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Design of Wind Energy System on the Building Tower Applications

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ABSTRACT: Renewable energy sources are placed vital Renewable system placed vital role in the electrical power generation due to reducing of fossil fuels. Wind energy system most popular generation in renewable system .wind turbine integrated with tower building more popular in wind energy system. . A wind energy conversion system differs from a conventional power system. The output of the generator depends up on the wind character so, where as the power output of a wind energy system on the wind character only. The appeal of integrating wind turbines in to our buildings is strong. Rooftops are elevated above ground, where it's winder: the electricity is generated right where it's needed: and wind energy can make a strong visual statement this nature of wind energy system makes it difficult for analysis, design and management. Various approaches have been developed to study the behavior of wind energy system. A valid choice for Operation of such systems may be the use of the induction machine. The study present power and torque characteristics of the wind energy system using the model of the induction machine with different pitch angle position applied different wind conditions. Induction generators driven with gear box and wind turbine system simulation results are developed in MATLAB for building tower applications.

KEYWORDS: Wind gear box, Induction generator, Variation with time, Wind turbine.

I. INTRODUCTION

Harnessing renewable alternative energy is the ideal way to tackle the energy crisis, with due consideration given to environmental pollution, that looms large over the world. Renewable energy is the energy which is from natural resources like solar, wind and wave energy. Renewable energy is also called "clean energy" or "green power" because it doesn't pollute the air or the water. Wind energy is one such renewable energy source that harnesses natural wind power. It proved a potential source for generation of electricity with minimal environmental impact; it is the fastest-growing source for electric power generation. Building towers is constructed depends on wind conditions only so on the tower surface the wind speed is nearly 75m/h to 90m/h. according to that wind speed generate wind power on tower. On the surface of the tower continuity wind flow happen so continuity power generation happen. The appeal of integrating wind turbines in to our buildings is strong. Rooftops are elevated above ground, where it's winder; the electricity is generated right where it's needed; and wind energy can make a strong visual statement. The wind industry pursued the significant economies of scale with larger turbines, leading to machines with output in the tens of kW, then hundreds of kW, then in the megawatt (MW) scale.

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Fig. 1 wind turbine system integrated with tower building

The wind industry pursued the significant economies of scale with larger turbines, leading to machines with best controllers. System design required knowledge of representative average wind conditions, as well as information on the turbulent nature of the wind. This information is used in the design of a wind turbine intended for a particular site, using aerodynamic principles; wind energy is converted into mechanical energy which is given as input to the induction generator. Wind energy system based on the wind characteristics. Variation of wind speed in time, Short-term wind speed variations of interest include ramp and gust. Show the output from an anemometer, shows the type of short term wind speed variations that nominally exist. Various approaches have been developed to study the behaviour of wind energy system.

A valid choice for Operation of such systems may be the use of the induction machine. The study present power and torque characteristics of the wind energy system using the model of the induction machine with different pitch angle position applied different wind conditions.

II. MODEL OF WIND SPEED

The model of the wind character is very important in particular location for design of wind turbine. The model of the wind should be able to simulate the temporal variations of the wind velocity, which consists of gusts and ramp wind speed changes shown in Fig.2 The wind velocity can be written as

$$V_W = V_{Wb} + V_{Wg} + V_{Wr} \quad (1)$$

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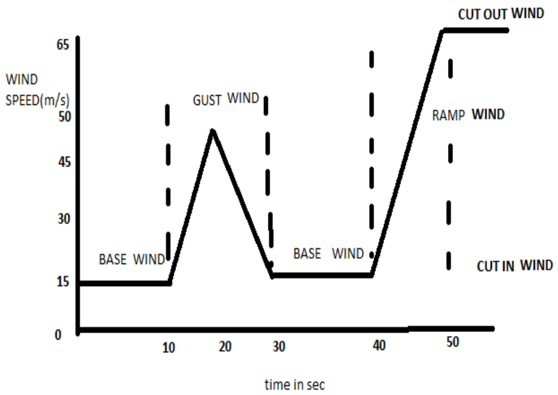

Fig.2 wind speed profile used for simulation

The cut in velocity- the wind speed at which the turbine starts to generate power, the cut out velocity-the wind speed at which the wind turbine is shut down to keep loads and generator power from reaching damaging levels, the rated velocity- the wind speed at which the wind turbine reaches rated turbine power. this is often but not always, the maximum power.

The base wind speed is a constant and is given by

$$V_{Wb} = C_1 \text{ (Constant)} \quad (2)$$

The gust component is represented as a (1-cosine) term and is given by

$$V_{wg} = \begin{cases} 0 & t < T_1 \\ C_2\left\{1 - COS\left[\Pi \dfrac{t - T_1}{T_2 - T_1}\right]\right\} & T_1 \le t \le T_2 \\ 0 & t > T_2 \end{cases} \quad (3)$$

C_2 is maximum value of the gust

T_2 is start time of the gust

T_2 is stop time of the gust

The rapid wind speed changes are represented by a ramp function and given by

$$V_{wr} = \begin{cases} 0 & t < T_3 \\ C_3\left[\Pi \dfrac{t - T_3}{T_4 - T_3}\right] & T_3 \le t \le T_4 \\ 0 & t > T_4 \end{cases} \quad (4)$$

C_3 is the maximum value of the ramp

T_3 is start time of the ramp

T_3 is start time of the ramp,

Equations (1) to (4) are used to model the wind characteristics and results are presented.

III. AERODYNAMIC MODEL

The wind turbine continuously extracts kinetic energy from the wind by decelerating the air mass, and feeds it to the generator as mechanical power. The aerodynamic model of the wind turbine is necessary because it gives a coupling between the wind speed and the mechanical torque produced by the wind turbine. The mechanical power (P_M), produced by the wind turbine rotor can be defined as above.

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The power captured by the turbine (P_M) can be expressed as

$$P_M = P_w * C_p(\lambda, \beta) \quad (5)$$

$$P_w = \frac{1}{2} * \rho * A * V^3 \quad (6)$$

$\rho = 1.225 kg/m^3$ (Sea level, 15^o)

$A = \pi * R^2$ (Area covered by the rotor blades)

C_P is commonly defined as a function of λ which is known as "tip speed ratio" and β is known as pitch angle expressed as follows

$$\lambda = (\omega * R)/V \quad (7)$$

IV. POWER COEFFICIENT WITH BETA

The relation between C_P and λ is normally established by the C_P / λ curve. This curve can be approximated using the power/wind curve, provided by wind turbine manufacturers.

$$C_P(\lambda, \beta) = C_1\left(\frac{C_2}{\lambda_i} - -C_3 * \beta - C_4\right) e^{-\frac{C_5}{\lambda_i}} + C_6 * \lambda \quad (8)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08 * \beta} - \frac{0.035}{\beta^3 + 1} \quad (9)$$

Where, The coefficients

$C_1 = 0.5176$, $C_2 = 116$, $C_3 = 0.4$

$C_4 = 5$, $C_5 = 21$, $C_6 = 0.0068$

V. TORQUE COEFFICIENT WITH BETA

The expression for torque is given by:

$$T_T = \frac{1}{2} * \rho * \pi * r^3 * V^2 * C_T \quad (10)$$

Where is the torque coefficient such as

$$C_T = \frac{C_P}{\lambda} \quad (11)$$

C_p and C_T are different for different types of turbines being their values depending on the aerodynamic characteristics of the turbine paddles. Figure1.2 represents a typical variation of C_T with respect to λ for a 3 paddle horizontal shaft turbine.

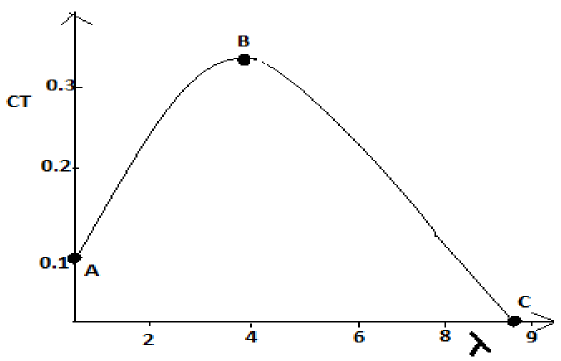

Fig.3 Relationship between Torque Coefficient and the Speed Tip Ratio

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Point **A** is the value of C_T to determine the starting torque for some typical condition of wind. The between points **A** and **B** is a region of un stability because if the resistant torque is increased due to an increase in the generator load, the speed will decrease tending to zero as well as C_T **'** the net torque. Between points **B** and **C**, for a decreased turbine speed, there will be an increase in C_T and in the net torque, tending so to stabilize the whole system. C_T Is a maximum on point B for a maximum efficiency and maximum power transfer from the wind to the turbine in this way it is important that the turbine operates as close to this point or to its right as possible there are several methods of load control used to maximally convert wind energy into electrical energy [8**].**

These tests can be nicely tested with the turbine generator once this one follows identical torque variation of the actual turbine. Variation of speed, power and torque as function of pitch angle and tip speed ratio presented.

VI. **GEAR BOX**

The gearbox is used to step up the low angular speeds of the turbine (normally about 25-30rpm) to the high rotational speeds of the generator (normally around 1800 rpm)

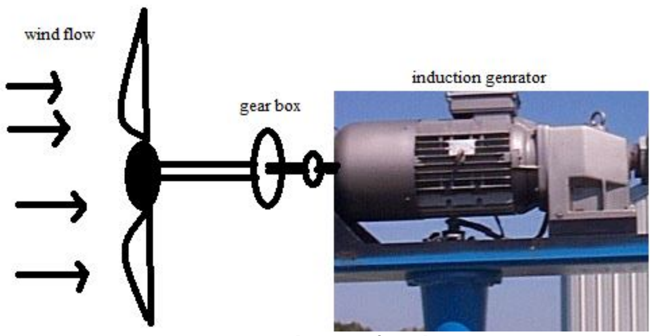

Fig. 4 side view of wind energy system

$$T_t - T_{s1} = J_t \frac{d\omega_b}{dt} \tag{12}$$

$$T_{S2} - T_e = J_r \frac{d\omega_r}{dt} \tag{13}$$

Assuming that the gearbox is ideal, with no backlash or losses and assuming that the shafts are rigid, [5]

$$\frac{T_{S1}}{T_{S2}} = \frac{\omega_r}{\omega_r} = \frac{n_1}{n_2} = g_r \tag{14}$$

$$\frac{d\omega_r}{dT} = \frac{1}{J}\left[T_t\left(\frac{n_2}{n_1}\right) + J_r\right] \tag{15}$$

Where, $J = \left[J_t\left(\frac{n_2}{n_1}\right)^2 + J_r\right]$

VII. **MODEL OF 3 -PHASE INDUCTION MACHINE**

As the wave period and period with which the wave height varies from time to time, are both quite large compared to the electrical time-constants involved, per phase steady state equivalent circuit of a 3-phase induction machine is used (Figure1.4).[9]

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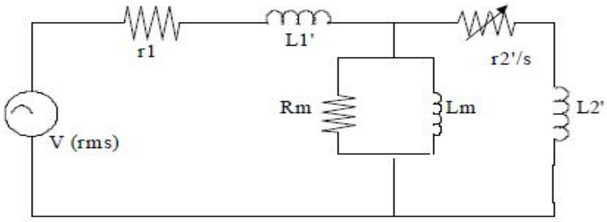

Fig.5 Per phase, steady state, exact equivalent circuit of a 3-phase induction machine

Where,
V = Per phase source voltage in rms volts
r_1 =Per phase stator resistance in ohm
L_1^1 =Per phase stator leakage inductance in henrys
r_2' =Per phase rotor resistance referred to stator side
L_2^1 =Rotor leakage inductance referred to stator side
R_m =Resistance equivalent of the core losses in ohm
L_m = Magnetization inductance of stator in henrys

Slip of the induction machine is given by:

$$s = \frac{\omega_S - \omega_r}{\omega_s} \tag{16}$$

Where,
ω_S = Synchronous speed of the induction machine
ω_r = Actual speed of the induction machine.

Whenever $\omega_S > \omega_r$ the slip is positive which means the induction machine acts as a motor and if $\omega_S < \omega_r$, slip is negative and the induction machine acts as a generator. The following equations are used for the modeling of the induction machine

$$Z_1 = r_1 + jX_1 \tag{17}$$

$$Z_2{}^1 = \left(\frac{r_2{}^1}{s}\right) + jX_1{}^1 \tag{18}$$

$$Y_m = \left(\frac{1}{R_m}\right) - j\left(\frac{1}{X_m}\right) \tag{19}$$

Therefore series impedance immediately after Z_S can be given as

$$Z_s = \left(\frac{1}{Z_2'} + Y_m\right)^{-1} \tag{20}$$

The net impedance faced by the source per phase is given as

$$Z = Z_1 + Z_S \tag{21}$$

Stator per phase current

$$I_S = \frac{V}{Z} \tag{22}$$

Rotor per phase voltage referred to the stator

$$E_{ph} = V - (I_S * Z_1) \tag{23}$$

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Rotor per phase current referred to the stator,

$$I_r' = \frac{E_{ph}}{Z_2'} \tag{24}$$

Power given to the rotor,

$$P_g = \left(3 * I_r' * I_r' * Z_2'\right) + j_O \tag{25}$$

Gross torque produced by rotor

$$T_g = \frac{p_g}{\omega_s} \tag{26}$$

Input active power taken by 3 phase induction machine

$$P_{in} = \left(3 * V * I_S\right) + jo \tag{27}$$

VIII. SIMULATIONRESULTS

The simulation studies are performed using MATLAB/SIMULINK.

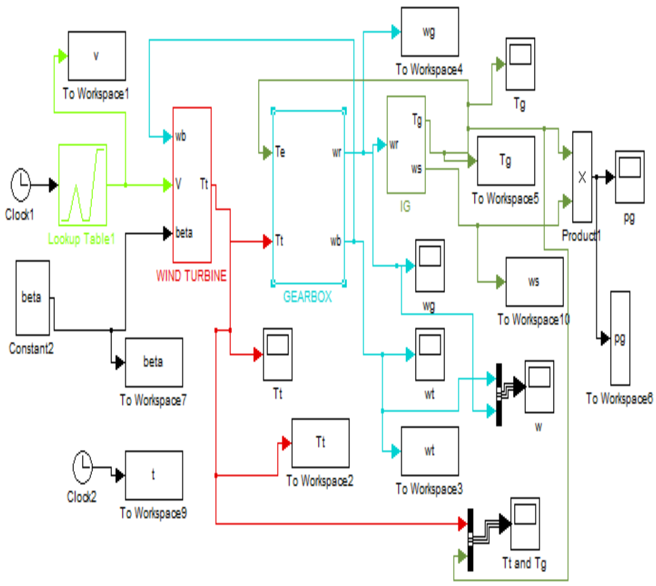

Fig.6 simulation block of wind energy system.

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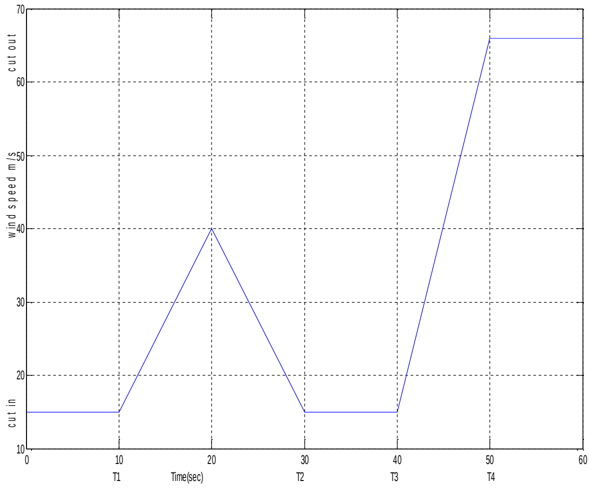

Fig.7 time vs wind speed

In the above fig.7, location wind speed with base wind, gust wind and ramp wind characteristic is mentioned with respect to time change. This character is the input of turbine.

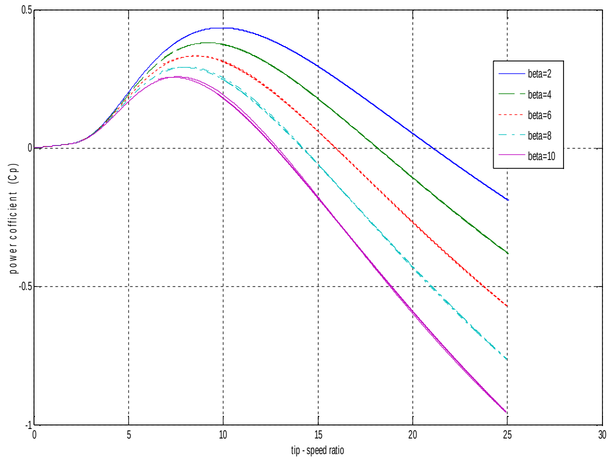

Fig .8 tip speed vs power cofficient

When the pitch angle changes the power coefficient also changes, shown in fig.8.maximum power coefficient at two degrees pitch angle and minimum at ten degrees pitch angle.

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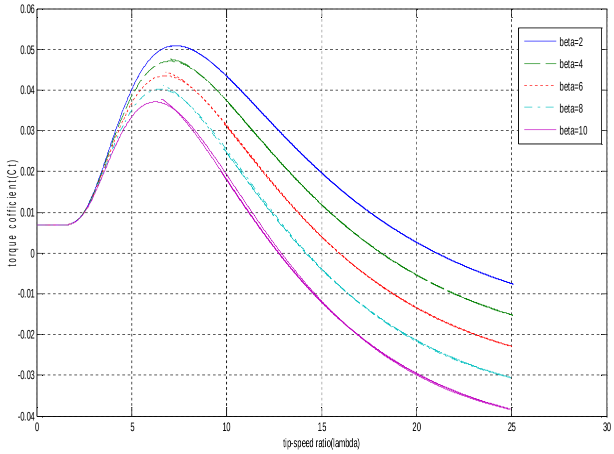

Fig .9 tip speed vs. torque coefficient

When the pitch angle changes the torque coefficient also changes, shown in fig.9.maximum torque coefficient at two degrees pitch angle and minimum at ten degrees pitch angle .

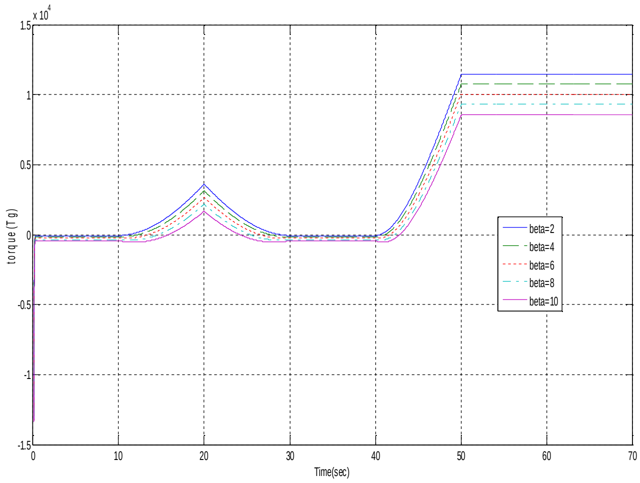

Fig.10 time vs. torque of generator

When the pitch angle changes the torque of the generator also changes, shown in fig.10.maximum power at two degrees pitch angle and minimum at ten degrees pitch angle.

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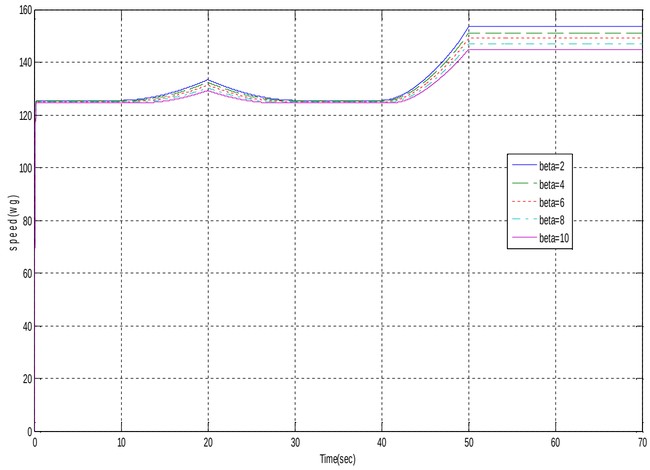

Fig.11 time vs speed of genrator

When the pitch angle changes the power of the generator also changes, shown in fig .11.maximum power at two degrees pitch angle and minimum at ten degrees pitch angle.

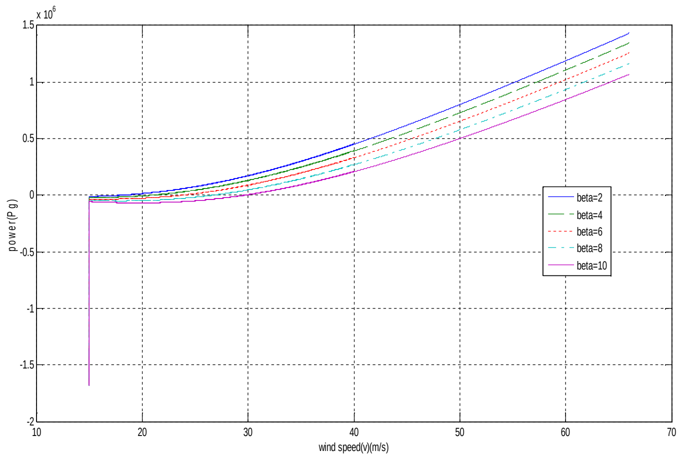

Fig 12 wind speed vs power

When the pitch angle changes the power of the generator also changes, shown in fig12.maximum power at two degrees pitch angle and minimum at ten degrees pitch angle. Generator output also depends on wind speed so that power generation starts from cut in wind speed and stops from cut out wind speed.

IX. CONCLUSION

The wind establishment in any location is based on the wind characteristics. For the wind model that was used in this project, the maximum power that can be generated is 1.5MW. The maximum power generation occurs at maximum power coefficient. From the studies, it is concluded power and torque variation of induction generator by varying pitch angle of the wind turbine. Above results applicable for tower building applications and design of the wind energy system performed using MATLAB/SIMULINK.

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