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MODEL BASED DESIGN OF WIND POWER PLANT BY SIMULINK

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ABSTRACT
Now a days Renewable Energy sources became a vital source of energy generation across the world one of that class is wind Energy. Wind energy is the form of solar energy; wind energy describes the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind in to mechanical power. A generator can convert mechanical power into electricity. Wind power can available throughout the year. By this factor wind power plant installation also becomes an important concern. In this paper wind power plant is designed by using Simulink software and reactive power is injected by using a capacitor bank. The model graphs of wind turbine characteristics, active power and reactive power are plotted.
KEYWORDS *Wind turbine induction generator, Three phase programmable voltage source, Three phase transformer.*

1. INTRODUCTION

Wind energy has been used for hundreds of years of sailing grinding grain and for irrigation. Energy in wind can be economically used for generation of electrical energy and has great potential as a good source. The energy available in the winds over the earth's surface is estimated to be $1.6*10^7$ MW, which is equivalent to the present energy consumption in the world. Wind is used to run a wind mill, which in turn drives a generator to produce electricity. Wind can also be used to provide mechanical power, such as pumping water. Wind mills for water pumping have been installed in many countries particularly, in the rural areas. Wind power generation capacity in India has significantly increased in recent years. As of 30 June 2018 the total installed wind power capacity was 34.293 GW, the fourth largest installed wind power capacity in the world. Wind power capacity is mainly spread across the South, West and North regions. Wind power costs in India are decreasing rapidly. The levelised tariff of wind power reached a record low of ₹2.43 (3.5¢ US) per kWh (without any direct or indirect subsidies) during auctions for wind projects in December 2017. In December 2017, union government announced the applicable guidelines for tariff-based wind power auctions to bring more clarity and minimise the risk to the developers. Figure1 shows the electrical energy from wind turbine to the load area.

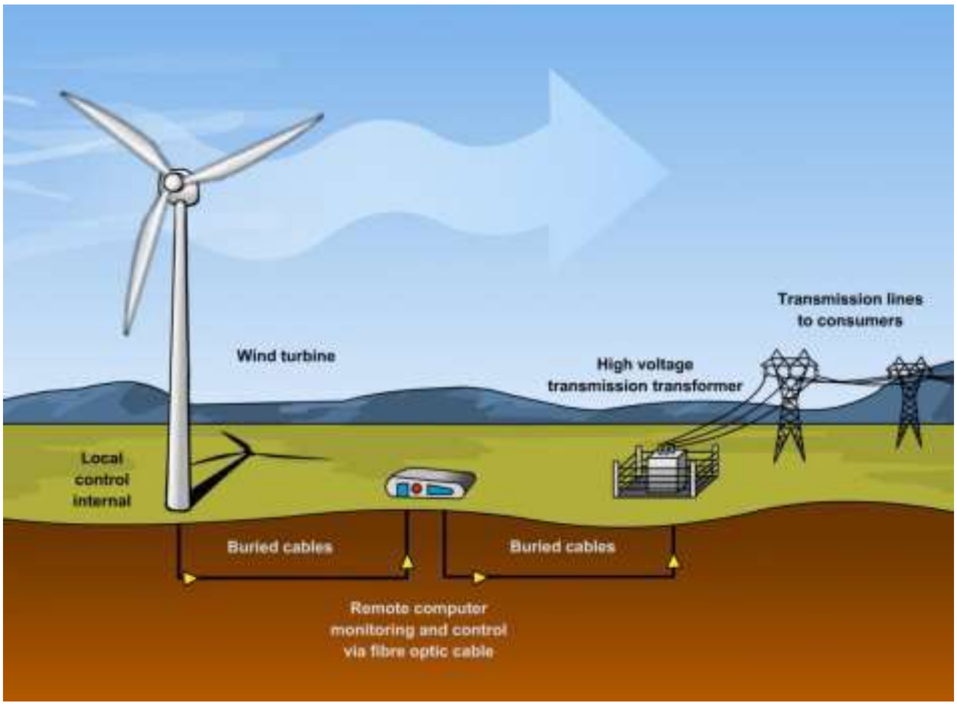

Figure 1: electricity form wind turbine to transmission line

Wind is caused by the uneven heating of the atmosphere by the sun, variations in the earth's surface, and rotation of the earth. Mountains, bodies of water, and vegetation all influence wind flow patterns. Wind turbines convert the energy in wind to electricity by rotating propeller-like blades around a rotor. The rotor turns the drive shaft, which turns an electric generator. Three key factors affect the amount of energy a turbine can harness from the wind: wind speed, air density, and swept area.

1.1 Wind speed

The amount of energy in the wind varies with the cube of the wind speed, in other words, if the wind speed doubles, there is eight times more energy in the wind. Small changes in wind speed have a large impact on the amount of power available in the wind.

1.2 Density of the air

The denser the air, the more energy received by the turbine. Air density varies with elevation and temperature. Air is less dense at higher elevations than at sea level, and warm air is less dense than cold air. All else being equal, turbines will produce more power at lower elevations and in locations with cooler average temperatures.

1.3 Swept area of the turbine:

The larger the swept area (the size of the area through which the rotor spins), the more power the turbine can capture from the wind. Since swept area is $A = \pi r^2$, where r = radius of the rotor, a small increase in blade length results in a larger increase in the power available to the turbine. Equation 1 shows the equation for the wind power.

$$P=\frac{1}{2}\rho A V^3 \qquad (1)$$

In this paper by using a wind turbine generator block which is in the Simulink active power and reactive power levels are displayed for 25 KV wind model. Figure (2) shows the wind turbine generator model.

Figure 2 Simulink block of wind turbine generator

2. WORKING PRINCIPLE OF WIND TURBINE GENERATOR

Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. Wind is a form of solar energy and is a result of the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and the rotation of the earth, the terms wind energy or wind power describe the process by which the wind is used to generate mechanical power or electricity.

Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity. Figure 3 shows the diagram of wind turbine generator.

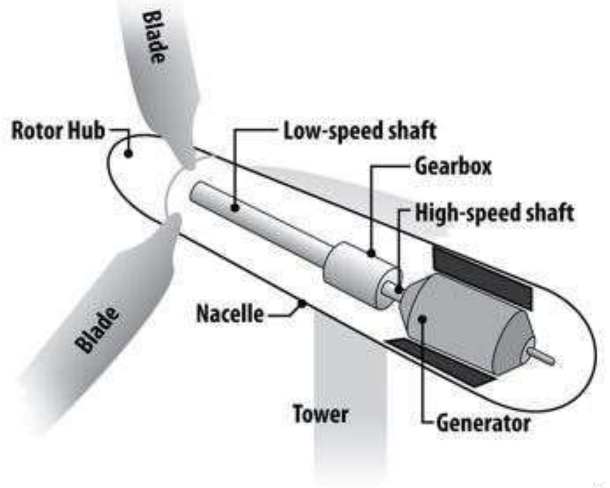

Figure 3 Wind turbine generator

A wind turbine is made up of two major components the Wind Turbine Generator or WTG's which is the electrical machine used to generate the electricity. A low rpm electrical generator is used for converting the mechanical rotational power produced by the winds energy into usable electricity to supply our homes and is at the heart of any wind power system.

The conversion of the rotational mechanical power generated by the rotor blades (known as the prime mover) into useful electrical power for use in domestic power and lighting applications or to charge batteries can be accomplished by any one of the following major types of rotational electrical machines commonly used in a wind power generating systems:

1. The direct current (DC) machine, also known as a Dynamo
2. The alternating current (AC) synchronous machine, also known as an AC Generator
3. The alternating current (AC) induction machine, also known as an Alternator

All these electrical machines are electromechanical devices that work on Faraday's law of electromagnetic induction. That is, they operate through the interaction of a magnetic flux and an electric current, or flow of charge. As this process is reversible, the same machine can be used as a conventional electrical motor for converting the electrical power into mechanical power, or as a generator converting the mechanical power back into the electrical power.

2.1 Electricity Generation

A Wind Turbine Generator is what makes your electricity by converting mechanical energy into electrical energy. Let's be clear here, they do not create energy or produce more electrical energy than the amount of mechanical energy being used to spin the rotor blades. The greater the "load", or electrical demand placed on the generator, the more mechanical force is required to turn the rotor. This is why generators come in different sizes and produce differing amounts of electricity.

In the case of a "wind turbine generator", the wind pushes directly against the blades of the turbine, which converts the linear motion of the wind into the rotary motion necessary to spin the generators rotor and the harder the wind pushes, the more electrical energy can be generated. Then it is important to have a good wind turbine blade design to extract as much energy out of the wind as possible.

All electrical turbine generators work because of the effects of moving a magnetic field past an electrical coil. When electrons flow through an electrical coil, a magnetic field is created around it. Likewise, when a magnetic field moves past a coil of wire, a voltage is induced in the coil as defined by Faraday's law of magnetic induction causing electrons to flow.

2.2 OUTPUT CURVE OF WIND TURBINE GENERATOR:

So the type of wind turbine generator required for a particular location depends upon the energy contained in the wind and the characteristics of the electrical machine itself. All wind turbines have certain characteristics related to wind speed.

The generator (or alternator) will not produce output power until its rotational speed is above its cut-in wind speed where the force of the wind on the rotor blades is enough to overcome friction and the rotor blades accelerate enough for the generator to begin producing usable power.

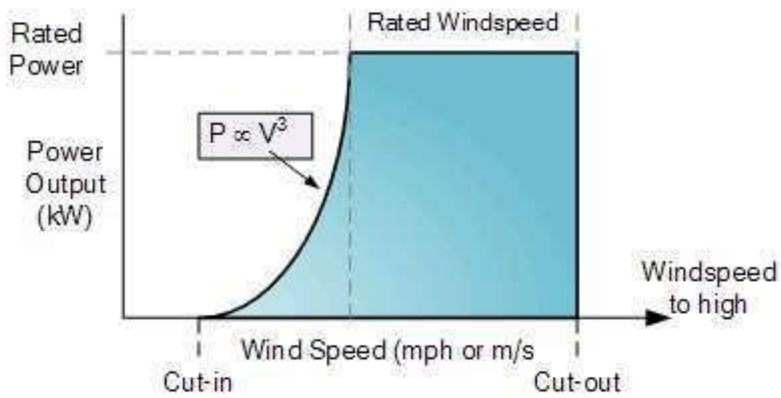

Figure 4: Output Curve Of Wind Turbine Generator

Above this cut-in speed, the generator should generate power proportional to the wind speed cubed (KV^3) until it reaches its maximum rated power output as shown.

Above this rated speed, the wind loads on the rotor blades will be approaching the maximum strength of the electrical machine, and the generator will be producing its maximum or rated power output as the rated wind speed window will have been reached. If the wind speed continues to increase, the paper wind turbine generator would stop at its cut-out point to prevent mechanical and electrical damage, resulting in zero electrical generation. The application of a brake to stop the generator for damaging itself can be either a mechanical governor or electrical speed sensor.

3. SIMULINK MODEL/ RESULTS OF THE WIND POWER PLANT

Below figure 5 shows the Simulink model of the

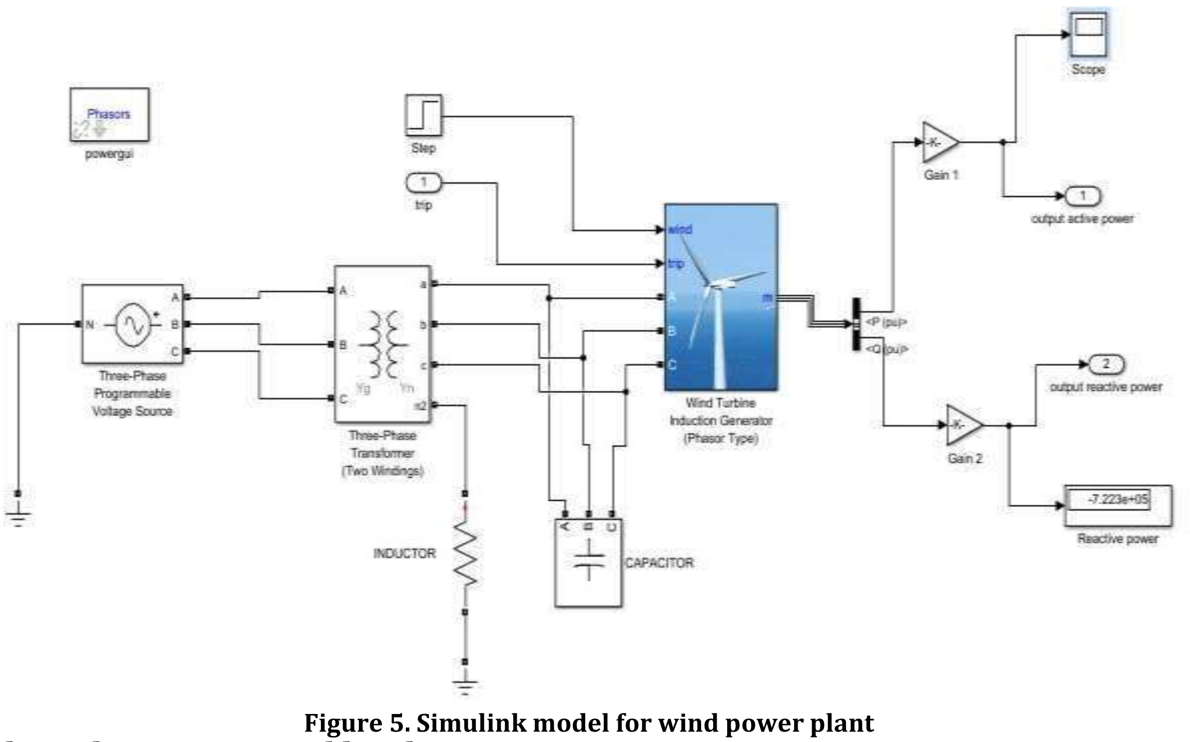

Figure 5. Simulink model for wind power plant

Three phase programmable voltage source:

This block implements the three-phase zero impedance voltage source. Positive sequence amplitude is given (ph-ph) 25kv with phase and frequency is 0^0 and 60 Hz.

3.1 Three phase transformer:

This block represents the three phase transformer with the help of three single phase transformers. Here Yn is taken in order to the utilize the neutral point.

3.2 Parameters of three phase transformer:

Nominal Power & frequency	$25e^3$ & 60Hz
Winding 1 parameters(V1 (ph-ph))	$25e^3$
Winding 2 Parameters (V2 (ph-ph))	575
Magnetizing resistance	500
Magnetizing Inductance	Infinity(inf)
RESISTANCE AND CAPACITIVE REACTIVE POWER	
Resistor (ohms)	66
Capacitive reactive power & nominal phase to phase voltage	$400e^3$ & 575

3.3 Wind Turbine Induction Generator:

By using this wind induction generator, we plot the active and reactive power according to the supply and we will display the wind turbine power characteristics.

3.3.1 Parameters of wind turbine induction generator:

Generator		**Turbine**	
Nominal Power	$1.5e^6$	Pitch angle	0 deg
Line to line voltage	575	Mech. Output power	$1.5\ e^6$
Frequency	60	Base Wind speed	10 m/s
Magnetizing inductance	6.71	Base Rotation speed	1
Inertia constant	5.04	Gain (Kp, Ki)	5,25
Friction factor	0.01	Max.pitch angle	45
Pair of Poles	3	Max.rate of change of pitch angle	2

3.4 Wind turbine power characteristics:

In this turbine power characteristics, the maximum output power w.r.t generator speed is plotted. The maximum output power will have obtained at 10m/s. These characteristics are displayed in figure 6.

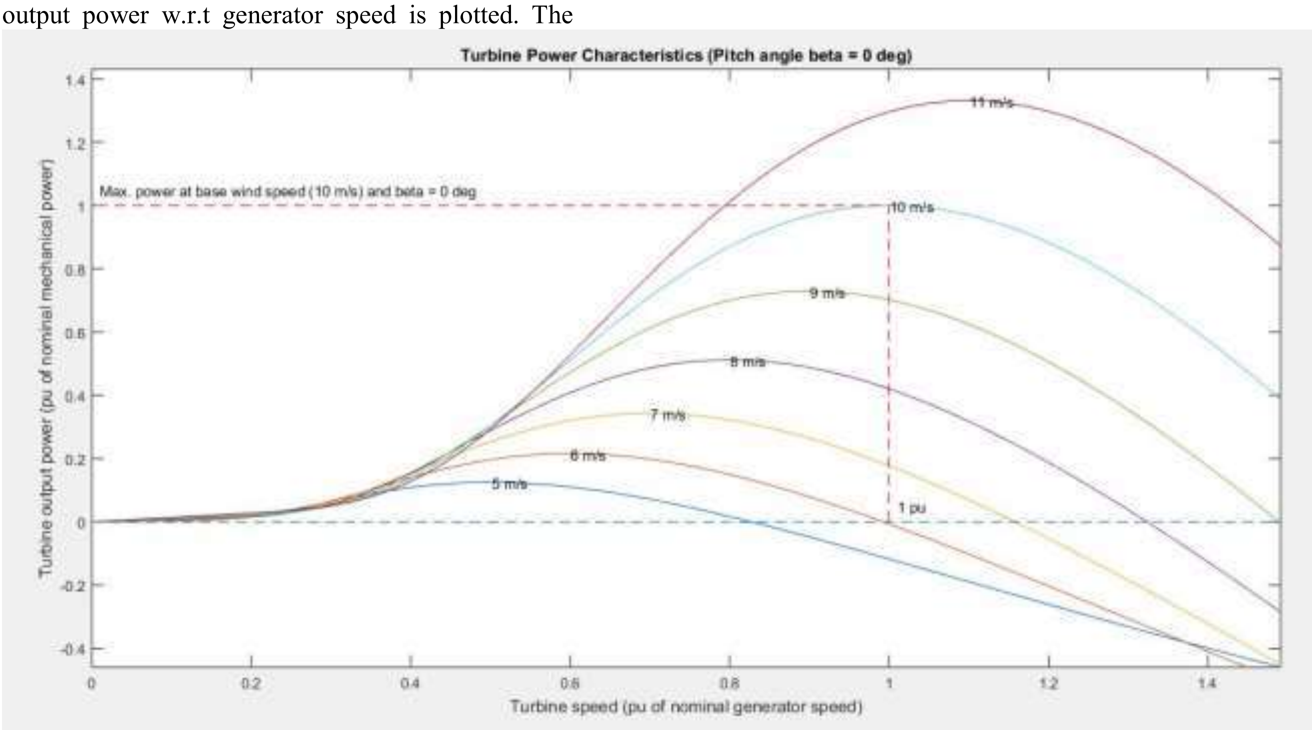

Figure 6 : Turbine power characteristics according to the speed of the blades

3.5 Active Power plot / Reactive Power display of Wind Turbine:

Up to certain time say t=8sec(approx.) as shown in the figure the wind turbine contains some transient after the time t=10 sec wind turbine having the output steady state. Figure 7 shows the active power plot. Reactive power output from the wind turbine is $-7.541e^{+0.5}$

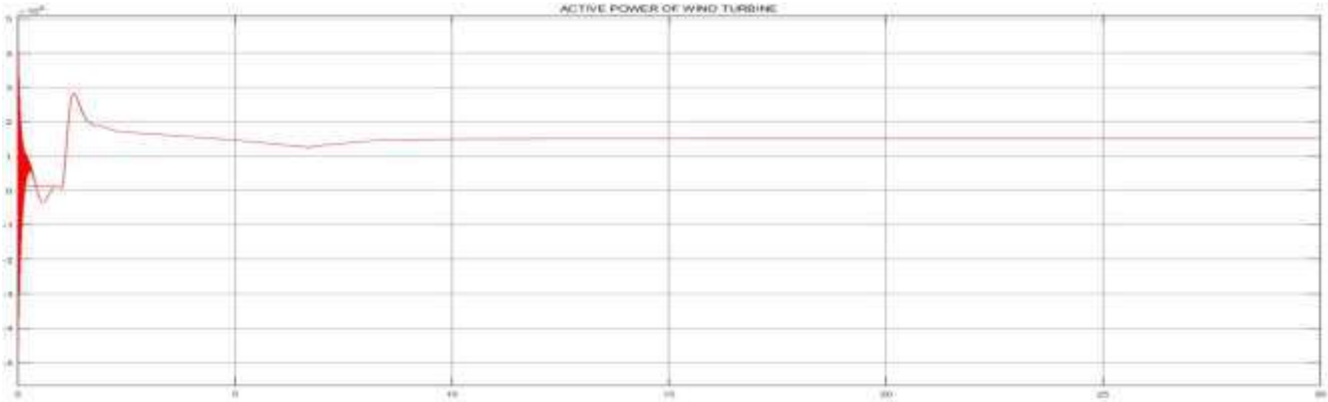

Figure 7: Active Power form the wind power turbine.

3.6 Total harmonic distortion:

The total harmonic distortion (THD) is a measurement of the harmonic distortion present in a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Distortion factor, a closely related term, is sometimes used as a synonym. The waveforms in alternating current electrical systems are ideally pure sinusoidal and have a constant magnitude and frequency to meet the expectations of the customers connected to the grid. A periodical deviation from this ideal condition, with a period of one cycle of the grid frequency, can be classified as a harmonic distortion. Harmonics in power systems can cause several issues. The unwanted harmonic currents in Type 1 and Type 3 WTGs can cause unnecessary extra losses in the copper windings and torque pulsations, and they may even excite mechanical modes of the turbine components. In this paper total harmonic distortion is 16.74%. figure 8 shows the harmonic distortion of wind turbine generator.

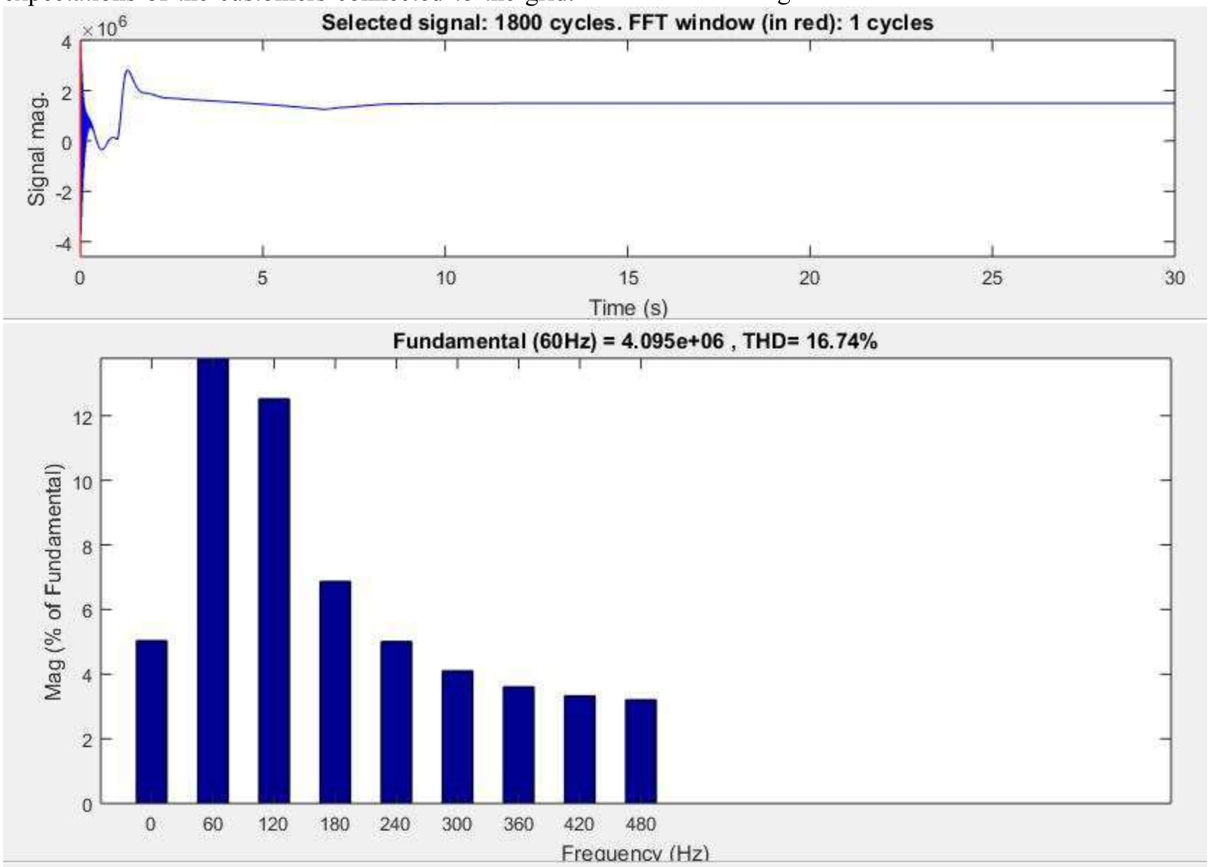

Figure 8: Harmonic Distortion of the wind turbine generator

4. CONCLUSION

In this paper model of wind power plant is designed and simulated by using Simulink software. This model is operated under the 60 Hz frequency. The various graph like active power, Turbine power characteristics are plotted, Reactive power is displayed. In the future scope this model is further used to integrate with various renewable energy sources. Total harmonic distortion is implemented in this paper. In further study various filters are used for improve the harmonic analysis. There by decreasing the value of total harmonic distortion.

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