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Harmonic Analysis of Voltage in Different Wind Speeds for Wind Farms

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Abstract— ***The increasing demand for electric power combined with depleting natural resources has led to the substantial improvements in the usage of renewable energy systems such as wind and solar especially among the developing countries. Today, wind turbine deployment shows the fastest growth both nationally and globally. Wind Electric Generators were earlier used for isolated power supplies especially in remote locations and rural areas. recently, grid-connected wind electricity generation shows the highest rate of growth, achieving global annual growth rates in the order of 30-35%. Squirrel Cage Induction Generator (SCIG) is the most used generator type for WEGs One of the major issues concerning SCIG coupled to wind turbine is voltage instability problem when it is interconnected with grid. It occurs in a power system when the reactive power demand by SCIG during grid faults and heavy loading conditions is not met by the capacitor banks installed near SCWEG. This paper examines the use of STATCOM to improve voltage of SCIG in the event of any unbalanced or balanced fault in the grid. Simulation is done in MATLAB SIMULINK for various conditions.***

Keywords— wind turbine, Harmonic, STATCOM

I. INTRODUCTION

With the increase in the ratio of wind generation to conventional generation, several problems related with integration of wind farms have emerged [1]. In addition, power transmission and distribution systems face increasing demands for more power, better quality and higher reliability at lower cost, as well as low environmental effect. Under these conditions, transmission networks are called upon to operate at high transmission levels, and thus power engineers have had to confront some major operating problems such as transient stability, damping of oscillations and voltage regulation etc [2].These problems are due to distinct properties of the generators used with the conventional form (Thermal & Hydro) of generation and wind based generation. In thermal and hydro power based generation synchronous generators are used while in wind based generation mostly induction generators are used [3]. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system The induction generator has inherent advantages of cost effectiveness and robustness. However induction generators require reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected [4].

Flexible AC Transmission Systems are represented by a group of power electronic devices. This technology was developed to perform the same functions as traditional power system controllers such as transformer tap changers, phase shifting transformers, passive reactive compensators, synchronous condensers, etc. Particularly FACTS devices allow controlling all parameters that determine active and reactive power transmission, nodal voltages magnitudes, phase angles and line reactance. Replacement of the mechanical switches by semi conductor switches allowed much faster response times without the need for limiting number of control actions. However, FACTS technology is much more expensive from the mechanical one. FACTS devices can be divided into two generations. Older generation bases on the thyristor valve, where newer uses Voltage Source Converters (VSC) [5].

Flexible AC Transmission Systems (FACTS) are used extensively in power systems because of their ability to provide flexible power control. Examples of such devices are the Static Synchronous Compensator (STATCOM) and the Unified Power Flow Controller (UPFC). STATCOM is preferred in wind farms due to its ability to provide bus bar voltage support either by supplying and/or absorbing reactive power in to the system [6].

II. WIND TURBINE MODEL

Wind power industry is developing rapidly, more and more wind farms are being connected into power systems. In the next years, there will be more significant growth in wind energy. Although the great development in the technology of electrical generation from wind energy, there is only one way of generating electricity from wind energy is to use wind turbines that convert the energy contained in flowing air into electricity.

There are many different types of wind turbines in use around the world, each having its own list of benefits and drawbacks. Presently there are three main turbine types available. They are: Squirrel cage induction generator, Doubly fed induction generator and Direct drive synchronous generator. In this paper Squirrel-cage induction generator is main model of wind turbines that shown in Figure 1.

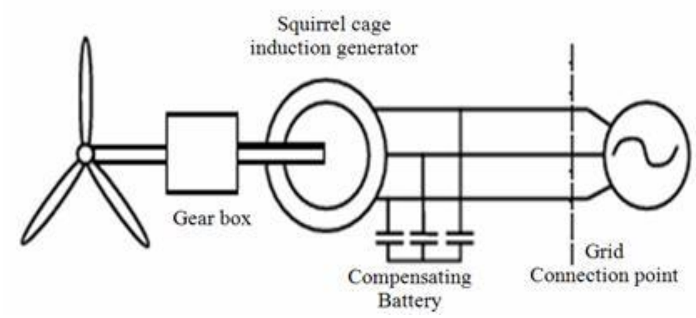


Figure 1 : Squirrel cage induction generator

A constant speed wind turbine (Fig 1), which consists of a grid coupled short-circuited induction generator [7]. The wind turbine rotor is connected to the generator through a gearbox. The power extracted from the wind is limited in high wind speeds using the stall effect.

The model of wind turbine used for the purpose of simulation is a per unit model based on the steady state power equation of a wind turbine. The gear train used for coupling the generator with the grid is assumed to have infinite stiffness while the friction factor component and the inertia of the turbine is aggregated with these quantities of the electric generator coupled with the turbine [10,8].

$$P_{\omega} = 0.5Cp(\lambda, \beta)\rho AV^3$$

Here Pm=mechanical power developed by the wind turbine, Cp= power coefficient of the turbine, ρ is the density of air striking the turbine blades (kg/m3), A is the swept area of the rotor blades of the turbine (m2), λ is the tip-speed ratio, β is the pitch angle (degrees)[9,11,12].

$$C_P(\lambda, \beta) = c_1(\frac{c_2}{\lambda_i} - c_3\beta - c_4)e^{\frac{-c_5}{\lambda_i}} + c_6\lambda$$

$$\frac{1}{\lambda i} = \frac{1}{\lambda + 0.008} - \frac{0.035}{\beta^3 + 1}$$

The relation between Cp, β and λ is shown in Figure 2.

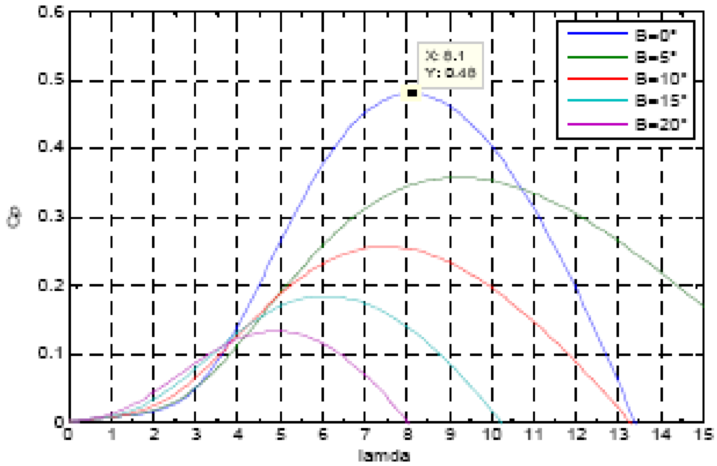


Figure 2: Aerodynamic Power Coefficient Variation Cp_ against Tip Speed Ratio λ and Pitch Angle β

III. THREE AC CAPACITORS IN SQUIRREL CAGE INDUCTION GENERATOR

Any induction machine requires excitation current to magnetise the core and produce a rotating magnetic field. The excitation current for an induction generator connected to an external source, such as the grid, is supplied from that external source. If this induction generator is driven by a prime mover above the synchronous speed, electrical power will be generated and supplied to the external source. An isolated induction generator without any excitation will not generate voltage and will not be able to supply electric power irrespective of the rotor speed.

In general an induction generator requires reactive power for its operation. Three charged capacitors connected to the stator terminals of the induction generator can supply the reactive power required by the induction generator. Provided that the conditions for self-excitation are satisfied the charged capacitors cause the terminal voltage to build up at the stator terminalsof the induction generator. When the harged capacitors are connected to the terminals a transient exciting current will flow and produce a magnetic flux. This magnetic flux will generate voltage and the generated voltage will be able to build the charge in the capacitors. As the charge increases, more exciting current is supplied to the induction generator. The magnetic flux continues to increase hence producing a higher generated voltage. In this way voltage is built up.

IV. STATCOM

Shunt compensators are primarily used for bus voltage regulation by means of providing or absorbing reactive power. They are effective for damping electromechanical oscillations. Different kinds of shunt compensators are currently being used in power systems, of which the most popular ones are Static Var Compensator SVC and STATCOM. In this work, only the STATCOM, which has a more complicated topology than SVC, is studied. The STATCOM is a FACTS controller based on voltage source converter VSC technology. A VSC generates a synchronous voltage of fundamental frequency and controllable magnitude and phase angle[2]. Static Synchronous Compensator (STATCOM) is a shunt controller mainly used to regulate voltage by generating/absorbing reactive power. The schematic diagram of STATCOM is shown in Figure 3.

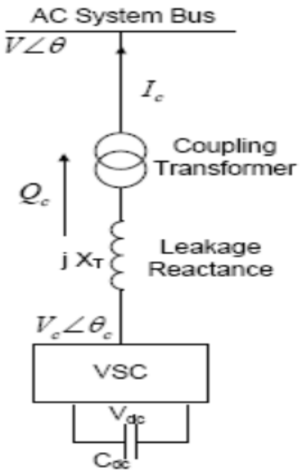


Figure 3: The schematic diagram of STATCOM

The resulting STATCOM can inject or absorb reactive power to or from the bus to which it is connected and thus regulate bus voltage magnitudes. The main advantage of a STATCOM over SVC is its reduced size, which results from the elimination of ac capacitor banks and reactors; moreover, STATCOM response is about 10 times faster than that of SVC due to its turn-on and turn-off capabilities [8-9]. The active and reactive power exchange between the VSC and the system is shown in Figure 6 are a function of the converter output voltage denoted as Vout, i.e.

$$P = \frac{V1V2sin\delta}{X}$$

$$Q = \frac{V1(V1 - V2cos\delta)}{X}$$

Where

V1=line to line voltage of source V1

V2=line to line voltage of V2

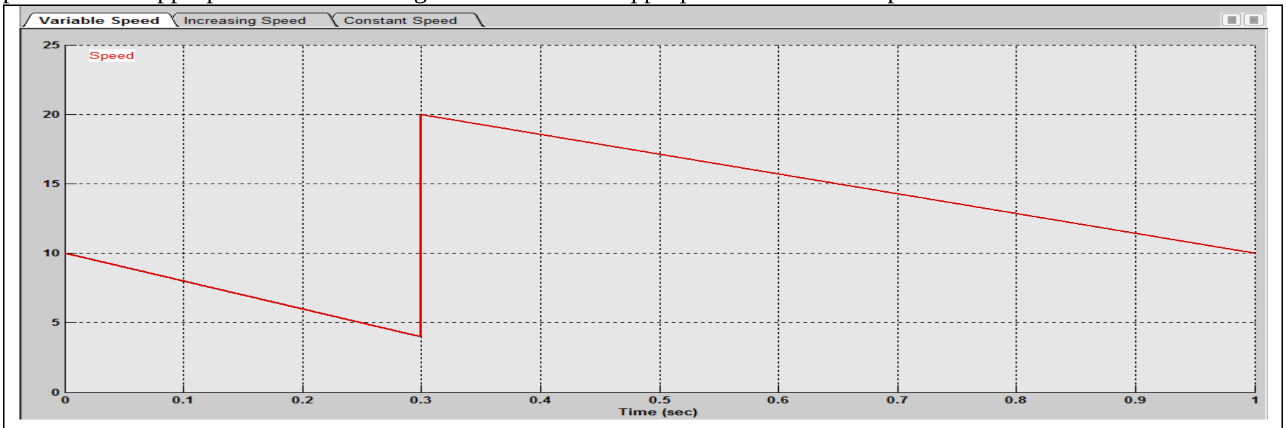
X=Reactance of interconnection Transformer and filters

δ= angle of V1 with respect to V2

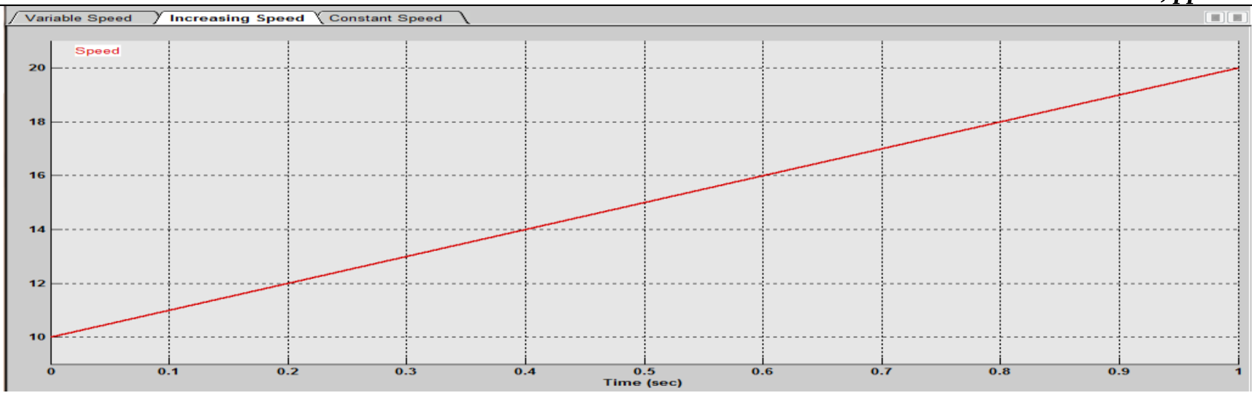
In steady state operation, the voltage V2 generated by the VSC is in phase with V1 (=0), so that only reactive power is flowing (P=0). If V2 is lower than V1, Q is flowing from V1 to V2 (STATCOM is absorbing reactive power).

V. SIMULATION RESULTS

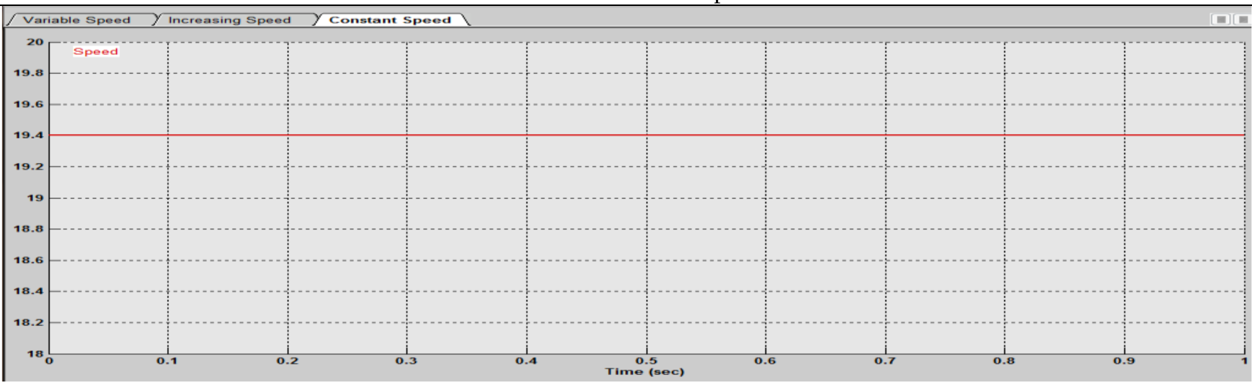
For the wind farm of three strategies for speed is used. Figure 4 different acts quickly to show the wind turbines. Without a doubt, the most important being a wind turbine in oscillating parameter can be of the nature of swinging wind speed that the appropriate control strategies can be a more appropriate and more output from wind farms achieved.



a: Wind variable speed



b: Incremental wind speed



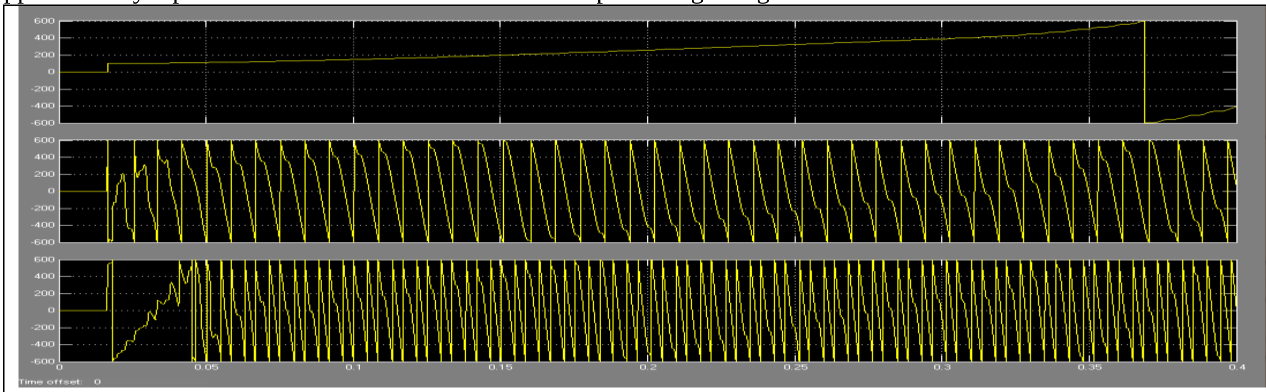
c: Fixed wind speed

Figure 4: Various speed applied to wind turbines

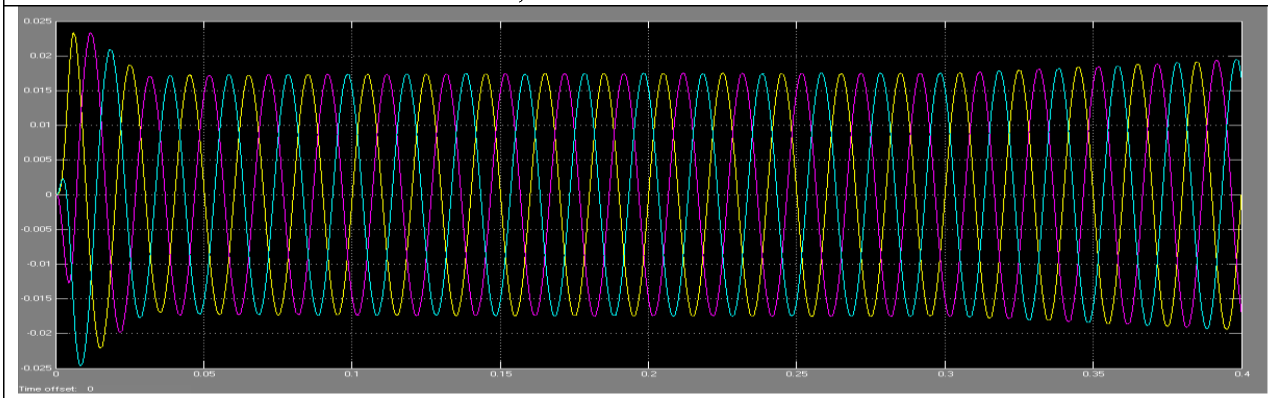
In this article the amount of harmonics to the value of the first harmonic is measured and compared to the first, beginning with the first harmonic measure that its value was obtained equal to 2/30 then use 33/3 with a gain of factor to its value to 100 and the third and fifth harmonics can express on the percentage.

A: Wind variable speed

For the third and fifth harmonic range variable speed respectively 6 and 5 times the first harmonic, or in other words approximately 6 per cent have a harmonic waveform output voltage range is also desirable.



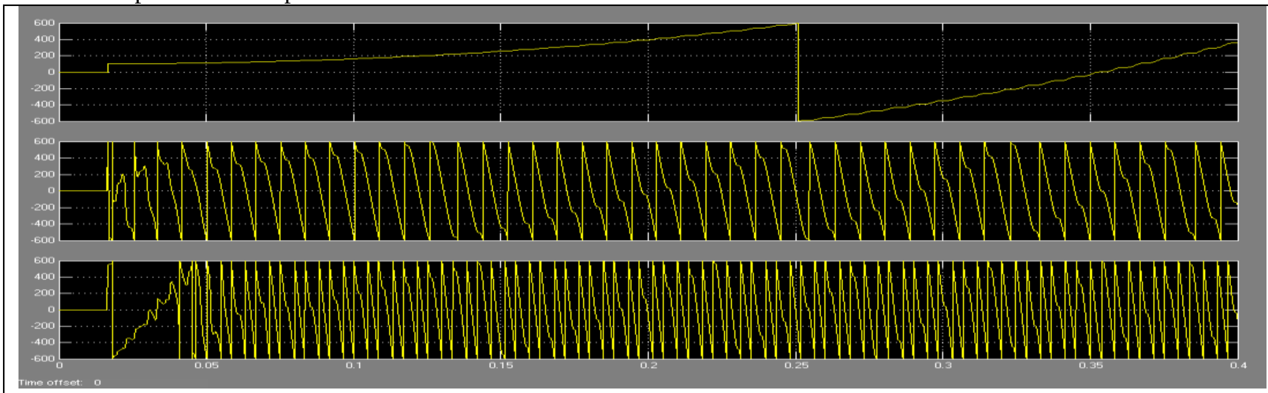
a: The first, third and fifth harmonics domain



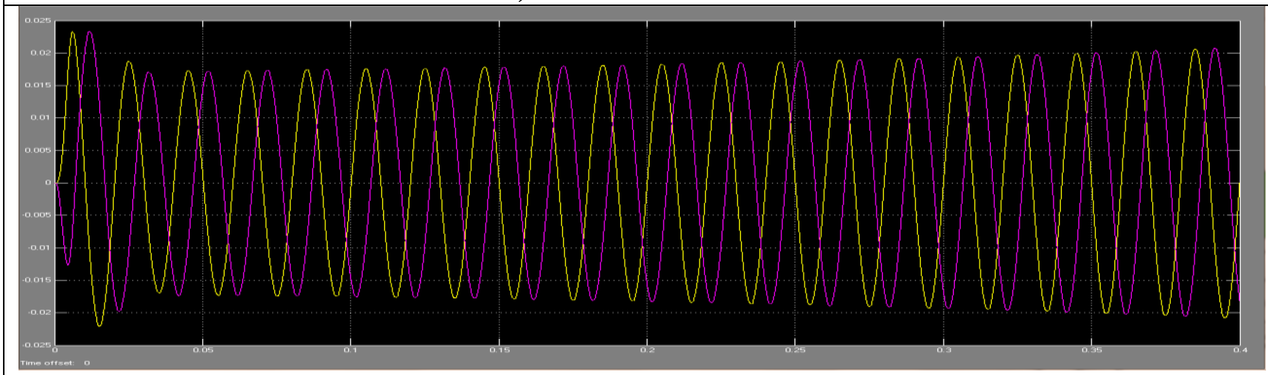
b : Output voltage waveform

B: Incremental wind speed

For the third and fifth harmonics amplitude increasing speed up to about the same variable-speed mode with a lot of the difference that the maximum amount of support to reach their fifth need more time there. Also, per domain still apply incremental speed oltaz output waveform is also desirable.



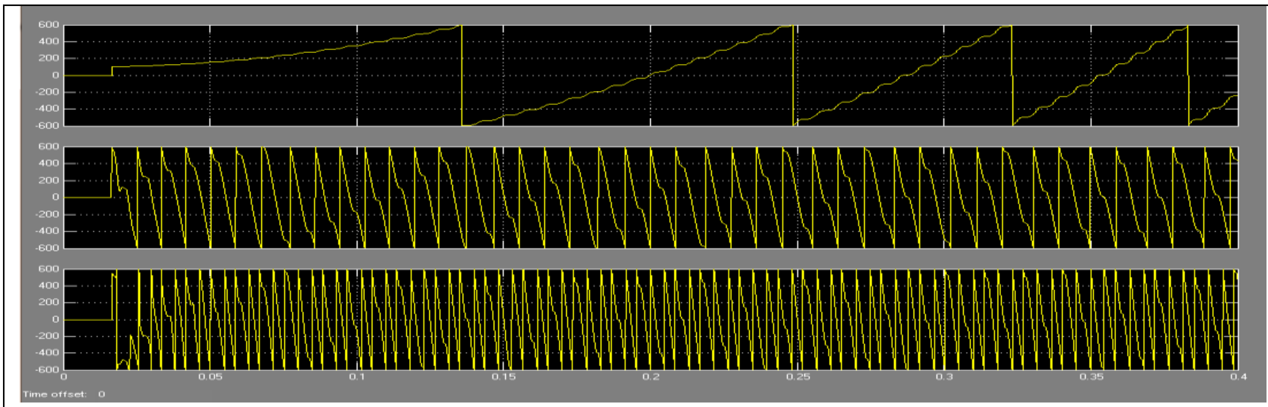
a: The first, third and fifth harmonics domain



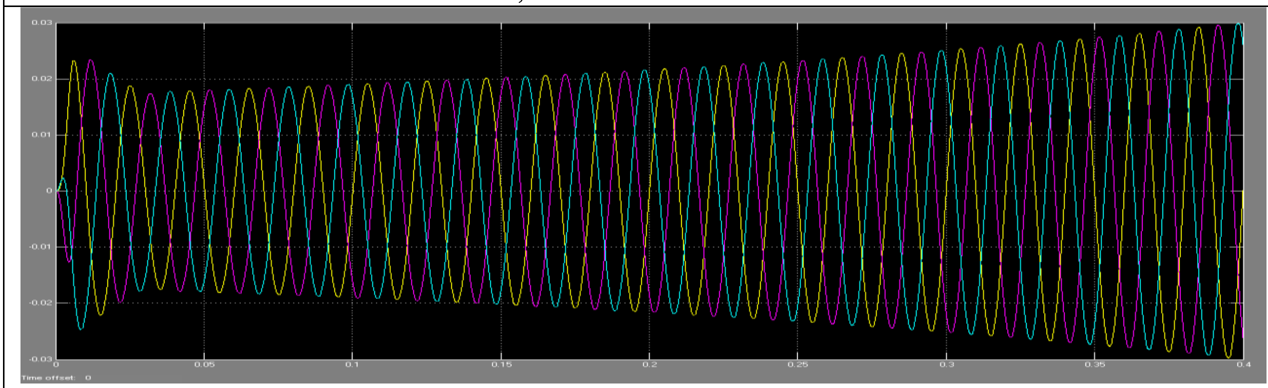
b : Output voltage waveform

C: Fixed wind speed

For the third and fifth harmonic range constant speed up to about a lot of different ways before and the first harmonic is also rated is wobbly. To apply for a fixed speed 19.4 m/s waveform output voltage over time with fluctuations in its domain and is also incremented.



a: The first, third and fifth harmonics domain



b : Output voltage waveform

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