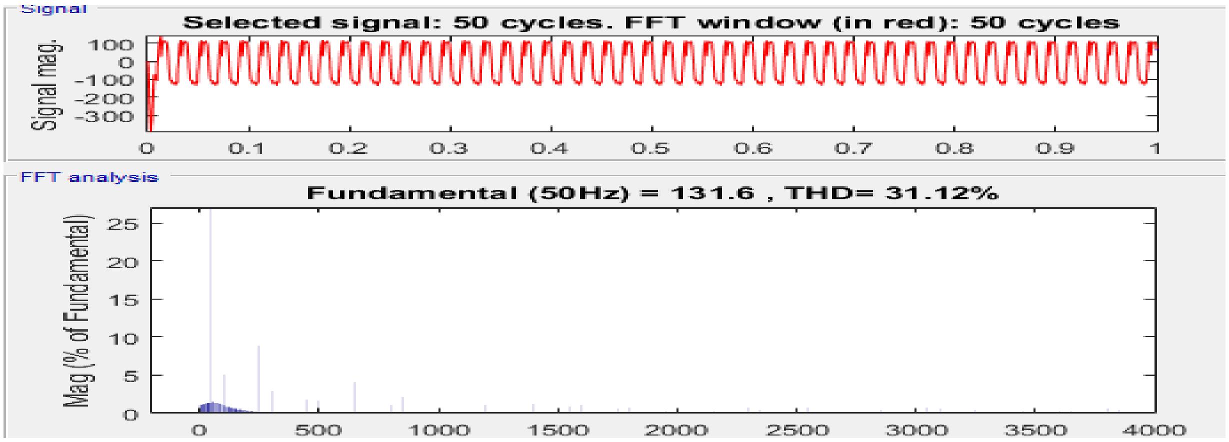


Fig : Fig : BusBar-1 Vph2

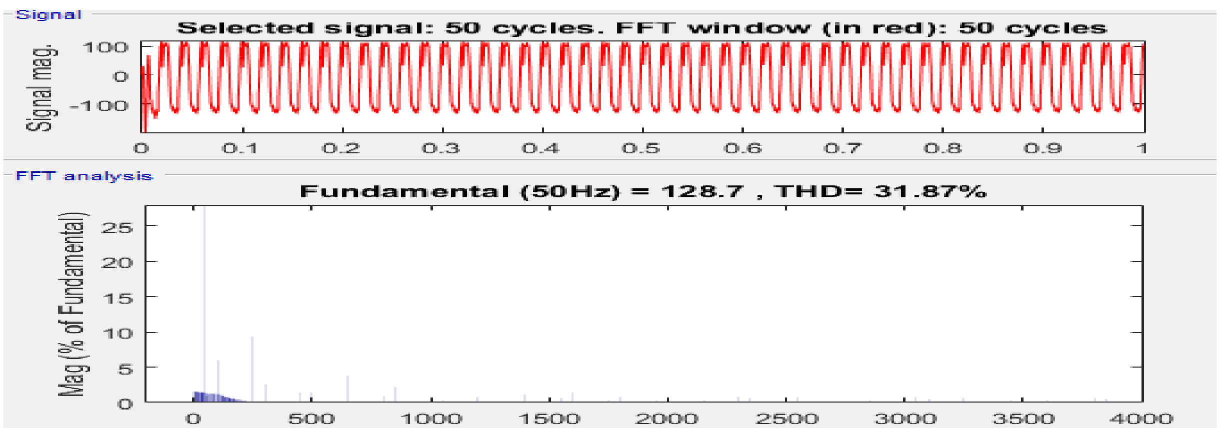


Fig : Busbar-1 Vph-3

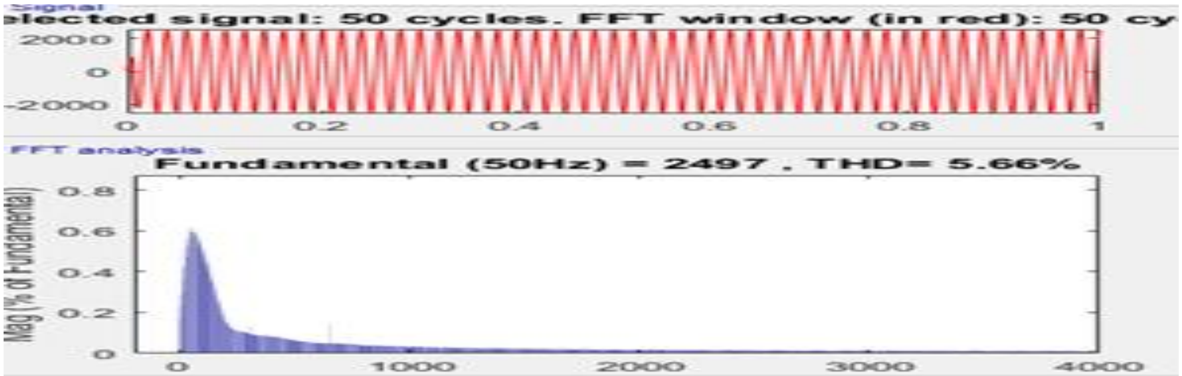


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Fig:Busbar-1Iph-1

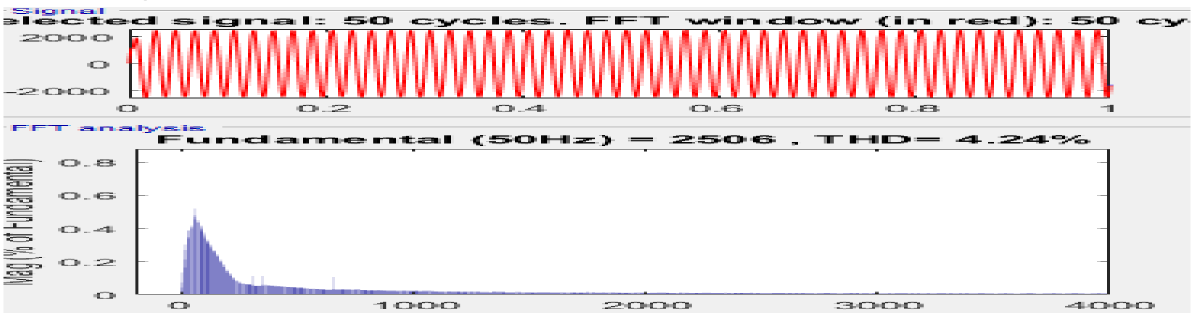


Fig : Busbar-1 Iph-2

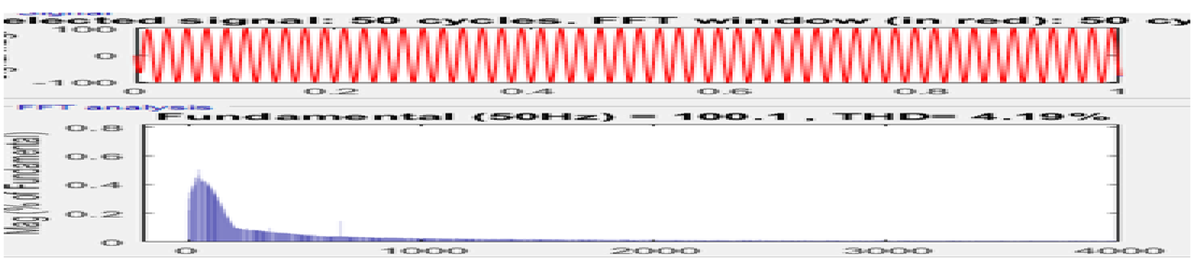


Fig : Busbar-1 Iph-3

Busar-1 Before Grid Connected Voltage and Current THD % with LC Filter Figures :

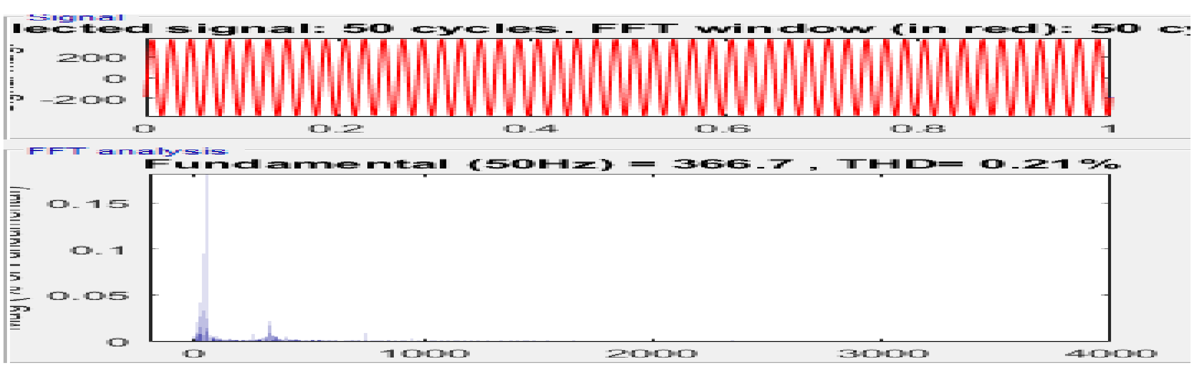


Fig : Busbar-1 Vph-1

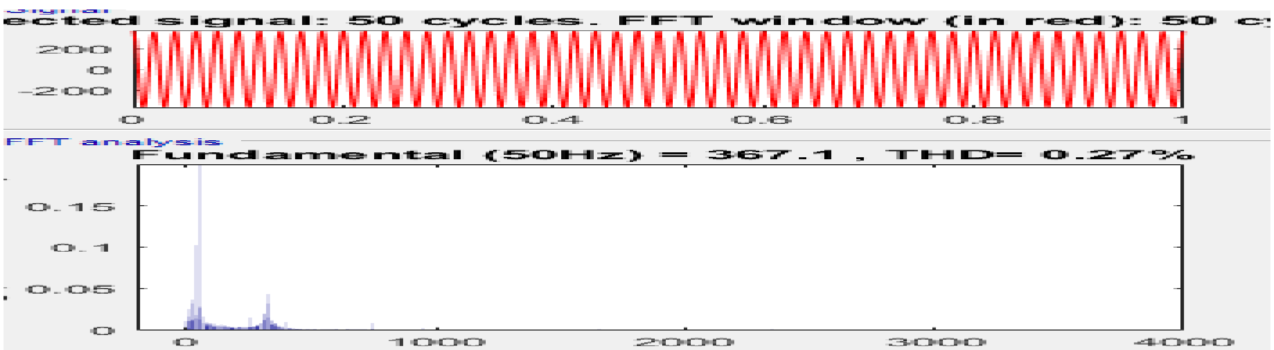


Fig : Busbar-1 Vph-1 & Vph-2 Are Same

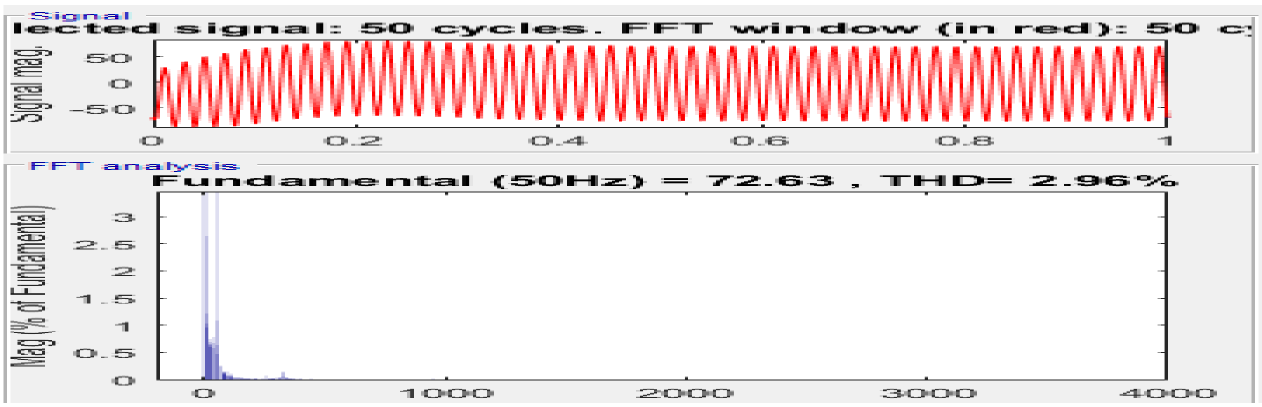


Fig : Busbar-1 Iph-1

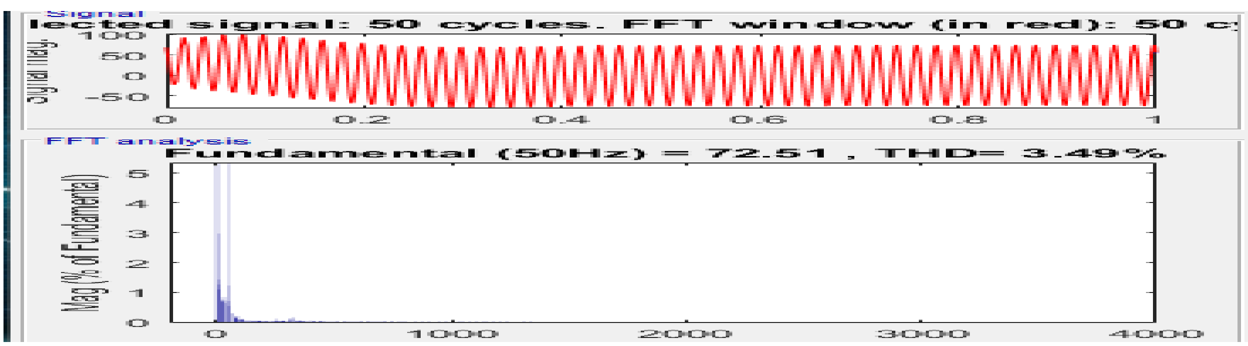
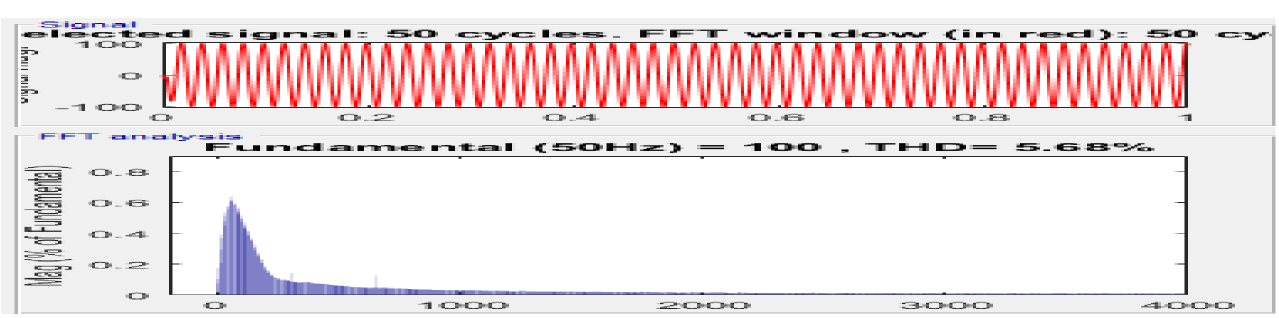
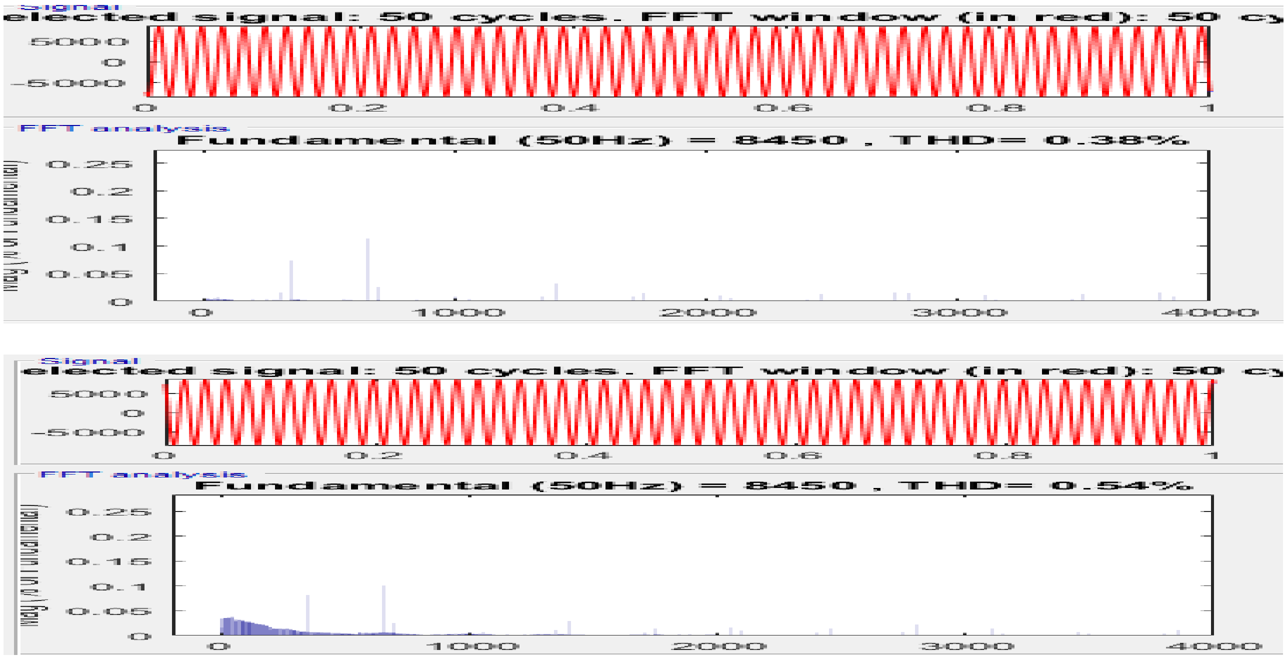


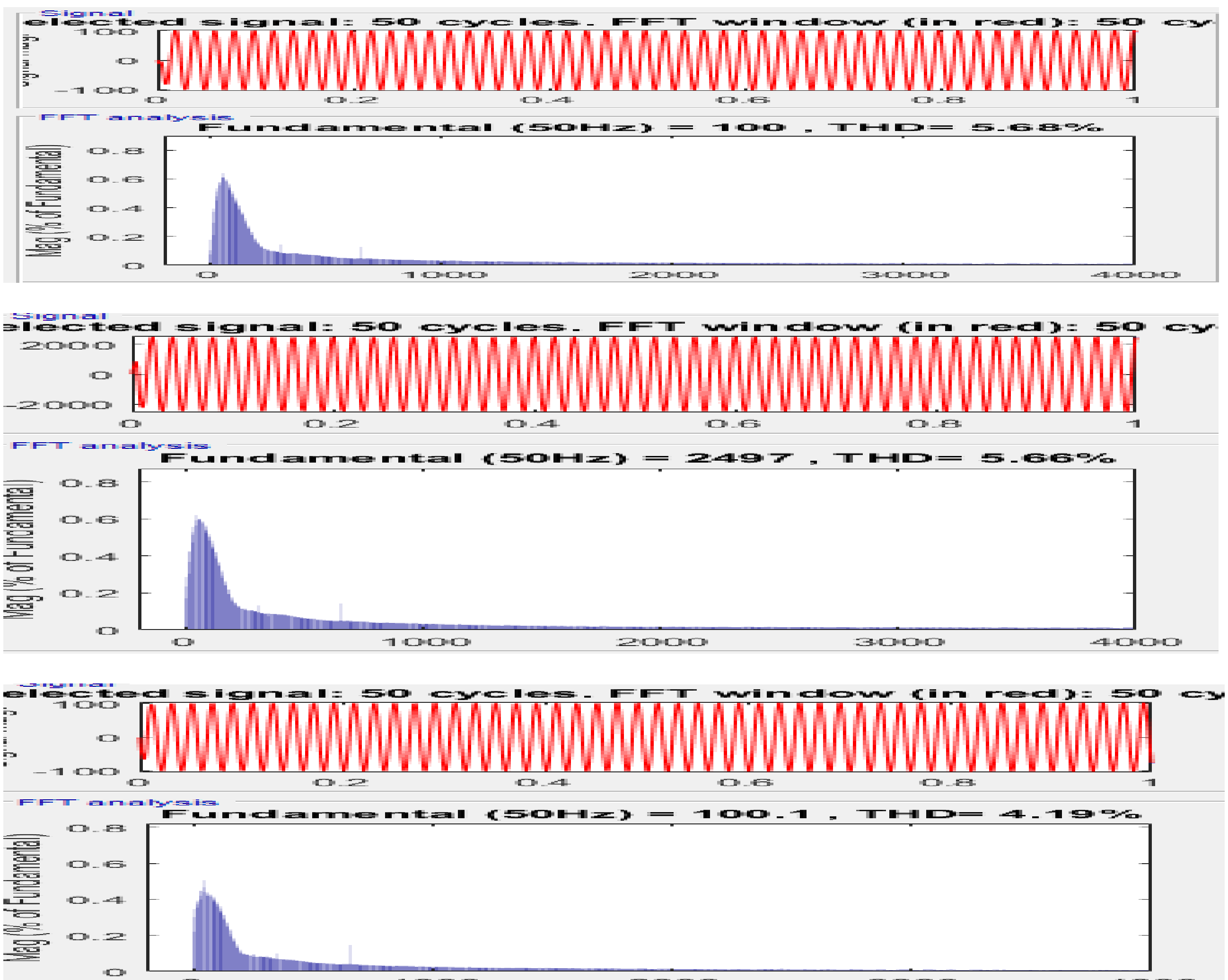
Fig : Busbar-1 Iph-2 & Iph-2 are both Same.

Busar-2 Grid Connected Voltage and Current THD % without LC Filter Figures:





Figures :Busbar-2 Vph-1,Vph-2 ,vph-3 Grid Connected without Filter .



Figures :Busbar-2 Iph-1,I ph-2 ,Iph-3 Grid Connected without Filter .

Busar-2 Grid Connected Voltage and Current THD % with LC Filter Figures:

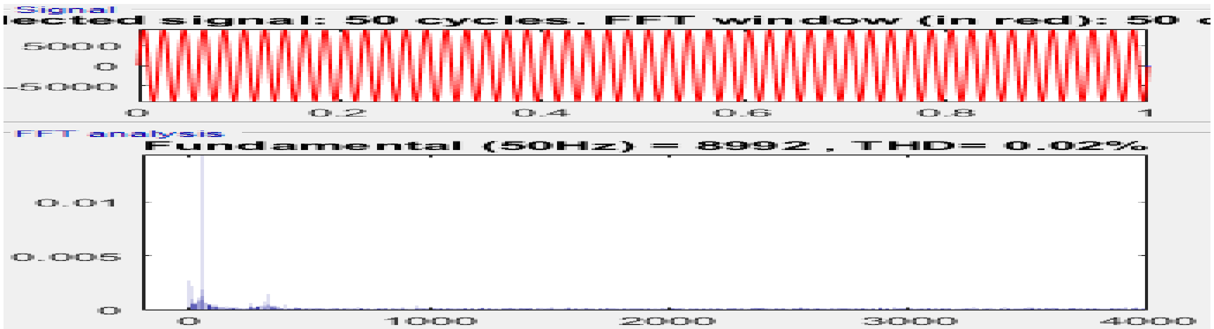


FiG :Busbar-2 Vph-1,Vph-2 ,vph-3 Grid Connected with Filter are same.

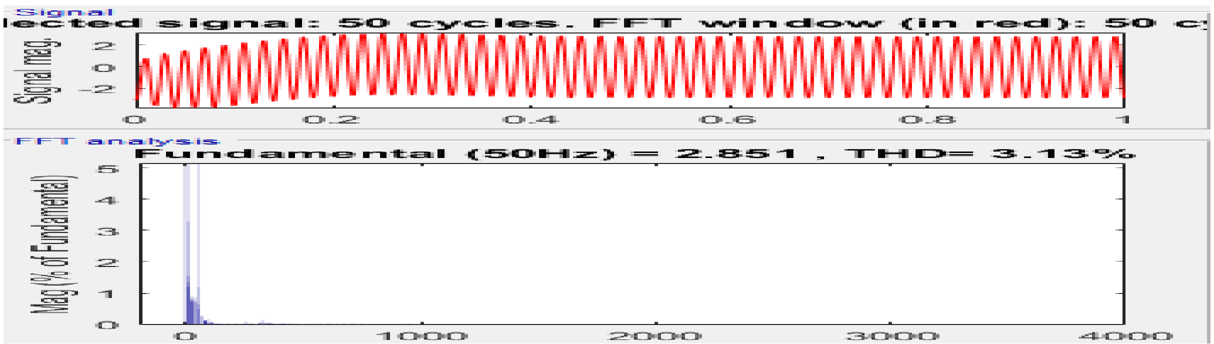
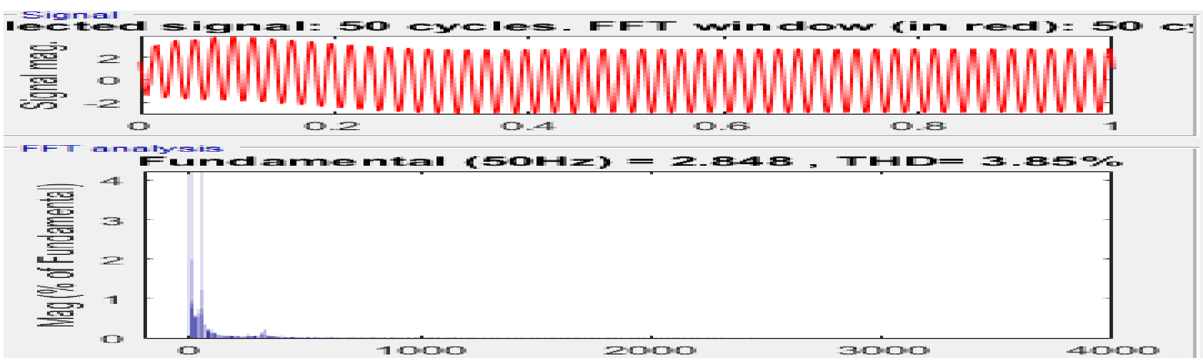
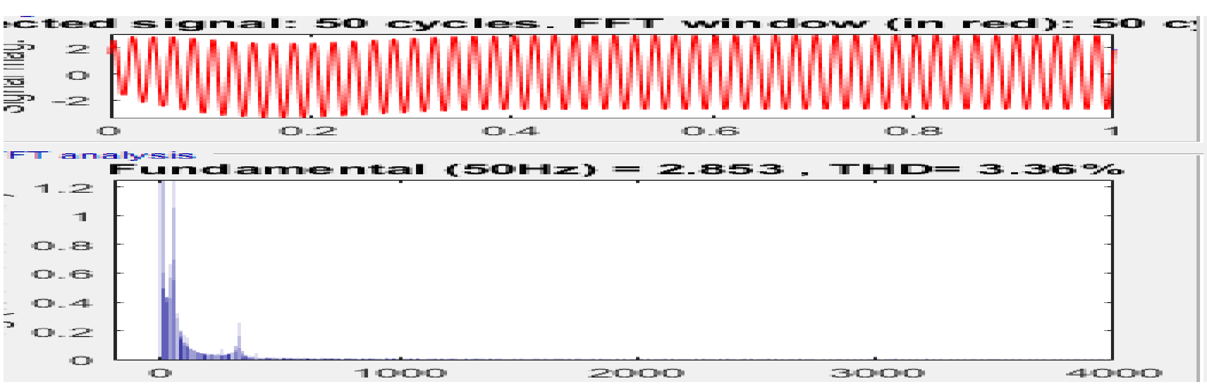


Fig :Busbar-2 Iph-1





Figures :Busbar-2 I ph-2 ,Iph-3 Grid Connected with Filter .

4.2 PV SYSTEM GAIN VOLATGE & POWER FIGUE OF MATLAB:

4.2.1 Solar Power Production Calculation(Average):

E=Energy

A=Total Solar Panel Area

=(77*39 inch^2)*66 (no. of panels)

r=Solar Panel Yield or efficiency

=15%

H=Annual average solar radiation on titled panels(place: Chittagong)

=1791 kWh/year

PR=Performance Ratio, co-efficient for losses (range between 0.5 and 0.9,default value=0.75)

E=A*r*H*PR

={(1.937*66)*.15*1791*0.75} kWh/year

=25758 kWh/year

=25.758 MWh/year

=70.57 kWh/day

=2.9kw/h

4.2.2MATLAB SIMULATED PV VOLATE AND POWER FIGURES :

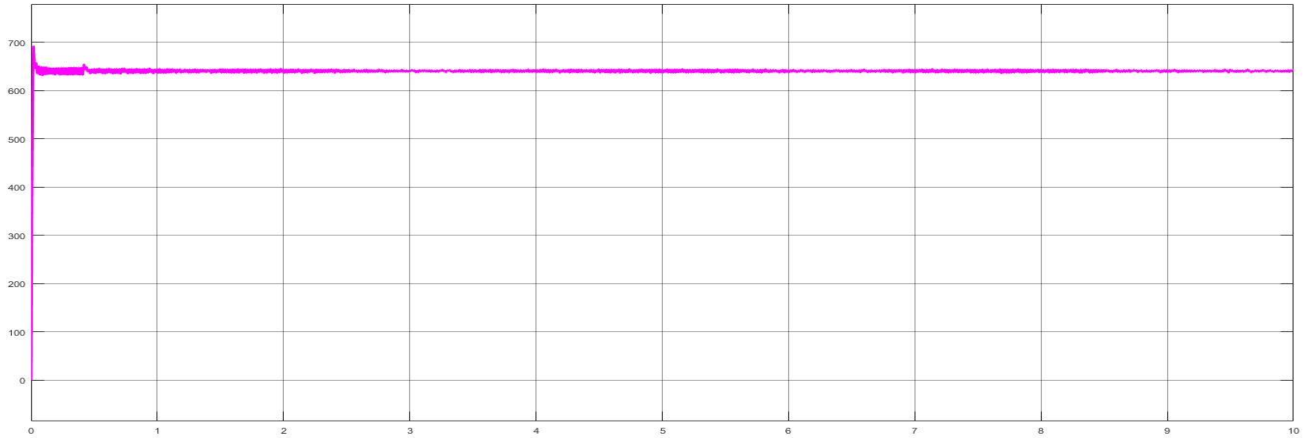


Fig : PV Volatge.(Maximum 690V)

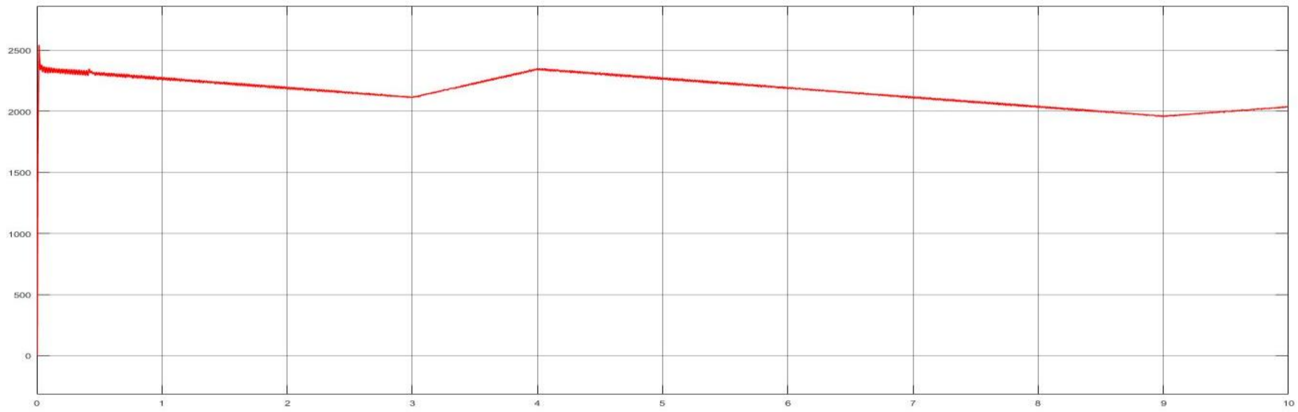


Fig : Pv Power Curve .

4.2.3 MATLAB SIMULATED WIND TURBINE VOLATGE & POWER FIGURE

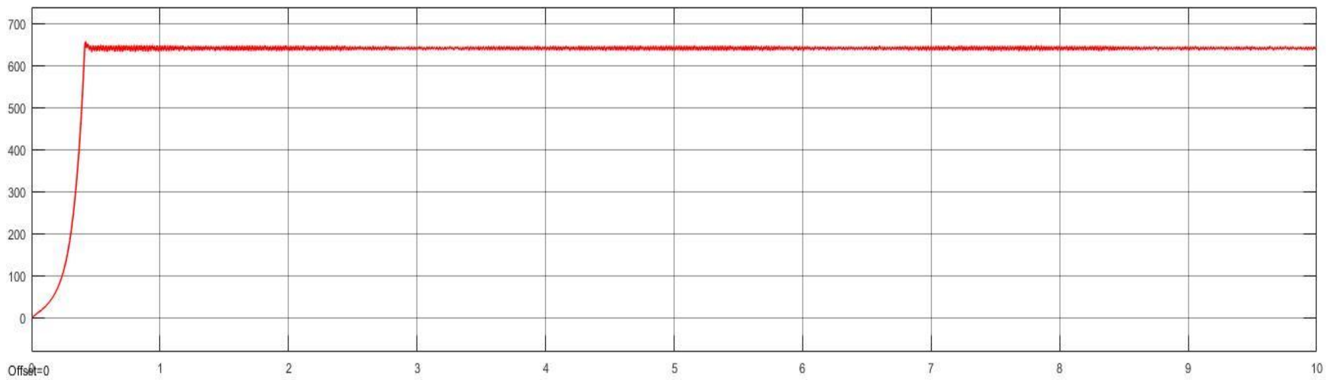


Fig : Controlled voltage of genartaor terminal of Wind Turbine

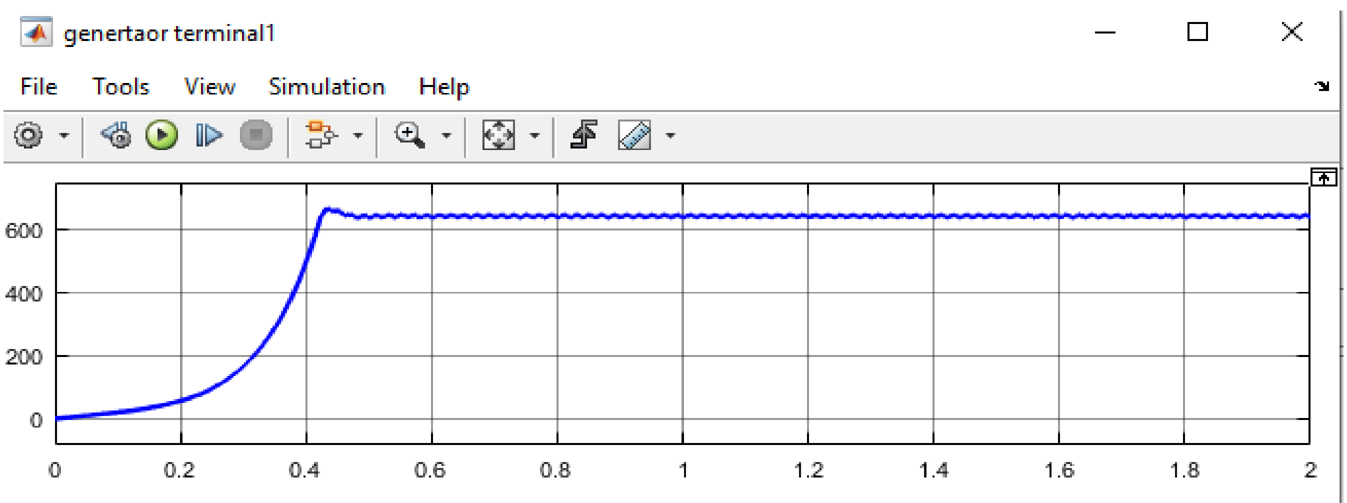


Fig : Wind Turbine Gain Volatge

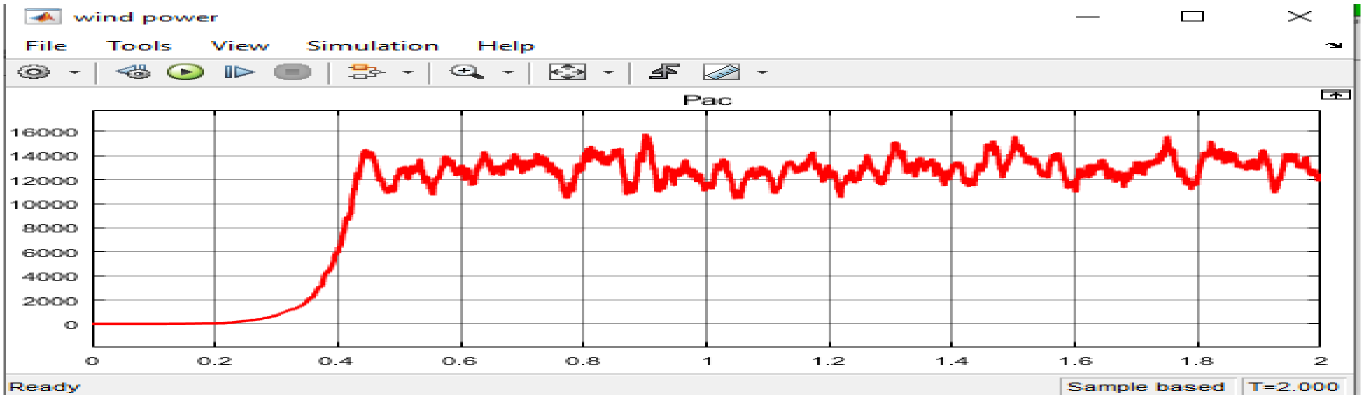


Fig : Wind Turbine Gain Power .

4.2.4 Matllab Simulated Hybrid Wind Turbine And Pv system Dc-BUS Volatge & Current Figure :

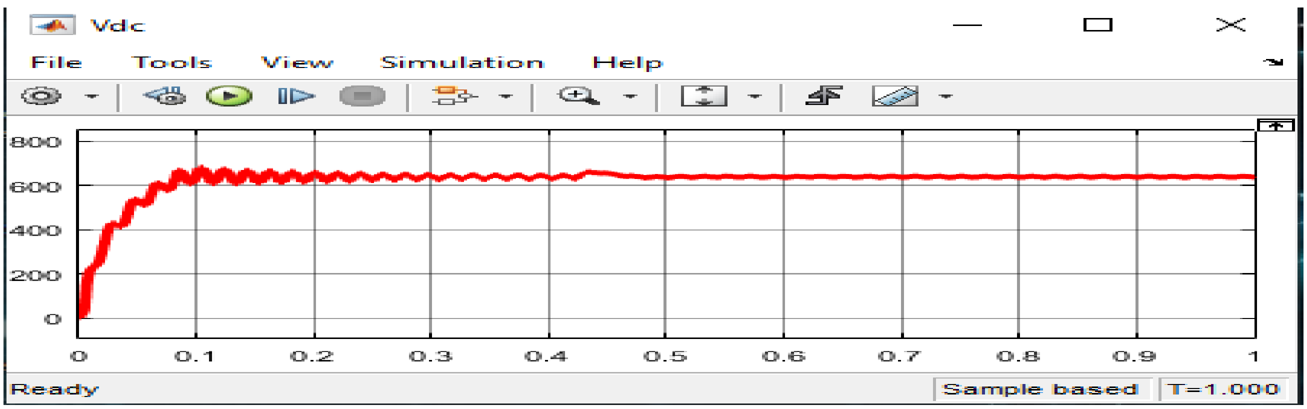


Fig : Dc-BUS voltage .

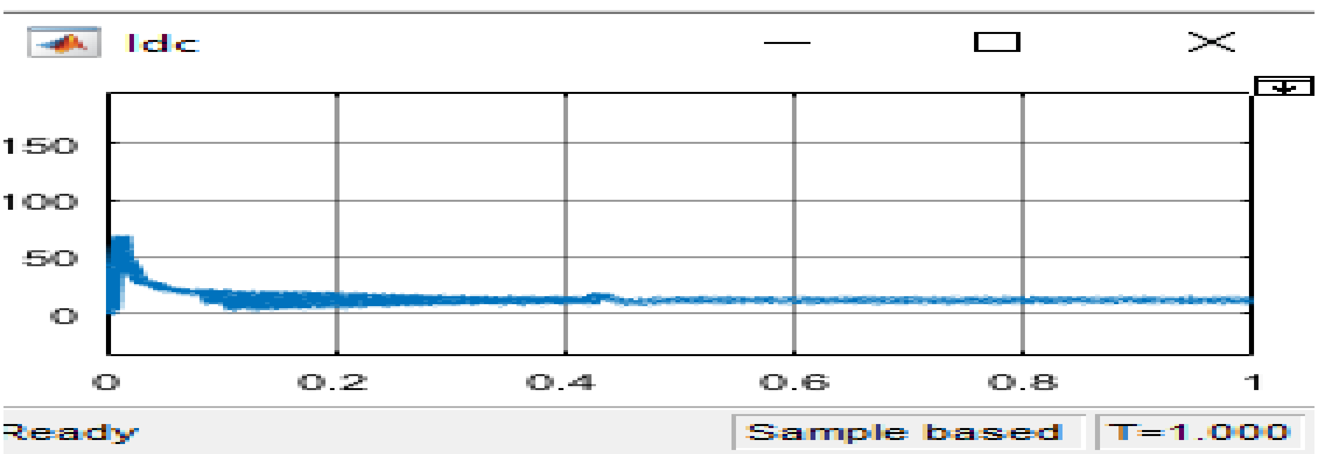


FiG : DC-BUS Current .

4.2.5 BUSBAR -1 CURRENT AND VOLATGE BEFORE STEP-UP VIA X_FORMER:

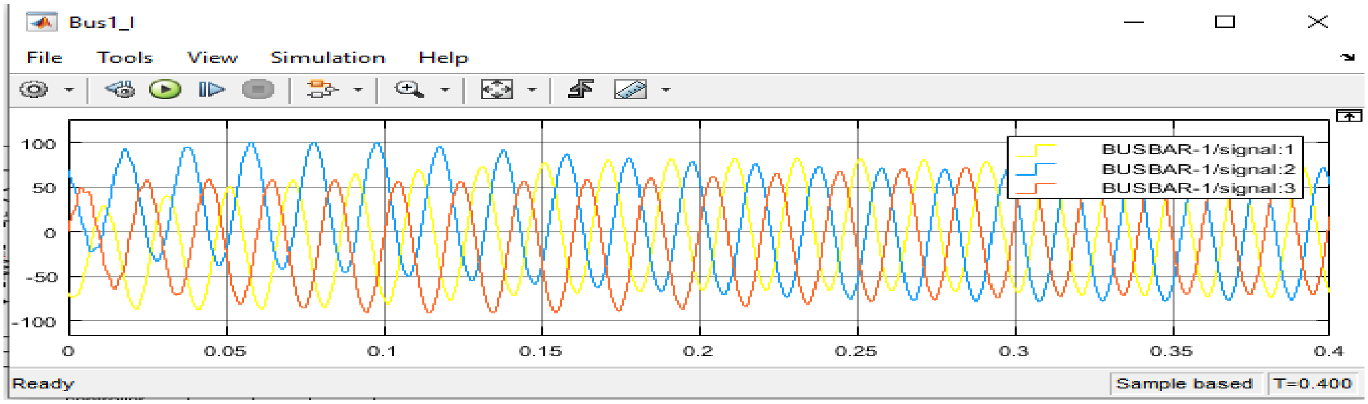


Fig : BUSBAR_1 Current

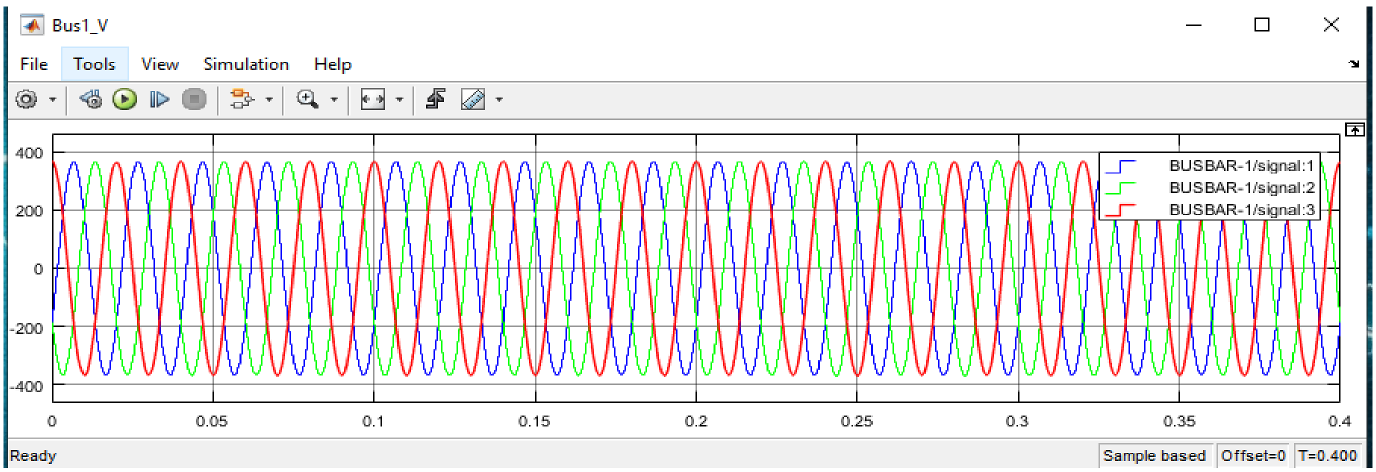


Fig: Busbar_1 Volatge

4.2.6GRID VOLATGE ,CURRENT & POWER FIGURES :

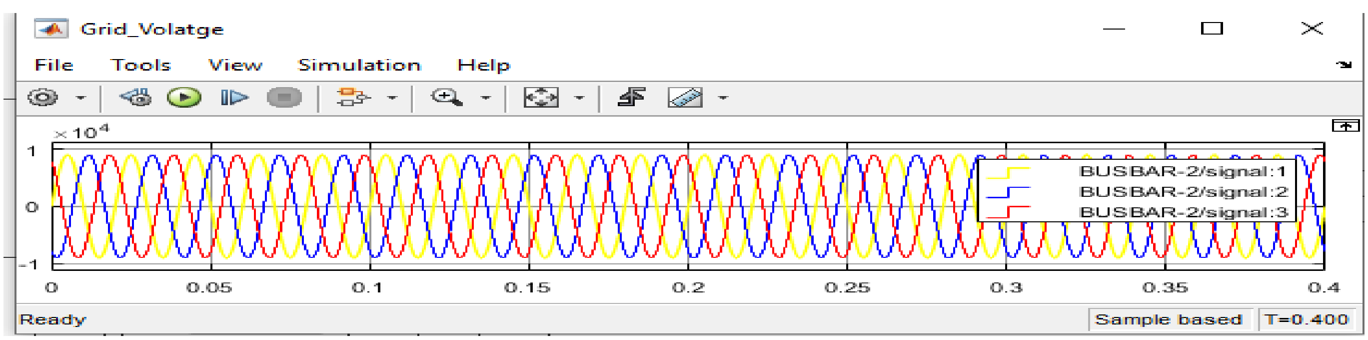


FiG : Grid Voltage

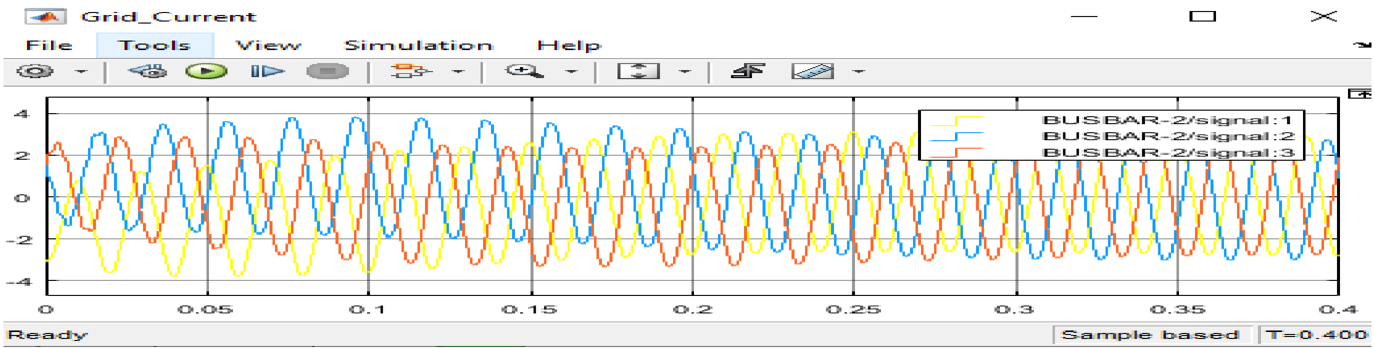


Fig : GRID _ CURRENT

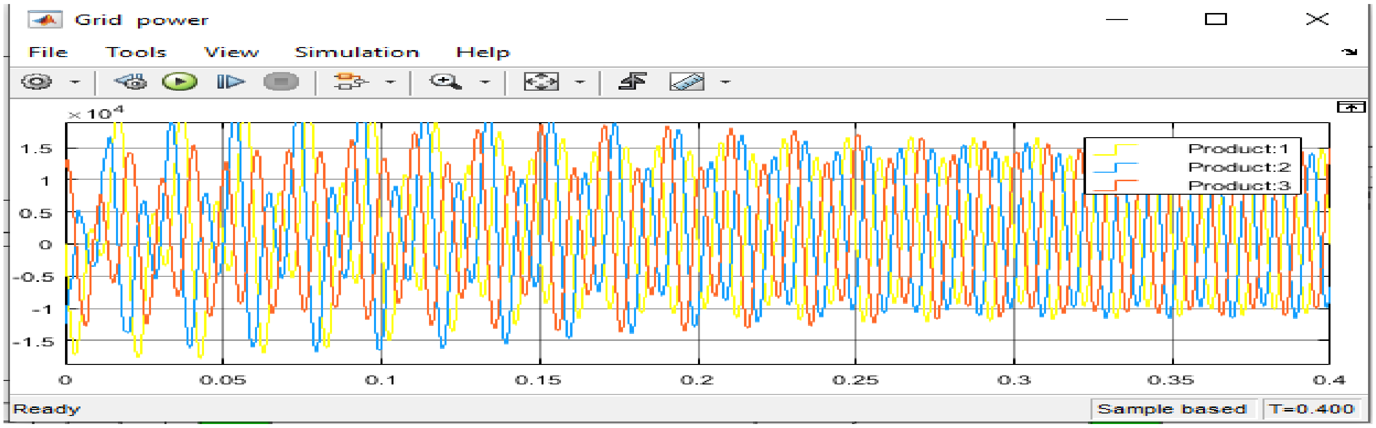


FIG : GRID_POWER

4.3 The Technical and Economic Analysis of Solar-Wind Hybrid Energy System In Potenga ,Chittagong .

Hybrid Optimization of Multiple Energy Resources (HOMER) software is chosen as the simulation tool for this study. This software is designed to simulate long-term operation of a combination of micropower system configurations. The reason behind choosing this software is that it can perform the three major tasks. They are simulation, optimization, and sensitivity analysis. After simulating a number of combinations based on the data supplied by the user, HOMER suggests the optimal configuration based on the lowest net present cost (NPC). Sensitivity analysis enables the designer to determine the best combination of system components under different conditions.

4.3.1Location of the Project : This study is done at Patenga (22.26∘N, 91.8∘E) which is a coastal area under Chittagong District. After assessing the potential of electricity generation from wind and solar resources in Chittagong coastal region, BPDB has planned to implement 50–200MW wind power project at Parky beach area, Anwara, which is 32.2 km away from Patenga [29]. This study is done considering community like office and hospitals where continuous electricity supply is essential and grid electricity is not reliable. Also, standalone RES can provide electricity to remote areas like motels along coastal areas where grid electricity is not available.

4.3.2Renewable Resources : The estimated global solar radiation (30) and monthly solar radiation measured by NASA over Chittagong are shown in the following Figure 1. Fromthefigure it is evident that measured radiation reported by NASA from the analysis of satellite captured image and estimated radiation are close enough. In this study estimated solar radiation is used in optimizing solar panel size.

4.3.3Wind Resources: Just like solar radiationdata, wind speed data are also essential for hybrid systemanalysis.Wind speed data are obtained from BMD [31]. HOMER requires four parameters to generate hourly wind speed from provided monthly wind speed data [32]. They are listed below in figure 2.

4.3.4Weibull Value. The Weibull value k is a measure of distribution of wind speed over the year. In this study, the value of k has taken 2. (ii) *Autocorrelation Factor.* The autocorrelation factor measures the randomness of the wind. Higher value indicates that the wind speed during an hour tends to depend strongly on the wind speed during the previoushour. Lower value means that thewind speed tends to fluctuate in a more random fashion from hour to hour. **The auto correlation factor value has taken 0.78.**

(iii) ***Diurnal Pattern Strength :*** Thediurnal pattern strength indicates howstrongly wind speed tends to depend on the time of a day.Tomeasure this, averagewind speed at each of the 24 hours over the year is calculated. HOMER then fits a cosine function to this diurnal profile. The diurnal pattern strength is equal to the ratio of the amplitude of the cosine wave to the average wind speed. The range of diurnal pattern strengthisnormally 0 to0.4. In this study, considering wind speed moderately depends on the time of a day, the value of this parameter is chosen as 0.3.

(iv) ***Hour of Peak Wind Speed :*** The time of day tends to be windiest on average throughout the year. In this study, 3 pm is used as the hour of peakwind speed. Figure 3 shows the monthly average wind speed, measured at he height of 10mabove ground level.

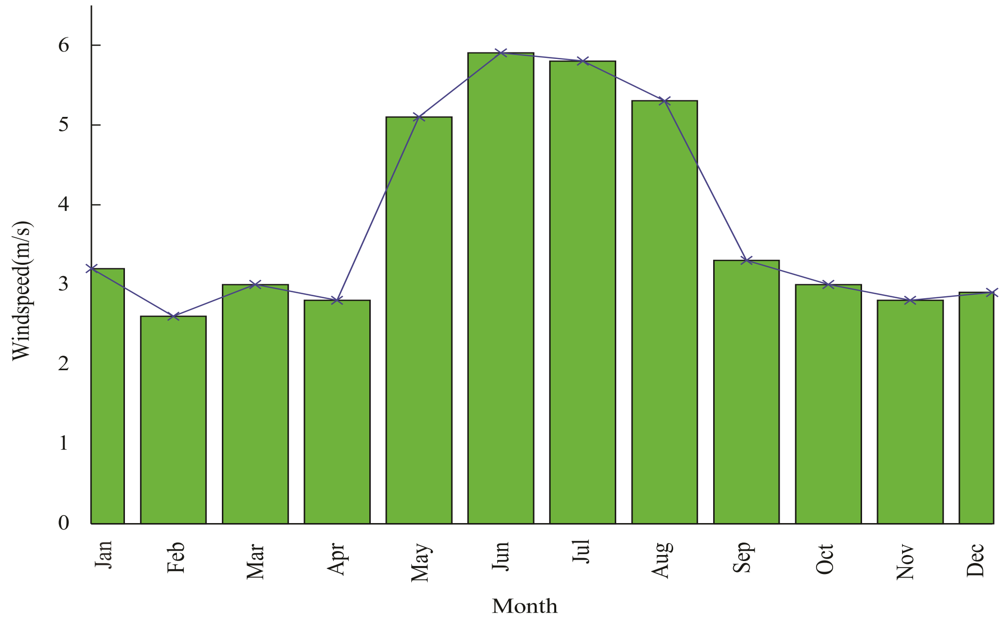
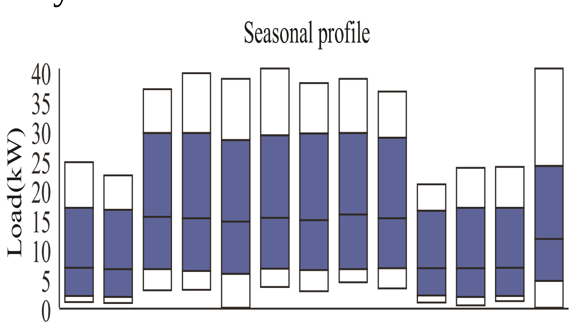


Fig 2: Average Monthly Wind Speed In Potenga per annual .

4.3.5Electrical Load

Seasonal load profile of proposed area is shown in Figure 4. Energy consumed by the hypothetical community is 276 kWh/day with a peak demand of 40 kW. Load profile is prepared by conducting survey on electricity consumption of tourist motels at Patenga. It is considered that day to day random variability is 15.2% and time step to time step variability is 20.4%. Demand is high during summer(March–September) and low during winter (October–February). Distribution system would be required for electric service regardless of whether the service is provided by grid or standalone RES. At present, utility is providing 11 kv line for new connection. So a 11 kv/220 v step-down transformer is required for grid connected System.Also an Automatic Transfer Switch (ATS) is required so that, in case of inadequate supply from RES, load is being connected automatically to

standby grid electricity



Maximum
Daily high

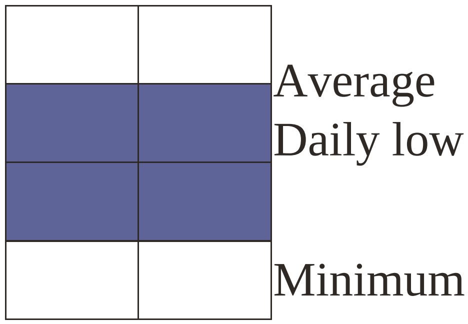


Fig 3: Seasonal Load Profile At Potenga .

4.3.6Hybrid System Component

In this study, grid connected renewable energy system is compared with grid only and RES only system. In the grid connected RES, grid is used as standby supply. When energy supply is inadequate from RES due to bad weather, electricity from grid is consumed. Distribution companies impose different charges for consuming electricity from grid during peak-hours, off-peak hours, and flat rate hours. For commercial and office buildings, charges determined by BPDB.

60

Table 1: Electricity consumption charge for different sectors by BPDB.

Consumer	Time (local time)	Rate	Rate type(BDT/kWh)
Nonresidential	11.00 am–5.00 pm	Flat	9
Commercial	5.00 pm–12.00 am	Peak	11.85
Office	12.00 am–11.00 am	Off-peak	7.22

Table 2: Technical parameters of PV array.

Output current	DC
Lifetime	20 years
Azimuth angle	0 degrees

Ground reflection	20%
Slope	22.05 degrees
Derating factor	85.50%

BPDB during different demand hours are shown in Table 2 **[28].**

4.3.7Photovoltaic Array: The optimal PV array size in kW for concerned load is determined in this study. PV array size is dependent on technical and economical parameters of PV panel. It is assumed that PV panel output is linearly proportional to incident radiation. Charge controller is required to control charging and discharging of battery by PV array current and as HOMER does not provide this option the price of charge controller is merged with PV panel price**.**

4.3.*8*Wind Turbine.: This study uses 10 kW wind turbine manufactured by Yangzhou Shenzhou Wind-Driven Generator Co., Ltd., China[33] .

Technical parameters of the wind turbine are shown in Table 4. Economical parameters are shown in Table 6. Power curve of this turbine is shown in Figure 5. Lifetime of considered wind turbine has taken 9 years while the lifetime of wind turbines made by Bergey Excel, Vestas, spans from 15 to 20 years. Though replacement cost for this low lifetime turbine is high, it is found from HOMER simulation that, due to low capital cost, considered turbine provides low net present cost (NPC) compared to high quality wind turbines over project lifetime. Surface area requirements for wind turbines are assessed for this study using the National Renewable Energy Laboratory (NREL) wind turbine area measurement [30]. According to NREL, average land capacity density (capacity per unit area) is 3.0 ± 1.7 MW/km^2. Therefore area required for 1 kW wind turbine is roughly 0.00025 km^2 or 250 $m^{2.}$

Wind Turbine Parameters is given below :

Rated power	10 kW
Hub height	25
Lifetime	9 years
Rotor diameter	14 m
Number of blades	3
Efficiency	0.85%

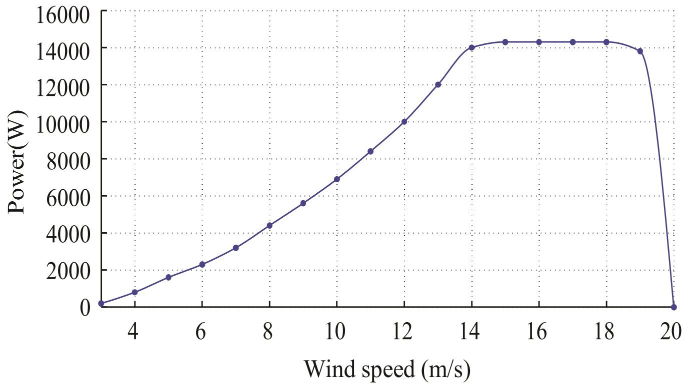


Figure 4: Power curve of the wind turbine.

4.3.9 Battery and Inverter. : As renewable resources like solar radiation and wind speed are seasonal, energy storage medium is required to get continuous supply of energy from RES. In case of grid connected RES electricity can be supplied reliably by using backup of shortage in renewable supply. Operating reserve is considered 10% of hourly load as recommended by Cotrell and Pratt.

Technical parameters of electrosolar lead acid battery is given below:

Nominal capacity=130 Ah

Nominal voltage=12 V

Round trip efficiency=80%

Minimum state of charge =40%

Float life	6 yrs
Maximum charge rate	0.4A/Ah
Maximum charge current	52 A
Lifetime throughput	2230kWh
Suggested value	2230kWh

Electrosolar deep cycle, lead acid battery manufactured by Electro Solar Power Ltd., Bangladesh is used in this study.

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4.3.10 Renewable Resource Variation : Solar and wind resources are varied from annual average value to determine the effect of resource variation on system economy. In the x-axis we have plotted solar radiation and varied it from 3.8 kWh/m^2/day to 6 kWh/m^2/day. The reason behind choosing this range is that, according to Figure 2, the annual solar radiation varies within this range annually. The same goes for wind speed. According to Figure 3, the wind speed at target location varies from 2.5 m/s to 6 m/s annually. So this range for wind speed variation is used. Now the sensitivity analysis in the HOMER software finds out the most cost effective system for a given set of resources. In Figure 6, when solar radiation is up to 4 kWh/m^2/day, the wind-PV/battery system is more cost effective than wind/battery system for wind speed up to 4.4 m/s.

If the wind speed is higher than that, the wind/battery system becomes more cost effective. Similarly, at solar radiation around 4.3 kWh/m^2/day, the wind-PV/battery system is more cost effective than wind/battery system if the wind speed is less than or equal to 4.8 m/s. All the analyses are done with the consideration that maximum annual capacity shortage is 8%.

4.3.11 ***Capital Cost Variation:*** HOMER provides option of cost variation of system components. In this study, capital and replacement costs of PV and wind turbine are multiplied by scaling factors. When cost multipliers are provided, these factors are multiplied by given costs in the cost table. HOMER then simulates system with these varying prices and calculates NPC.

Table 9 : COE of different system configurations with 3 different multipliers

System	Capital multiplier	COE ($)
Grid/wind	1 0.8 0.6	0.129 0.112 0.096
Grid/PV/wind/inverter	1 0.8 0.6	0.145 0.127 0.109
Grid/PV/battery/inverter (5 kW PV, 22 kW inverter)	1 0.8 0.6	0.173 0.171 0.17
Grid/PV/wind/battery/inverter	1 0.8 0.6	0. .174 0.156
PV/wind/battery/inverter	1 0.8 0.6	0.292 0.254 0.215

The study showed that per watt installation price of PV panel decreased by around 15% from 2010 to 2011 and around 30% from 2010 to 2012. On the other hand, another study [37]showed that cost of energy production in MWh from wind turbine reduces by around 62% from 1990 to 2000 and around 20% from 2000 to 2005. To include this trend in system size optimization, capital cost of PV panel and wind turbine is multiplied by 0.8 and 0.6, for all system configurations shown in Table 9. COE are reported when both PV panels and wind turbines capital cost are multiplied by the same factorit is evident that 20% reduction of installation cost results in nearly 9%–12% reductions in cost of per unit energy.

4.4 INPUT VALUE :

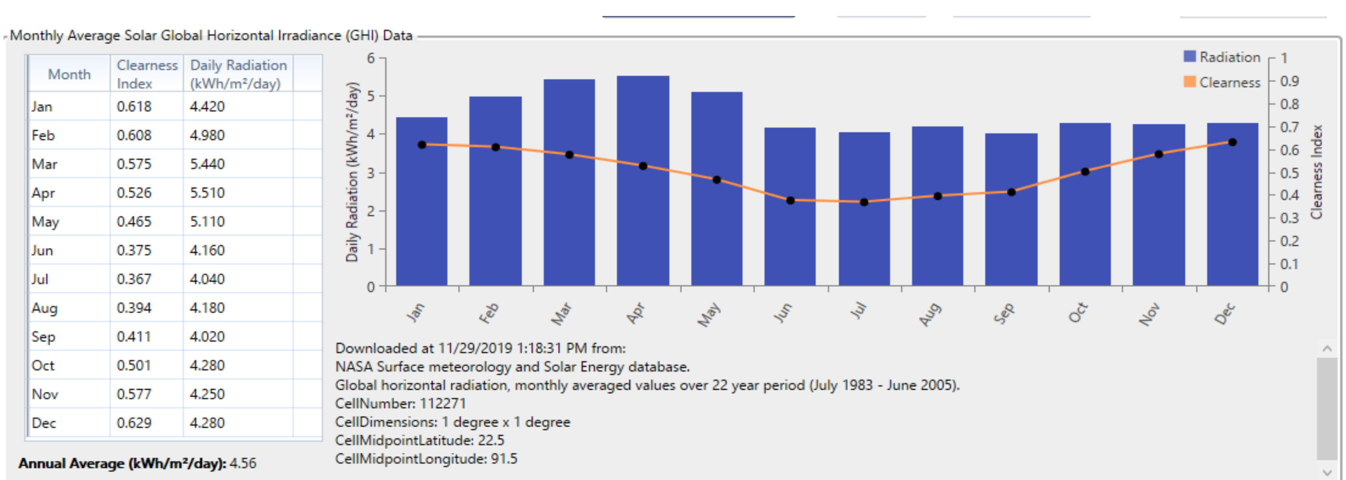

Fig : Solar Resource (According To NASA MESUARMENT)

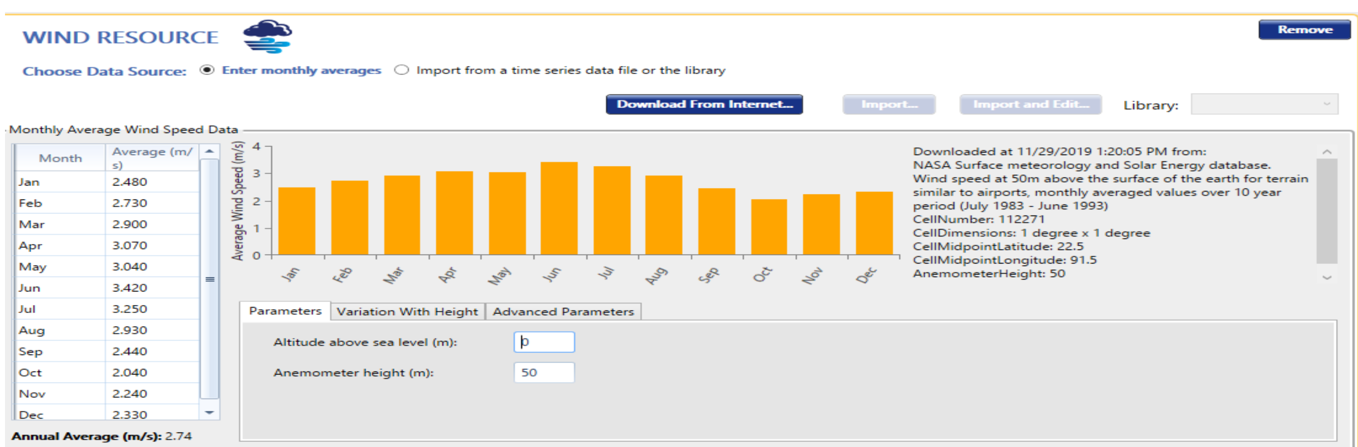

Fig : Wind Resource (According To NASA MESUARMENT)

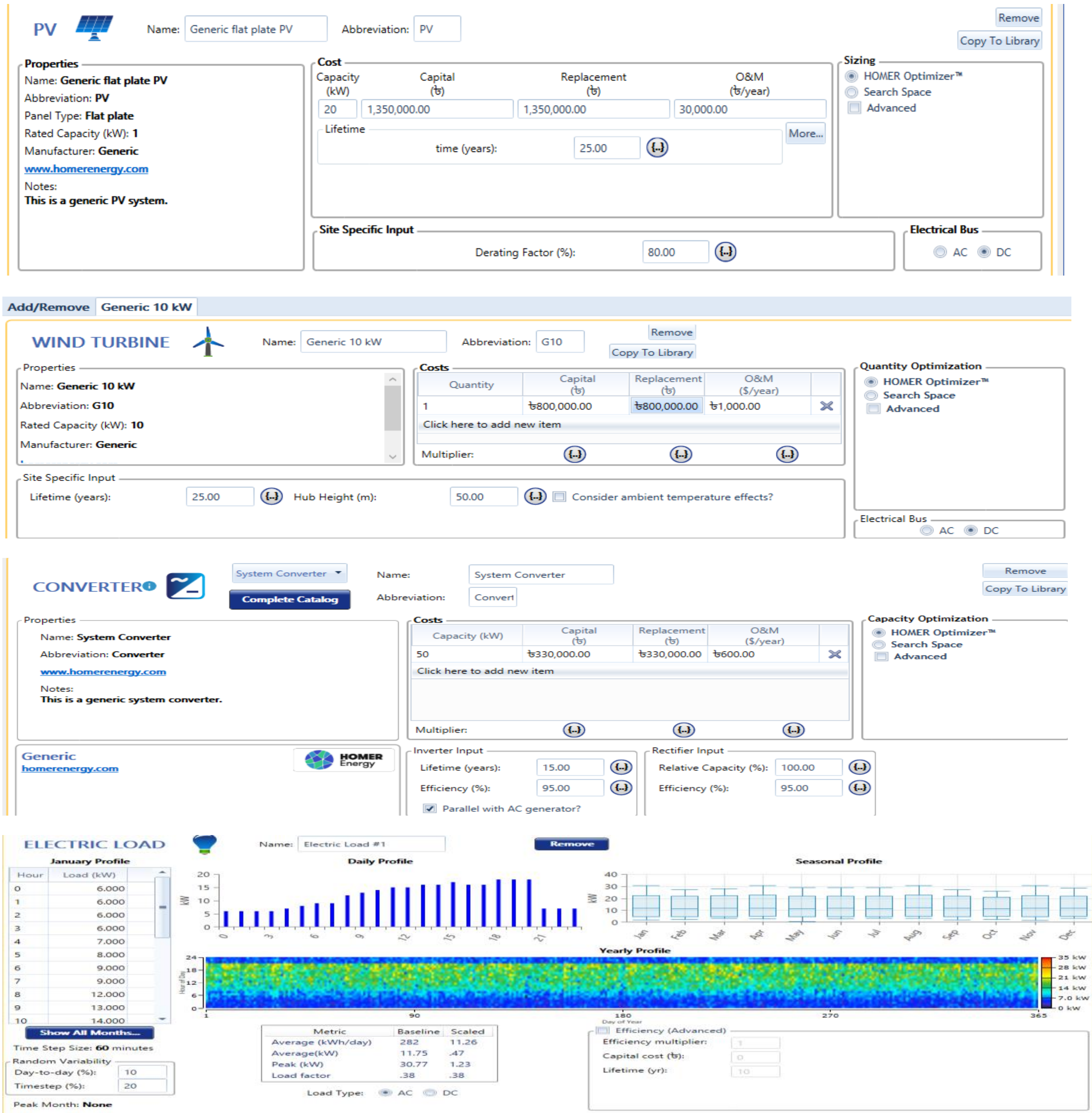

Fig : PV ,Wind Turbien ,Converter & Load input In Homer.

4.5 RESULTS :

Architecture					Cost				System		PV		G10		
PV (kW)	G10	Grid (kW)	Converter (kW)	Dispatch	NPC (৳)	COE (৳)	Operating cost (৳/yr)	Initial capital (৳)	Ren Frac (%)	Total Fuel (L/yr)	Capital Cost (৳)	Production (kWh/yr)	Capital Cost (৳)	Production (kWh/yr)	O&M C (৳)
3.40		999,999	2.68	CC	৳396,912	৳4.55	৳11,603	৳246,920	68.4	0	229,212	4,878			
		999,999		CC	৳478,086	৳9.00	৳36,982	৳0.00	0	0					
3.37	1	999,999	3.05	CC	৳1.13M	৳11.89	৳6,548	৳1.05M	75.6	0	227,702	4,846	800,000	1,091	1,000
	1	999,999	0.0833	CC	৳1.26M	৳23.79	৳35,837	৳800,550	5.84	0			800,000	1,091	1,000

Fig :Homer Output .

Summary | Tables | Graphs | Calculation Report

Compare Economics | Column Choices...

Export...

Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

Categorized | Overall

Cost		System		PV		G10			Converter		Grid	
Operating cost (৳/yr)	Initial capital (৳)	Ren Frac (%)	Total Fuel (L/yr)	Capital Cost (৳)	Production (kWh/yr)	Capital Cost (৳)	Production (kWh/yr)	O&M Cost (৳)	Rectifier Mean Output (kW)	Inverter Mean Output (kW)	Energy Purchased (kWh)	Energy Sold (kWh)
৳11,603	৳246,920	68.4	0	229,212	4,878				0	0.527	2,132	2,636
৳36,982	৳0.00	0	0								4,109	0
৳6,548	৳1.05M	75.6	0	227,702	4,846	800,000	1,091	1,000	0	0.635	1,800	3,257
৳35,837	৳800,550	5.84	0			800,000	1,091	1,000	0	0.0274	3,869	0.0158

Fig : Homer Output production

4.6 Conclusion :From this study it is clear that, in case of off-grid system, the optimized PV-wind-battery hybrid system is more cost effective compared to *wind-alone system*, *PV alone system*, and wind-PV hybrid system for the load with 8% annual capacity of shortage for this hypothetical system at the proposed site. From the sensitivity analysis, it is also clear that the major portion of the energy comes from wind. The sensitivity analysis also predicts that the reduction of installation cost of PV or wind energy system results in per unit electricity cost that is comparable to the grid electricity price. The analysis can be further improved and system economy can be determined more precisely if more related data like minute-wise load curve, land price, variable interest rate, and environmental hazard effects are taken into consider.

CHAPTER 5 : REFERENCES

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