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A Comparative Performance analysis of ENERCON 3MW E-82 E3 Wind Generator for Vijaydurg, Chalkewadi and Pachgani location of Maharashtra, India

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***Abstract*:** *ENERCON manufacturer-specific Units of wind turbines are favoured for use in wind power interconnection studies. Certain manufacturer specifications are mentioned in datasheet like Wind Power curve, Power coefficient (Cp), Rated Power, rotor diameter, Hub height Swept area, Cut in, rated and cut-out Wind velocities. The primary objective of the work is to perform comparative performance analysis of ENERCON 3MW E-82 E3 Wind Generator for Vijaydurg, Chalkewadi and Pachgani location of Maharashtra.Wind Power Output under variable speed condition, actual power developed by wind generator, power coefficient (Cp), Power developed by rotor (Pr) and aerodynamic torque developed by wind turbine is calculated on the basis of mathematical modelling of Wind generator in Matlab. The best suitability ofENERCON 3MW E-82 E3 Wind Generator is evaluated on above mentioned performance indices for the locations detailed above.*

***Keywords*:** *Power coefficient (Cp),Power developed by rotor (Pr), Wind Energy Conversion System (WECS), Hourly Mean Wind Speed(HMWS)*

I. Introduction

A quick glance at the electrification world map will show that rural areas are in great need of affordable and reliable electricity to achieve development. Likewise, an overview through the most important literature on rural electrification will prove that renewable energies (RES) are one of the most suitable and environ-mentally friendly solutions to provide electricity within rural areas.

Over the last years the wind systems became the fastest developing renewable energy technology.
There are three main factors which determine the power output of a whole wind energy conversion system (WECS), i.e., the Wind Power Curve of a chosen wind turbine, the wind speed distribution of a selected site where the wind turbine is to be installed, the hub height of the wind tower, power coefficient (Cp), Power developed by rotor (Pr) and aerodynamic torque.

Wind turbine power production depends on interaction between the wind turbine rotor and the wind. The mean power output is determined by the mean wind speed, thus only steady-state aerodynamics has been considered and turbulence has been ignored. The first aerodynamic analyses of wind turbines were carried out by Betz and Glauert in the late 1920s and early 1930s. Betz proved that the maximum power extractable by an ideal turbine rotor with infinite blades from wind under ideal conditions is 59.26% (0.5926 times) of the power available in the wind. This limit is known as the Betz limit.The ratio of extractable power to available power is expressed as the rotor power coefficient Cp.The tip-speed ratio or TSR, denoted by λ, is the ratio of the blade-tip linear speed to the wind speed. The impact of all the above parameters on the performance of ENERCON 3MW E-82 E3 Wind Generator for Vijaydurg, Chalkewadi and Pachgani location of Maharashtra is analysed thoroughly in this paper considering the wind speed data for these locations and mathematical equations pertaining to Wind Power Generation dynamics.

II. Enerocon Turbine Technology

ENERCON's rotor blade concept has set new standards in the wind energy sector. Due to their modified shape, the blades not only draw energy from the outer edges of the swept area but also make more efficient use of the inner radius considerably increasing power output. The new rotor blades are also less susceptible to turbulence and provide an even flow of air along the entire length of the blade profile. The blade tips have also been improved to reduce noise emission and increase power output. Turbulence at the blade tips caused by over and under pressure is effectively eliminated in the rotor plane. The entire length of the blade is therefore utilised without energy loss resulting from turbulence. In order to withstand extreme wind loads during the entire lifespan of the machine, ENERCON rotor blades are engineered with a large flange root. The double-row bolt connection specially developed by ENERCON for large wind turbines also provides additional strength by creating even load distribution. The safety of turbines with longer rotor blades is further enhanced by sensors at the blade root, enabling the turbine to react to extreme loads. These are important factors, particularly in locations with extreme wind and considerable load fluctuations. ENERCON rotor blades are manufactured using a vacuum infusion system and the so-called sandwich technique. In a final step, the rotor blades are finished with a special coating in order to efficiently protect their surface from weathering.

III. Enercon Direct Drive System

Fewer rotating parts reduce mechanical stress and increase the machine ́s lifespan . Wind turbinemaintenance and service

Fig.1:Cross Sectional view of Wind Generator

costs are reduced (fewer wearing parts, no gear oil change, etc.) and operating expenses lowered. The rotor hub and the rotor of the annular generator are directly interconnected to form one consolidated unit. The rotor unit is mounted on a fixed axis, the so-called axle pin. Unlike conventional geared systems with a large number of bearing points in a moving drive train, ENERCON's drive system only requires two slow-moving rolling-element bearings; the reason being its low direct drive speed

Fig.2: Magnified View of Stator Winding

IV. Annular Generator Technology

Amongst other features, the annular generator is a key component in ENERCON's gearless wind generator design. Combined with the rotor hub, it provides an almost frictionless flow of energy, while a smaller number of moving components ensure minimum material wear. Unlike conventional fast-running generators, ENERCON's annular generator is subjected to little mechanical wear, making it ideal for particularly heavy loads and guaranteeing a long service life. It is a low-speed synchronous generator with no direct grid coupling. Output voltage and frequency vary with the speed and are converted for output to the grid via a DC link and inverter which allow for high speed variability.

Stator and rotor:

According to ENERCON's service life requirements, the copper winding in the stator (the stationary part of the annular generator) is produced in insulation class F (155 °C). Because this resembles basket weaving, it is also called closed, single-layer basket weaving. It consists of individual varnish-insulated round wires gathered together in bundles. At ENERCON, the copper winding is exclusively done by hand. In spite of increasing automation in other manufacturing areas, there is a good reason for relying on manual labour in this instance. It ensures that all materials are thoroughly inspected. Furthermore, a special work process allows continuous windings to be produced. Each individual wire strand is continuous from start to end. ENERCON wind energy converters are based on a gearless turbine design that uses an annular generator with separates excitation. The magnetic fields required to generate electrical power are created electrically, so permanent magnets containing the controversial rare earth element neodymium can be dispensed with. The magnetic field of the stator winding is excited by means of the so-called pole shoes. These are on the rotor – the rotating part of ENERCON´s annular generator. Since the shape and position of the pole shoes have a decisive influence on the generator's noise emission, ENERCON´s Research & Development department has devoted particular attention to this aspect. Because the pole shoes are precisely adapted to the slow rotation of ENERCON's annular generator, there is virtually no tonal noise.

V. Resource Inputs To Wind Generator

1. Site Details

Sr .No	Name Of Location	Latitude	Longitude
1	Vijaydurg	16° 52´	73° 28´
2	Chalkawadi	17° 52´	73° 77´
3	Pachgani	17° 82´	73° 77´

2. Hourly Mean Wind Speed(HMWS)

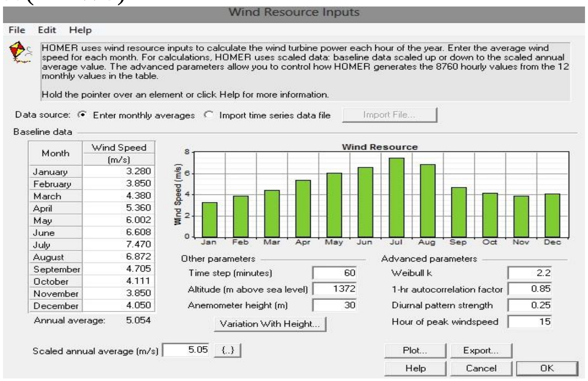

Fig.3: Wind Speed variation for Panchgani

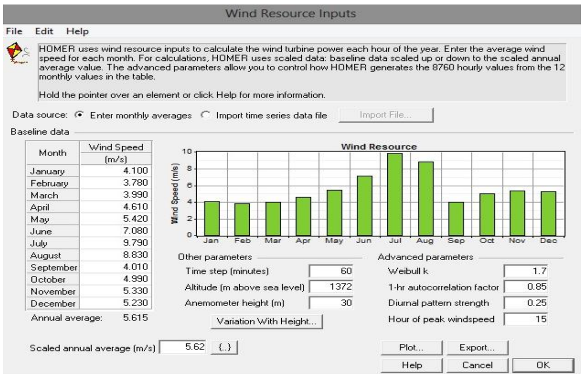

Fig.4: Wind Speed variation for Chalk wadi

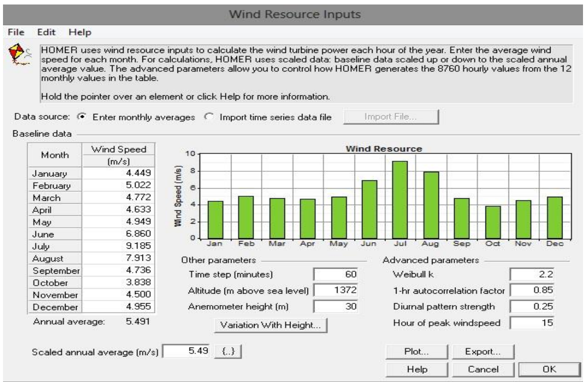

Fig.5 Wind Speed variation for Vijaydurg

3. 2. ENERCON 3MW E-82 E3 WIND GENERATOR SPECIFICATIONS

Specifications	**Ratings**
Rated Power	3MW
Rotor diameter	82m
Hub Height	78m/85m/98m/108m/138m
Swept Area	5281 sq.m
Rotational Speed	6-18.5rpm
Cutout Wind Speed	28-34 m/sec

VI. Mathamatical Modelling Equations

$v(t) = v_r(t).(\frac{h}{h_r})^{\gamma}$ (i)

Where:

- v is the wind speed at projected height h,
- vr is wind speed at reference height hr ,
- γ is the power-law exponent (~1/7 for open land).
- In function of this wind speed, the model used to calculate the output power, PWT(t) (W), generated by the wind turbine generator is as follows:

$a.v^3(t) - b.P_R v_{ci} < v < v_r$ (ii)

$P_{WT}(t) = P_R v_r < v < vc0$ (iii)

Where,

$a = \frac{P_r}{(v^3{}_r - v^3{}_{ci})}$ (iv)

$b = \frac{v^3{}_{ci}}{(v^3{}_r - v^3{}_{ci})}$ (v)

Pr is the ratedpower, vci, vr and vcoare respectively the cut-in, rated and cutout wind speed of the wind turbine.

$Pactual = P_{WT}(t) * A_w * eff$ (vi)

Pactual-Actual Power generated

$P_{WT}(t) - RatedPowerofWindGenertor$

Aw-Swept Area (in Sq.m)

$\lambda = \frac{\omega_{rotor} .R_{rottor}}{V_{wind}}$ (vii)

$\omega_{rotor.}$ - Angular velocity of wind Turbine

Rrotor - Rotor radius in m

V_{wind} − Wind velocity in m/sec

During the analysis, beta is varied from 1 to 13 and angular velocity is varied from 6m/sec to 18m/sec

$\lambda_{i=}\frac{1}{(\lambda+(0.08*\beta))} - \frac{0.035}{\beta^3+1}$ (viii)

$\lambda_{i1=}\frac{1}{\lambda i}$ (ix)

$C_{p=0.22*}exp(\frac{-12.5}{\lambda_{i1}}) * (\frac{116}{\lambda i1} - 0.4 * \beta - 5)$ (x)

Where,

β - Blade pitch angle

λ -Tip Speed ratio

C_p -Power Coefficient

$Protor = 0.5 * \rho * Cp * \pi * Rrotor^2 * v^3$

$AerodynamicTorque = \frac{Protor}{\omega rotor}$ (xi)

VII. Matlab Programming Results

1. Wind Power Curves

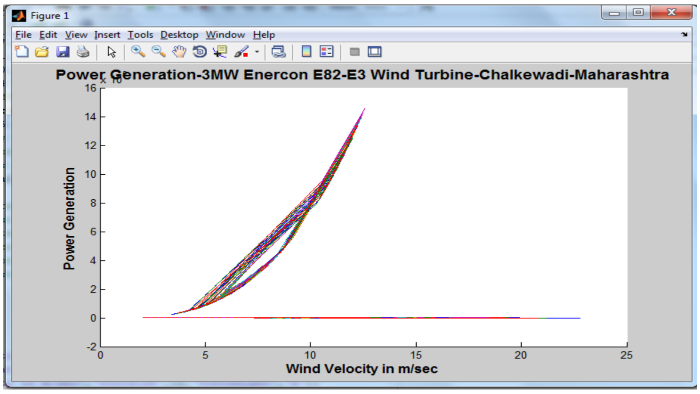

Fig.6 Wind Power Curve- Chalkewadi

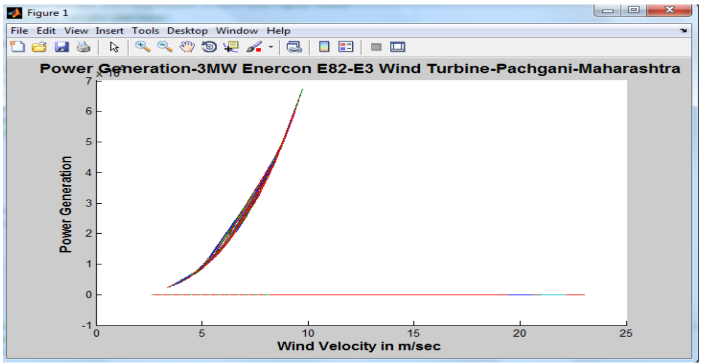

Fig.7 Wind Power Curve-Panchgani

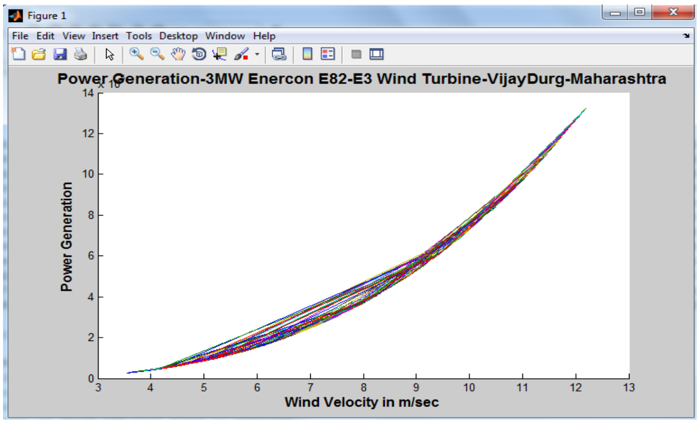

Fig.8 Wind Power Curve-Vijaydurg

2. Lambda Versus Power Coefficient

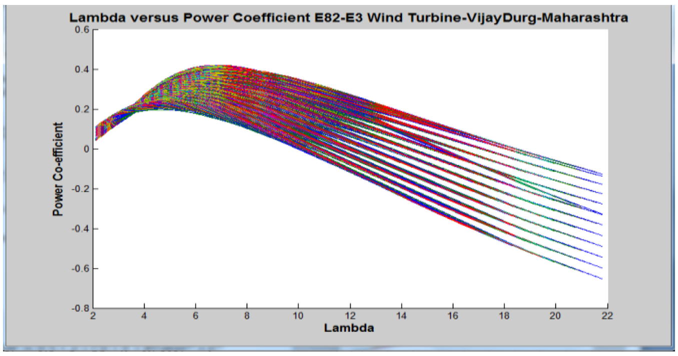

Fig 9: Cp versus λ-Vijaydurg

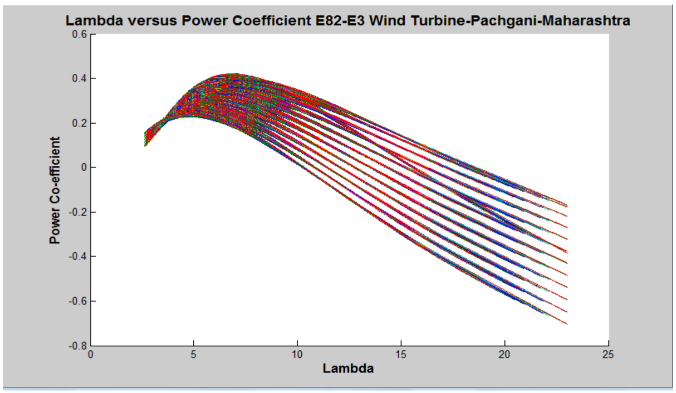

Fig.10: Cp versus λ-Panchgani

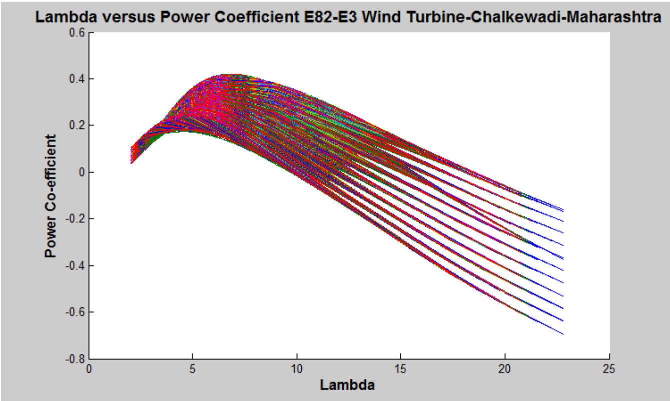

Fig.11: Cp versus λ- Chalkewadi

3. Wind Velocity Versus Aerodynamic Torque

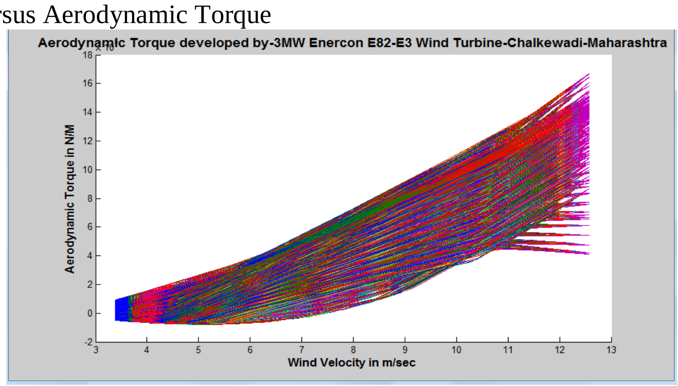

Fig.12:V versus Aerodynamic Torque-Chalkewadi

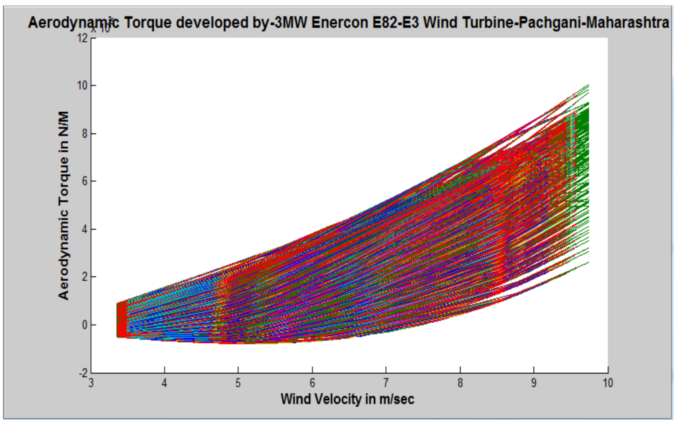

Fig.13: V versus Aerodynamic Torque-Panchgani

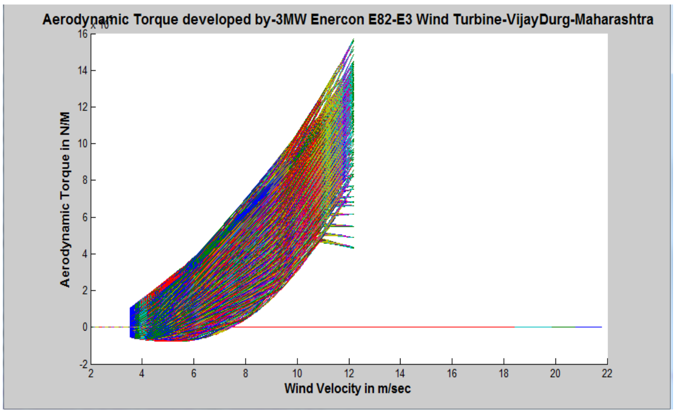

Fig.14 V versus Aerodynamic Torque-Vijaydurg

VIII. Result Analysis

1. Power Extraction From Wind Generator

Location	Max. Power (MW)	Rated Power (MW)	Rated velocity (m/sec)	% Efficiency
Vijaydurg	1.39	3.0	12.5	46.33
Chalkawadi	1.5	3.0	13	50
Pachgani	0.69	3.0	10	23

2. Power Coefficient And Aerodyamic Torque

Parameters	Vijaydurg	Chalkawadi	Pachgani
Range of Power co-efficient(Cp)	-0.6 to 0.4	-0.6 to 0.4	-0.6 to 0.4
Maximum Aerodynamic Torque(N/m)	15	15	10

IX. Conclusion

ENERCON 3MW E-82 E3 Wind Generator gives maximum wind power extraction for Chalkewadi location and minimum wind power extraction for Pachgani location whereas maximum aerodynamic torque produced is maximum for Vijaydurg and Chalkewadi.

References

[1]. Thomas, Wind power in power system, New York:Wiley, 2005.
[2]. Bin Wu, Power conversion and control of wind energy system, New Jersey:Wiley, 2011
[3]. Jes'us L‘ open, Pablo Sanchis, Xavier Roboam, Luis Marroyo, "Dynamic Behavior of the Doubly Fed Induction Generator During Three-Phase Voltage Dips", IEEE Transactions On Energy Conversion, vol. 22, no. 3, september 2007
[4]. C. Lewis and J. Müller, ‘‘A direct drive wind turbine HTS generator,’’ inProc. IEEE Power Eng. Soc. General Meeting , Jun. 2007, pp. 1–8
[5]. Y. Liang, M. D. Rotaru, and J. K. Sykulski, ‘‘Electromagnetic simulations of a fully superconducting 10-MW-class wind turbine generator,’’IEEETrans. Appl. Supercond., vol. 23, no. 6, pp. 46–50, Dec. 2013
[6]. The most suitable wind energy converter for every location ENERCON product overview
[7]. H. Li, Z. Chen, "Overview of different wind generator systems and their comparisons," IET Renew. Power Gen., vol.2, n.2, pp.123 –138, 2008.
[8]. Jiawei Chen; Jie Chen; Chunying Gong, "New Overall Power Control Strategy for Variable-Speed Fixed-Pitch Wind Turbines Within the Whole Wind Velocity Range," IEEE Trans. Ind. Electron., vol. 60, n. 7, pp. 2652- 2660, 2013.
[9]. G.M. Joselin Herbert, S. Iniyan, E. Sreevalsan, S. Rajapandian, "A review of wind energy technologies," Renewable and Sustainable Energy Reviews, 11 (2007) 1117–1145.
[10]. Wei Qiao, Ronald G. Harley, "Grid Connection Requirements and Solutions for DFIG Wind Turbines", IEEE Energy Conference, 2008.