International Journal of Engineering and Techniques - Volume 4 Issue 2, Mar-Apr 2018

RESEARCH ARTICLE OPEN ACCESS

Analysis of Pitch Angle Variation in Asynchronous Generator Wind Turbine

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Abstract:

This paper presents the analysis of pitch angle variation in Asynchronous generator wind turbine. The asynchronous generator wind turbine model consists of wind turbine profiles which attribute to the mechanical power and torque characteristics of wind turbine. The simulation model for Asynchronous generator wind turbine has been developed using a MATLAB/SIMULIK. The Asynchronous generator wind turbine model can work as induction generator. The wind turbine simulation model can display generated power and their values changes according to the wind velocity. The torque from the wind turbine simulator can be used to drive the asynchronous generator to generate the power fed into the load. The asynchronous generator wind turbine was tested upon step changes in the wind velocity as well as the blade pitch angle requirement of for power control. Simulation results obtained are encouraging.

Keywords — **Wind energy, MATLAB/SIMULINK, pitch angle, induction generator, Wind velocity, Turbine power, Power coefficient, Tip speed ratio, Generator, Grid.**

I. INTRODUCTION

Wind energy is one of the fastest growing renewable energies in the world. Wind as a source of power is very attractive because it is plentiful, inexhaustible, renewable and non-polluting. in recent years, due to decreases in fossil fuels, the energy shortage and environment pollution has affected the lives of the humans and social development. Conventional energy such as coal, oil and gas will be used out in a few years and will cause serious environmental problems. so the renewable energy, especially wind energy and solar energy have become more considerable all over the world *[1]*. a wind turbine is a rotary device that extracts energy from the wind and converts into rotary mechanical energy. Conventional wind energy is divided into three components. The first is the rotor which consists of two or three fibre glass blades joined to a hub that contains hydraulic motors that change each blade according to prevailing wind conditions so that the turbine can operate efficiently at varying wind speeds. the nacelle sits atop the tower and holds all the turbine machinery. Because it must be able to rotate to follow the wind direction, it is connected to the tower via bearings. the nacelle is the housing that protects the main frame and the components attached to it. the structural tower supports the rotor and the nacelle. The kinetic energy in the wind is converted into mechanical energy by the turbine shaft and gearbox arrangement because of the different operating speed ranges of the wind turbine rotor and generator. the generator converts this mechanical energy into electrical energy. The mechanical power obtained can be used to perform important tasks such as grinding of grain or pumping of water. the electricity generated can be used in daily life activities such as power homes, schools, hospital, industries, businesses etc *[4]*.as the wind penetration increases, the structure and dynamics of the power system network will change significantly over the coming decades. due to the intermittent nature of wind power, the replacement of traditional synchronous generators with power electronic converter-based synchronous generators will introduce special challenges in; grid interconnections and bi-directional power control, tight voltage and frequency regulation, dynamic stability, low voltage fault ride through, satisfy grid code, system security, reliability, and protection. Therefore, a better understanding of the technology involved with the grid integration of the variable speed wind turbines and possible impacts of large scale wind integration to the power grid is mandatory to ensure reliable and secure operation of the power system[8].

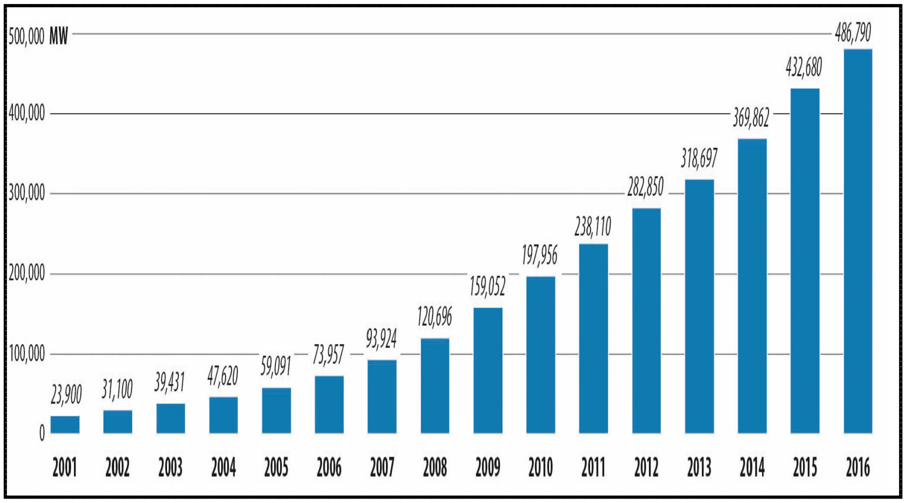

FIG. 1 : GLOBAL WIND POWER CUMULATIVE CAPACITY (2001-2016)

II. WIND TURBINE COMPONENTS

Wind turbines are designed to exploit the wind energy that exists at a location. Aerodynamic modelling is employed for determination of optimum tower height, control systems, number of blades and blade shape. Conventional horizontal includes the blades can be divided into three components. The rotor component includes the blades for converting wind energy to low speed rotational energy and costs about 20% of the total cost of wind turbine. The generator component includes the electrical generator, the control electronics and most likely a gearbox for converting the low speed incoming rotation to high speed rotation suitable for generation of electrical energy. it approximately costs about one- third of total cost of wind turbine. The structural support component includes the tower and rotor yaw mechanism and costs about 15% of the wind turbine cost. Other equipment's including electrical cables, ground support equipment and interconnection equipment.

III. WIND TURBINE OUTPUT EQUATION

The actual power output of a wind turbine generator (WTG) system depends on the actual wind speed, rated wind speed, cut in speed (i.e., speed at which system losses equal the extracted wind power) and cut out speed (i.e. speed at which the wind mill has to be shut down for safety reasons.) The power output can be approximated by the relation [6].

Actual power output $= 0$ for $0 < \nu < \nu_{ci}$

$= (A + B\nu + c\nu^2)\, p_r$ for $\nu_{ci} < \nu < \nu_r$ ……….1

$= P_r$ for $\nu_r < \nu < \nu_{co}$

$= 0$ for $V > V_{co}$

Where ν = actual wind speed

P_r = rated power output

ν_{ci}= cut in wind speed

ν_r = rated wind speed

ν_{co} = cutout wind speed

A, B, C are functions of ν_{ci} and ν_r

Fig.3 shows three circular at inlet, turbine blade and exit of wind

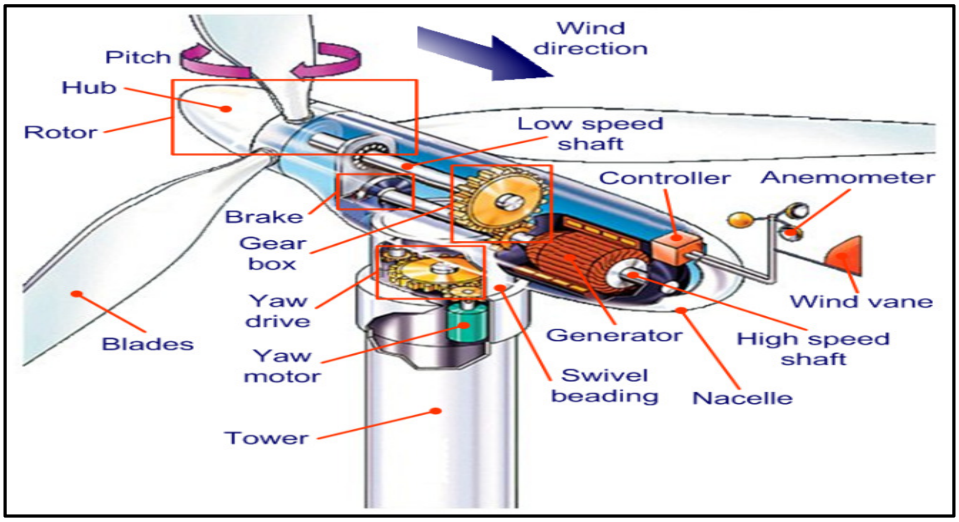

Fig. 2 : General Layout of Wind Turbine

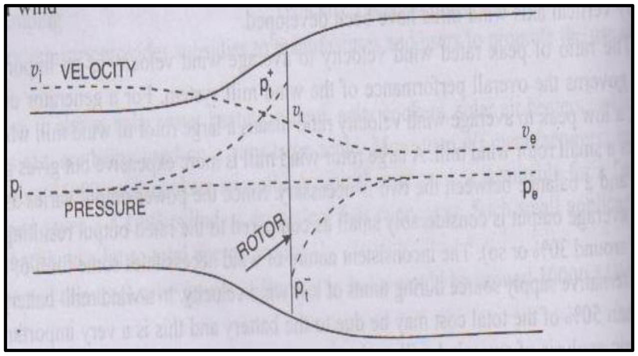

Fig.3 : Energy Extraction by Wind Turbine Rotor [6]

Let A_i = area at inlet, m^2

A_t = area at turbine rotor, m^2

A_e = area at exit, m^2

ν_i = wind velocity at inlet, m/s

ν_t = wind velocity at turbine rotor, m/s

ν_e = wind pressure at exit,m/s

p_i = wind pressure at inlet, N/m^2

p_e = wind pressure at exit, N/m^2

p_t^+ = wind pressure at rotor upstream, N/m^2

P_t^- = wind pressure at rotor downstream, N/m^2

ρ = density of air, kg/m^3

The mass flow rate must be the same across the three areas i.e. inlet, turbine rotor and exit. Therefore

$\rho A_i \nu_i = \rho A_t \nu_t = \rho A_e \nu_e$ ……….2

The rotor induces a velocity variation which is superimposed on the free stream velocity. The induced flow at rotor is – a ν_i where 'a' is called the axial flow induction factor. Therefore

$\nu_t = \nu_i(1 - a)$ ………..3

The air undergoes a change in velocity $\nu_i - \nu_e$ from inlet to exit. The rate of change of momentum is equal to mass flow rate multiplied by change of velocity. Therefore

Rate of change of momentum = $(\nu_i - \nu_e) \rho A_t \nu_t$ ……….4

The force which causes change of momentum is due to pressure difference across the rotor. The change in pressure is form p_t^+, to p_t^-,. Therefore

$(p_t^+ - p_t^-) A_t = (\nu_i - \nu_e) \rho A_t \nu_i = (\nu_i - \nu_e) \rho A_t \nu_i (1-a)$ ……….5

To find $(p_t^+ - p_t^-)$ we can use Bernaulli's equation. As per Bernaulli's equation, under state conditions the total energy in the flow (i.e. sum of kinetic energy, static pressure energy and gravitational potential energy) remains constant provided no work is done on or by the fluid. Thus for a unit volume of air

$$\frac{1}{2}\rho v^2 + p + \rho gh = \text{constant} \qquad \text{..........6}$$

Upstream conditions give

$$\frac{1}{2}\rho_i v_i^2 + p_i + p_i g h_i = \frac{1}{2}\rho_t v_t^2 + p_t^+ + \rho_t g h_t \qquad \text{..............7}$$

Assuming the flow to be incompressible ($\rho_i = \rho_t$) and horizontal ($h_i = h_t$) we get

$$\frac{1}{2}\rho v_i^2 + p_i = \frac{1}{2}\rho v_t^2 + p_t^+ \qquad \text{.............8}$$

Downstream conditions give

$$\frac{1}{2}\rho v_e^2 + p_i = \frac{1}{2}\rho v_t^2 \qquad \text{...........9}$$

Subtracting Eq. (9) from Eq. (8)

$$p_t^+ - p_t^- = \frac{1}{2}\rho(v_i^2 - v_e^2) \qquad \text{..........10}$$

Subtracting Eq. (10) into Eq. (5) we get

$$\frac{1}{2}\rho(v_i^2 - v_e^2) A_t = (v_i - v_e)\rho A_t v_i (1-a) \qquad \text{.....11}$$

Eq. (11) gives

$$v_e = (1-2a) v_i \qquad \text{...........12}$$

Thus half of axial speed loss occurs upstream of rotor and half downstream. From Eq. (5) the force F on air is

$$F = (p_t^+ - p_t^-) A_t = 2\rho A_t v_i^2 a(1-a) \qquad \text{..........13}$$

The rate of work done by force F is F v_t. The power extracted from air is P_t and is given by

$$P_t = Fv_t = 2\rho A_t v_i^3 a(1-a)^2 \qquad \text{..........14}$$

Power coefficient C_p is defined as

$$C_p = \frac{P_t}{\frac{1}{2}\rho v_i^3 A_t} \qquad \text{..........15}$$

In Eq. (15), $\frac{1}{2}\rho v_i A_t$ represents power available in air.

Combining eq. (14) and (15)

$$C_p = 4a(1-a)^2 \qquad \text{..........16}$$

For maximum value of C_p, $\frac{dC_p}{da}$ should be zero.

$$C_p = 4a(1-a)^2 = 4a(1+a^2 - 2a)$$

or $C_p = 4a^3 - 8a^2 + 4a$

$$\frac{dC_p}{da} = 12a^2 - 16a + 4 = 0$$

or $3a^2 - 4a + 1 = 0$

Which gives $a = \frac{1}{3}$ 17

Therefore

$$C_{p.\max} = 4\left(\frac{1}{3}\right)\left(1 - \frac{1}{3}\right) = \frac{16}{27} = 0.593 \qquad \text{......18}$$

This means that an ideal turbine cannot extract more than 59.3% of power in the undisturbed wind. This is known as Betz Criterion (named after German aerodynamicist Albert Betz)[6].

IV Simulation Results for Asynchronous Generator wind Turbine Model

Study is done by keeping following parameters as

Fixed parameters = pitch angle in degree, Variable parameter = Wind speed in meter per second (m/s). The value of power for asynchronous generator wind turbine model is shown in Table-1.

Table-1 : Simulation Results of Generated Power (P) in Watts for Asynchronous Generator Wind Turbine Model

Wind Speed (m/s)	P at Pitch angle =7	P at Pitch angle =8	P at Pitch angle =9	P at Pitch angle=10	P at Pitch angle=11	P at Pitch angle=12
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	-74.4	-77.79	-81.09	-85.41	-88.2	-90.94
2	-15.01	-26.55	-40.84	-55.01	-67.56	-82.31
3	215.2	193.9	172.6	149.9	126.7	102.4
4	518.3	497.2	476.1	453	427.5	401.3
5	797.1	787.5	775.9	761	743.8	724
6	1007	1015	1021	1023	1022	1016
7	1142	1172	1200	1223	1243	1258
8	1219	1271	1320	1367	1410	1449
9	1260	1330	1400	1468	1533	1596
10	1286	1369	1455	1541	1627	1712
11	1312	1404	1501	1602	1705	1809
12	1348	1445	1549	1660	1775	1896
13	1402	1499	1606	1723	1848	1980
14	1476	1570	1677	1796	1928	2069
15	1569	1660	1764	1884	2018	2165
16	1683	1768	1868	1986	2120	2271
17	1814	1893	1989	2104	2237	2389
18	1963	2036	2126	2236	2367	2520
19	2127	2194	2278	2384	2511	2663
20	2305	2366	2445	2545	2669	2818
21	2495	2551	2624	2719	2839	2985
22	2697	2748	2816	2906	3021	3164
23	2909	2955	3018	3103	3215	3354
24	3132	3174	3231	3311	3417	3554
25	3362	3400	3453	3528	3630	3761

V Graphically Representation of AGWT- Model Result

The graphs between power and wind speed for asynchronous generator wind turbine model are shown in figures 4 to 9.

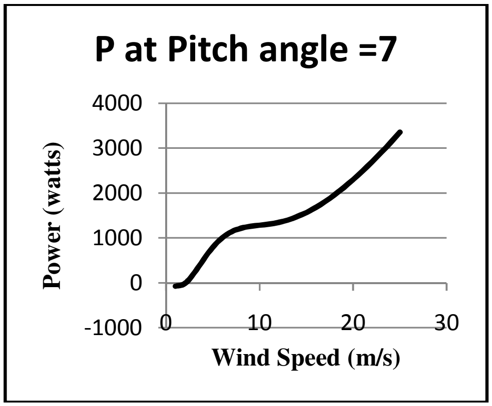

Fig.4 : Power v/s Wind Speed Curve

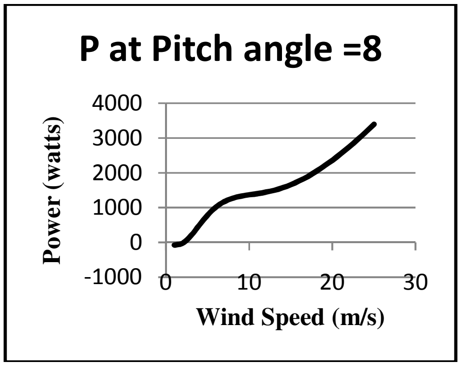

Fig. 5 : Power v/s Wind Speed Curve

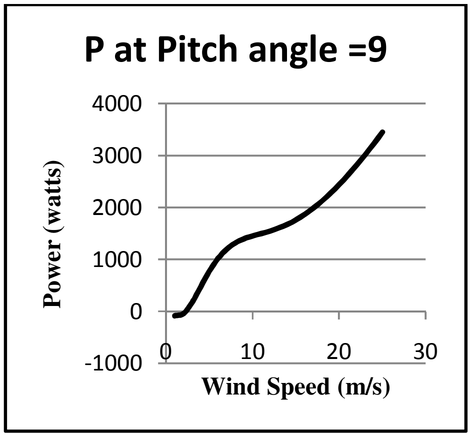

Fig. 6 : Power v/s Wind Speed Curve

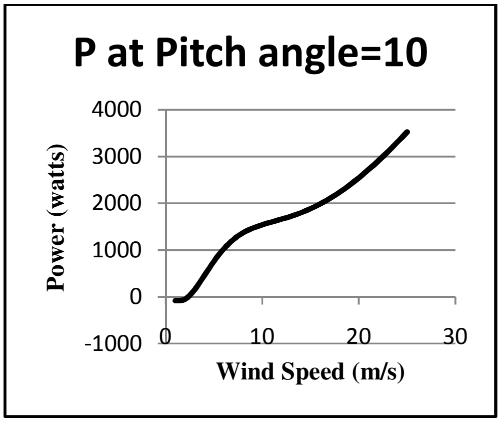

Fig. 7 : Power v/s Wind Speed Curve

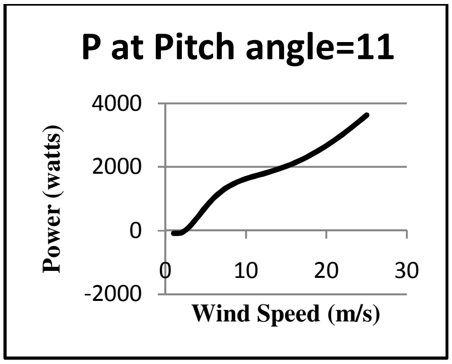

Fig. 8 : Power v/s Wind Speed Curve

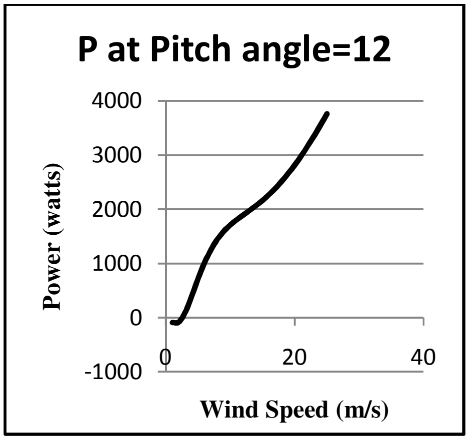

Fig. 9 : Power v/s Wind Speed Curve

VI. CONCLUSION

This paper has presented the simulation of Asynchronous generator wind turbine model by using a MATLAB/Simulink. Variable values of power are obtained for fixed pitch angle and different wind speed. This paper gives the brief description of the output characteristics of wind turbine as well as asynchronous generator. Also describes the effect of changes the value of wind speeds and pitch angle on output characteristics. This Asynchronous generator wind turbine Model is designed to give maximum power at different values of pitch angle and wind speed.

REFERENCES

1. *Phlearn Jansuya and Yuttana Kumsuwan, "Design of MATLAB/Simulink Modeling of Fixed-Pitch Angle Wind Turbine Simulator", Sciversa ScienceDirect, Energy Procedia , August, 2013.*
2. *Jasmin Martinez, "Modeling and Control of Wind Turbines", Department of Chemical Engineering and Chemical Technology, Imperial College, London, September 21, 2007.*
3. *A. Honrubia-Escribano, F. Jiménez-Buendía, A. Molina- García, J.A. Fuentes-Moreno, E. Muljadi, and E. Gómez- Lázaro, "Analysis of Wind Turbine Simulation Models: Assessment of Simplified versus Complete Methodologies", ISEF 2015 – XVII International Symposium on Electromagnetic Fields in Mechatronics, Electrical and Electronic Engineering Valencia, Spain, September 2015.*
4. *A. W. Manyonge, R. M. Ochieng, F. N. Onyango, and J. M. Shichikha,"Mathematical Modelling of Wind Turbine in a Wind Energy Conversion System: Power Coefficient Analysis", Applied Mathematical Sciences,Vol.6,June 2012.*
5. *D.johra Saheb-Koussa, Mourad Haddadi , Maiouf Belhamel, Mustapha koussa &Said noureddine, "Modeling and simulation of windgenerator with fixed speed wind turbine under Matlab-Simulink", Sciversa ScienceDirect, Energy Procedia 18, November 2012.*
6. *Mujaddin Morshed Chowdhury, "Modelling and Control of Direct Drive Variable Speed Wind Turbine with Interior Permanent Magnet Synchronous Generator", PhD Thesis, University of Tasmania, June 2014.*
7. *Makbul Anwari, "Modeling and Simulation of Grid-Connected PV/Wind Power System", Jordan International Energy Conference, Amman 2011.*
8. *Deepak Bohra, M.K.Bhaskar, Dharmendra Jain, Manish Parihar, "Modelling and Simulation of Asynchronous Generator Wind Turbine for Different Wind Speed", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 10, October 2017.*
9. *Deepak Bohra, M.K. Bhaskar, Dharmendra Jain, Manish Parihar, "Performance Based Comparison of Asynchronous Generator Wind Turbine Model and Permanent Magnet Synchronous Generator Wind Turbine Model", IJSART, ISSN [ONLINE]: 2395-1052, Volume 3 Issue 11 – NOVEMBER 2017.*
10. *Deepak Bohra, M. K. Bhaskar, Dharmendra Jain, Manoj Chouhan, Vishvendre Prasad Goyal, "Performance Analysis of Permanent Magnet Synchronous Generator Wind Turbine for Variable Wind Velocity", International Journal for Research in Applied Science & Engineering Technology (IJRASET)ISSN: 2321-9653; IC Value: 45.98; SJ , Volume 6 Issue I, January 2018.*