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Exploring Feasibility and Scope for Wind Resource Potential with Turbine Selection for a Land Site

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Abstract - **The paper presents a synthesized approach by developing a ranking criteria for deciding a wind farm location based on wind potential, site consideration factors interfaced to matching turbine design characteristics with wind properties such as its power density, cut in speed, sustainable pattern counts of air distributions and prioritized selection factors based on literature, technical expertise derived from wind manufacturers and experience of wind farm developers so as to achieve enhanced capacity factor with reduced risk of investment of the customer on a long way without suffering the surroundings and environment. For efficiency, safety, and optimized production with higher degree of reliability; concepts of variable speed turbine with basic automation is covered. Based on yearly, "metrological data" in coordination with "wind resource data" using statistical tools for deciding firm probability of average and peak wind cut in speed, frequency of occurrence of wind distributions with power density, geographical location over land nature such as terrain, off shore or on shore locations taking a feasible hub height and a economical criteria the turbine size decision; is concluded. After selecting a wind turbine, its performance data based on turbine selection factors and wind potential for the site under consideration are simulated and projected to assess its financial impact on wind farm operation and likely benefits. Measures for capacity Factor enhancement concepts are presented for higher wind energy conversion and economy.**
Keywords: **Ranking criteria, wind potential, site selection, turbine selection, Capacity factor**

I. INTRODUCTION

The wind source is much intermittent than solar because of wind flow on sea and earth with surface irregularities from plain to terraines, hills with varying heights and temperature zones; a cyclic pattern of warm and cool air is generated with warm air expansion upward and cool, being heavy air is rushing downwards to fill the space left by warm air. This phenomenon is universal but it's over all profile and potential, flow rate and direction is always varying and truly speaking totally beyond prediction. However, a systematic approach on metrological and geographical data collection for a wide period starting from a year to decade for probable air distribution, speed range deciding minmum and maximum air densities, gust, cyclones; is the basis for matching the turbine size, its swept rotor area and thus estimate for electrical energy conversion from wind kinetic energy is worked out through simulations and statistaical tools.

A comprehensive economic analysis covering appropriate wind site with turbine interface and its converting power and control technology selection are prime needs for enhanced increase in the wind energy usage [1]. The wind power potential of a wind turbine is related with its characteristic and its compatibility to the environmental conditions [2, 3]. The environmental conditions involve wind velocity and air density.

The model of Lye and Hamilton [4] for the importance of the supplier selection criteria: product quality, mutual trust and awareness, reliable delivery, accountability in problems, and long-term relationships are some of main factors which any investor wants to tie up with a reliable partner so that based on local site specifications; the overall total cost including operation: is kept at reasonable level over a business cycle period.This order of the themes, is more or less in line with, the advices taken from experts during informal interviews.

As compared to for conventional hydrocarbon fuel sources, wind energy is estimated to have the lowest cost of all renewable options like biomass, geo-hydro fluid, geo-thermal rock, solar, solar-thermal, solar tower, solar concentrator, tide and mini hydro projects; despite the fact that there has been over 80% cost reduction over the last decade[5]. The next constraint is being an intermittent energy source but these are being overcome by hybridizing with either RES or even conventional sources to reduce carbon emission, if not to its full extent.

Wind speed distributions are commonly used to indicate the annual available wind energy [6]. These distributions are estimated using measurements, wind maps, statistatical analysis, simulations and iterations for future patterns and projections. Such study indicates how often a certain wind speed occurs. For example, if at a given site; the wind energy potential is such that the sum of frequencies with wind speeds lower than 4 m/s is more than 65%; means for practical electrical generation, wind speeds above 4 m/s exist only for 35 % of the time. In [7], Weibull probabilitydistribution model is the most widely used mathematical model to describe the distribution characteristics of a site in terms of two parameters, the shape factor and scalefactor and provable repeated counts of occurrence of wind speed frequency curves.

Determination of wind zone in a region and then Wind site selection among various options; is a first primary step [8]. Site selection itself is a backbone of wind power project and needs extensive study with in depth assessment of wind resources data from past 10 years of an area's topology, wind speeds, distribution to reduce the project risk and economic stability [9]. A high capacity factor ensures low cost of wind energyconversion system [10]. A high value of availability factor indicates that windturbine is operational most of the time [11].

Method for decision making combined with BOCR (benefits, opportunities, costs, risks) analysis; Lee et al. [12] and Kang et al. [13] have researched on the traditional AHP (analytical hierarchy process) method. It covers a wide range of variables for capacity assessment starting from wind conditions to turbine properties and their manufacturers and land acquisition.

Ranges of power producing turbines are available producing 300W to 1MW and large wind turbines have typical size of 35kW-3MW [14, 15].To economize Levelized cost of electricity (LCOE), the basic need is technology development as it is one such primary theme which provides continuous long time benefit to investors. The Manufacturers like WinWinD (32%), Siemens (30%) ,Vestas (16%), Enercon (12%), Hyundai (3.5%), Harakosan (2.6%), Nordex (1.7%), and Mervento (1.6%) have lead in research and development as per their share in market. To the knowledge, the wind turbine manufacturer selection criteria have not been scientifically studied extensively from the customers' point of view [16-17].

By adapting variability of wind speed into nearly constant wind speed, ensures turbine to be almost free from mechanical thrusts during change of wind direction or turbulence wind flow. Turbine designs matched with various wind class are significantly improving its conversion efficiency. Larger rotor designs up to 180 meter with variable blade pitch control as per wind flow are working at low wind speeds. The forces on mechanical structure, tower and blades are constantly monitored which adds to safety as well as higher energy conversion.

A combination of converter designs with automation adopting space control techniques, power devices with latest Si MOSFET and IGBT technology, the physical stress on turbine as well as conveter and grids are reduced; resulting higher safety, reliablity and at the same time THD (Total harmonic distortion) are naturally reduced following compliance of IEC standards. As energy storage devices like battery Energy source (BES) of various technologies like lithium, lead acid cell, dry cell, fuel cell, hydrogen cylinders etc. are to be chosen economically.

The motivation of the present paper is to reduce the gap in matching process among site properties, selecting and pin pointing the site among a region; based on ranking criteria followed by enlarging understanding of turbine evaluation especially for small wind farm owners and individuals. A remote site located at latitude (DMS) 25^0 37' 30N longitude (DMS) 74^0 55′ 35E Altitude (meter) 362 near Kukas (Jaipur) is selected; where a wind resource potential is estimated as an example and criteria for its selection too. The wind data are based on NASA at the above location followed by actual measurement by anemometer The methodology follows by building comprehensive Ranking criteria for various attributes and variables and the corresponding weight age point score so as to get rid of subjective biased decision and adding strength in project venture along with techno-economic over view of the project. The wind turbine capacity is based on remote location load. A Homer software help is taken for solving empirical formula and alternative options, based on site conditions and load requirements.

The organization of the paper includes site selection factors in section II followed by wind class, mapping, wind data and its potential study in section III. The section IV describes a site selection ranking criteria. Section V covers Evaluation of wind turbine, its selection factors and discussion on enhancing capacity factor of the site. Next section VI includes likely produced energy estimation, load requirement and turbine structural data. The section VII deals with adding automation and variable speed mode for enhanced energy efficiency. The section VIII includes economic over view followed by conclusion.

II. WIND POTENTIAL MAPPING AND SITE SELECTION

Cost justification based on farm location, turbine selection, civil construction, installation cost and electrical infrastructure ongoing operation & maintenance, safety, techniology evaluation and its life is estimated then to analyze its economic workability in totality. The identification of the wind class and whether it lines up with the cut-in speed and optimal wind speed for the proposed wind turbine is ascertained. Low wind speeds have no significant extractable energy. Sites having wind power density exceeding 200 W/m^2 at 50 m hub-height; the average capacity factor based on matching of wind turbine with windy site may be close or higher than 30%.

It is also important to evaluate whether nearby obstacles will cause turbulence to disrupt airflow access to the site and reduce turbine life. An industry rule of thumb: the distance between a turbine and the nearest obstacle should be at least twice the turbine height. It is important to note that locations such as the bottom of a hill or inside a valley are not good sites for a wind turbine. The best locations in terms of wind resource are typically high on mountains, in large open fields, or on the edge of bodies of water. An important point is whether the produced electricity is for local utility scale or is a case of distributed generation and accordingly electricity infrastructure and rates are going to be estimated. It is important to determine how the power from the wind farm is metered, who is obligated to purchase the power, and what happens to the asset at the end of the lease or if the host customer goes out of business. Load study may help if it is an off grind wind farm or mixed with other Renewable Energy Sources (RES).It is important to identify all local, regional, and national permits required for a proposed site, to meet extreme seismic requirements site is physically appropriate for the technology. Structural stability of the soil, slope and its direction on the site, and proximity to a nearby interconnection point is necessary. A check on space for civil construction equipment, crane, transportation, water, electricity, road site etc. is helpful in reducing initial project.

III. WIND POTENTIAL, CLASSIFICATION AND DATA PROCESSING

The wind class is well accepted determination of wind density related with its speed measured at certain hubhight of 10 meter and 50 meter as shown in table 1. It is observed that wind below 4m/sec at 10m tower height is considered as of no economical use but at the same location at 50m hub height, wind power density is nearly 28% higher and considered as moderate economically. Other values upto 8m/sec are graded well within the beneficial zone. These wind class are considered and are important in matching the wind turbine capacity.

TABLE I SHOWING WIND CLASS AT 10M AND 50M TOWER HEIGHT

Class of Wind Power Density at 10m and 50m Hub Height					
Wind Power class	**Wind power density w/m²**	**Speed (m/sec)**	**Wind power density w/m²**	**Speed (m/sec)**	**Subjective Potential Grading**
	Height 10 meter		**Height 50 meter**		**Land area**
1	<100	4.4	< 200	< 5.6	moderate
2	100-150	4.4-5.1	200-300	5.6-6.4	Fair
3	150-200	5.1-5.6	300-400	6.4-7	Good
4	200-250	5.6-6	400-500	7-7,5	Very good
5	250-300	6-6.4	500-600	7.5-8	Excellent
6	300-400	6.4-7	600-800	8-8.8	Excellent
7	>400	>7.0	>800	>8.8	Outstanding

A. Wind Potential data Collection and Processing

The basic purpose of data collection is to mitigate uncertainties, taking precautionary and suitable corrective measures for reduced risk. For preliminary assessment wind resource data may be obtained from NASA, DLR, NREL, or respective national centre for weather research of a country. The realistic wind distribution patterns come with measurements at 50m and 80m height ensuring wind measurements over minimum 10 minute average time intervals; at minimum 2 or 3 elevations and at least one year data are required to minimize the investment risk and more realistic picture of assumptions and financial data work out.

Manual data generation is laborious but accurate at a particular instant and such measurements are to be corelated with virtual metrological data (VMD) to correlate past and future forecast. The meteorological station though being expensive, usually is a tower with height for 30 to 60 meters and installed with various instruments such as anemometers and wind vanes in different heights of the tower in order to record the wind speed and the wind direction. If the height of the wind turbine is more than the height of the anemometer; in such cases the wind speed needs to be scaled up in order to correspond of the actual wind turbine height.For large scale data generation and earth surface mapping, a remote sensing instrument like LIDAR (Light Detection and Ranging) consisting of laser, scanner and a specialized GPS receiver; is used.

B. Global Wind Regime Data Generation

Weather research forecast (WRF) is consortium of more than 150 research organizations, industries and universities. VMD are generated with various inputs such as Modern-Era Retrospective Research analysis and Applications (MERRA); along with satellite data of soil temperature, moisture, sea surface temperature, and ice and snow depth; recorded at 25 km surface resolution scale on 3 hourly interval bases. A sophisticated land surface model predicting surface fluxes of heat and moisture in the atmosphere with reflected short and long wave radiation emitted to the atmosphere; is prepared. MERRA data is available on an hourly basis over a grid spanning most of the globe at a resolution of 1/2 ° in latitude and 2/3 ° in longitude and at a height of 50 m above ground level. The data so generated are applied for wind speed measurement and deciding wind regime at a site.

IV. WIND SITE RANKING CRITERIA (WSRC) FOR WIND SITE SELECTION

For small projects(<100kW), only basic ratings like soundness of resource, selecting and matching technology as per available data of resources and disposal of energy and waste products without impacting environment and community with weighted finance and risk factors are sufficient for a certain life period of resource and technology under consideration.

For large size projects, the priorities are decided based on previous experience, advice from experts and collection of data in concerned field; and a mathematical model using prevailing criteria and scientific approach is developed and solved through linear programming with iteration methods.Other methods such as fuggy logic and functional matrixes are utilized when number of variables are more and complexity of logic is increased. Here most important is learning from experience of other processes and therefore consultancy is needed even if a big price is to be paid. It is more justified for large projects involving risk on finance investment and engineering and resources too. A wind Site RankingCriteria(WSRC),for wind site as shown in table 2; is developed based on interaction from experienced experts from manufacturers and users, relevant literature and project reports in the field.

TABLE II PROPOSED WSRC RANKING CRITERIA FOR A WIND RES

Factor	Criteria/ Description	Relative Weighting [%]	Power density Class [w/m^2]	Rating score	
				Wind speed [m/sec]	score
Wind Resource	Wind speed class1	40	<100	4.4	5
	Class2		100-150	4.4-5.1	6
	Class 3		150-200	5.1-5.6	7
	Class 4		200-250	5.6-6	8
	Class 5		250-300	6-6.4	9
	Class 6		300-400	6.4-7	10
	Class 7		>400	>400	10
Land		10	Fertilized Less Fertilized Non fertilized Hill with approach		2 4 8 10
Grid Location	Distance and infra structure For energy transmission including cabling, transformers, protection including peak hours	15	Within 50km Within 40km Within 30km Within 10km Within 3km		1 2 4 8 10
Energy cost	Normally profitability starts At production cost above 4.00 per KWh excluding Transmission part	15	Below INR 2.0 INR 2.50-3.50 INR 3.50-3.75 INR 3.75-4.25 INR 4.25-4.50 INR 4.50-5.00 >INR 5.00		2 3 5 6 7 8.5 10
Road to site		8	< 150 km < 100 km < 50 km < 30 km < 20 km < 10 km		2 3 4 6 8 10
Risk Factors		6	Cyclone Siesmic Major fault Design mismatch		-3 -5 -7 -8
Environment		6	Noise Vision effect when approachng WT site Birds Legal, social, Impact on other trade		2 1 1 2 4

The validation of the WSRC ranking criteria was examined by applying it for a running 1MW wind project and discussed with the user team and minor correction in score is implemented.

This WSRC ranking criteria is sufficient at primary stage of decision and refinement in decision is based on projected economic and production data which are worked out using Excel tool and simulation results. The usefulness is to eliminate subjective biasing during decision process. Secondly it provides a written record which may be referred in future for other sites and based on feedback, a justification may be reviewed and ranking score factors may be improved. It is a continuous process and with real experience it may be near to realistic and more correct decision.

V. EVALUATION OF WIND TURBINE CAPACITY, SELECTION PROCESS AND ENHANCING PLANT CAPACITY FACTOR

A. Wind Energy capture concept

Wind is an air mass moving from a high pressure area to one of low pressure. To calculate the energy in wind, consider a segment of air shaped horizontal cylinder in which energy depends on the volume of air, density, and wind speed and the mass per unit time for a slice of the cylinder is shown in 1:

$$M = \rho AV \qquad (1)$$

Where M = mass, ρ= density, A = area and V = wind speed

The function of a wind turbine is to transform the wind's kinetic energy (Ek) into electricity. Therefore, Substituting the mass of the air cylinder (1) gives:

$$Ek = \frac{1}{2}\rho AV^3 \qquad (2)$$

Thus, the amount of energy in the wind depends on the density of the air, area (in this case, the area swept by the wind turbine rotor) and the cube of the wind velocity. If a turbine was completely 100% efficient, it would transform all kinetic energy from the wind into electricity. This would mean the wind velocity would drop to zero behind the blade. We know that is not the case and as per Albert Betz (Book 1926) it is only possible to extract 16/27 or 59% of the energy from a wind turbine and therefore the theoretical energy model for a wind turbine is expressed in 3:

$$E_{kmax} = \frac{16}{27}(\frac{1}{2}\rho AV^3) = E_{kmax} = Cp(\frac{1}{2}\rho AV^3) \quad (3)$$

Cp = Maximum power coefficient, ranging from 0.25 to 0.47 (theoretical maximum = 0.59)

In practice, however, the amount of extractable energy ranges from wind is only 40 to 47%. The range of wind speeds that are usable by a particular wind turbine for electricity generation is called productive wind speed. Productive wind speeds will range between 4 m/sec to 35 m/sec depending upon location in field or sea shore. The minimum prescribed speed for optimal performance of large scale wind is 6m/sec.

B. Enhancing Capacity Factor with optimized Turbine selection Parameters

1. Role of Optimized Rotor speed &Tip Speed Ratio

The available wind turbine designs ranges with rotor lengths from 40 meters to 180 meters for a 60 KW to 7MW capacity. Referring to rotor rpm, if it is slow, most of the wind (and energy) would pass through the space between the blades, thus “wasting” the energy and reducing the efficiency of the turbine and if the turbine spins “too” fast, the blades themselves create issue of turbulence as well as acting like a building wall against wind with thrust. Therefore getting an optimum rotational speed most suited for maximum energy yield in between too slow and too fast; is an important factor in rotor design. A term introduced as the rotor tip-speed ratio (*Rts*) refers to the ratio between the wind speed and the blade-tip speed:

$$R_{ts} = V_{bladetip\text{-}spd/}V_{wind\text{-}spd.} \quad (4)$$

A best tip-speed ratio depends on the number of blades in the rotor. The fewer blades, the faster the wind turbine spins to extract maximum power from the wind. Early experiments showed that a two-blade rotor has an optimum tip-speed ratio of about 6, a three-blade design about 5, and four blades, about 3. However, more recent highly efficient aerofoil designs have increased the numbers by 25 to 30%, which allows increasing rpm and therefore generating more power.

2. Turbine Blade design and cost considerations

As the trend of larger rotor diameters continues, both material consumption and blade cost will also increase. There is direct advantage of a two blade design leading to smaller mechanical equipment, lower torque and faster rotor speeds. A lower turbine weight, then allows reducing the size or even eliminating yaw controls. There is further reduction in installation cost, tower plate farm, transportation and its operational cost. However, a cost comparison between three and two-blade designs is not as simple as eliminating the cost of one blade. The three-blade turbine is a proven design and its rotor solves some mechanical loading challenges as well.

3. Controlling Gyroscopic Forces by Pitch control of Blades

A technique like controlling pitch of blades for reduced gyroscopic forces (reisitance against changing direction of a spinning rotor) on the rotor when yawing; would take advantage of the wind’s kinetic energy on the blade to assist in turning the turbine into the wind. Such a control feature cyclically alters blade pitch as the wind direction changes so as to present different angles of collision between the blades and wind. With proper design research and investment; it is feasible to eliminate the large gyroscopic forces on two blade windmills, thereby making them viable for 5 to 20MW machines. However, the advantage of a three blade design is that at least two of the blades are always out the vertical plane at one time, thus reducing shaft and gearbox stresses when the turbine yaws. Secondly, it eliminates the need for yawing mechanism including drive motors.

4. Wind Performance and Tower Height

In order to reduce wind shear, turbulence and operation at increased wind speed; the lowest part of turbine rotor should be at least 10m above any obstacle located within 100 to 150m radius. A taller tower is always the best investment in a wind energy system. An increase in tower height from 100 to 120 ft will produce more energy by 20 to 25%. A dramatic energy increase by 100% is possible; if tower height is increased from 30 ft to 100 ft above obstacle free ground level.

5. Energy Production vs. Peak Power

The peak power rating of a wind turbine should not be used as selection basis. A wind turbine that is “rated” at a high kW power output in high winds region may demonstrate be very poor productivity over an entire year, as the high winds at which it is rated do not occur over a long period of time. To avoid confusion, power producing and energy curves based on testing and certified by an industry-accepted, qualified, independent, test agency should be trusted.

6. Wind Turbine Layout &Turbulence

Non-laminar wind causes interference with the ground, nearby objects, and the wind turbine components like tower itself; reduces effective productive wind speed available to the wind turbine, as well as its efficiency and reliability. In addition, it is recommended to separate adjacent wind turbines by a distance of at least 3 times the rotor diameter (or width), and to not align multiple wind turbines in prevailing wind directions.

7. Wind Shear

It is an increasing difference in wind speed with height. Wind shear is greater closer to the ground and in terrain with tall objects, such as buildings and trees. Wind shear can cause differential stress on wind turbine, and so reduces working limit of wind speed and corresponding performance.

8. Turbine Selection factors

Based on informal interviews and interaction with manufacturers, field experts and literature we summerise following themes to decide the product and its supplier:

1. The reliability is wide spread term affecting product life, consistency in production, effective support by maintenance team, warranty conditions and all these further contribute to the reputation of manufacturers.
2. Further the reliability is essentially linked to the production volume, tower height, blade length and converters system.
3. Performance is examined from two perspectives, the power curve between wind speed at a given pole height vs. power produced by the wind turbine as well as production unit's (kWh or MWh).
4. Cost factor: Overby and Servais [19] state in their wide literature review that quality and relationships between firms are more important in supplier selection criteria than price. The total cost in this context means the plant procurement costs including also the infrastructure works in the location of the plant (e.g., earthmoving, tower foundations, high voltage substations, etc.) and the next essential part of the cost-effectiveness is that what are the anticipated operating and maintenance costs over the long term.
5. Turbine's price, offered electrical grid technology solutions, along with electrical and mechanical infrastructure, are considered as four most important cost components.
6. Availability Factors: The availability of desired type of power plant (for example, onshore/offshore, the desired output class), its delivery and the rapid availability of spare parts are equally important.
7. Organization of maintenance to upkeep the system operation with increased mean time before failure (MTBF).
8. R&D has a vital role in developing the technology affects performance price ratio of the wind farm.
9. Safety and noise level and arresting environmental issues.

VI. PROJECTED ENERGY ESTIMATION FROM SITE

A projected estimate of the annual energy output (kWh/year) from selected wind turbine is the best way to determine whether a particular wind turbine and tower will produce enough electricity to meet economical criteria and needs.

The power produced from wind turbine is governed by equation 3 where the air density, ρ, changes slightly with air temperature and more with elevation. The ratings for wind turbines are based on standard conditions of 15 °C at sea level. A density correction should be made for higher elevations. A correction for temperature is typically not needed for predicting the long-term performance of a wind turbine.
To estimate the energy production a calculation based on the particular wind turbine power curve (see fig.3), and formula as per equation 5 may be referred.

$$Annual\ Energy\ Output(AEO) = 0.01328 D^2 V^3\ KWh/yr \quad (5)$$

Where: D = Rotor diameter, feet, V = Annual average wind speed, mph

For a site at Kukas near Jaipur (India) located at latitude (DMS) 25^0 37' 30N longitude (DMS) 74^0 $55^{'}$ 35E Altitude (meter) 362; Homer Based synthesized data simulation of wind speed for the year is presented in figure 2. It is observed that wind speed is between 3-4.6 m/sec at a hub height of 10 meter which is considered lower for a full fledged wind farm. However a turbine with large rotor diameter at 50 meter or even above may be considered within scope; but certainly at higher investment. The reason is for higher tower height the construction cost for tower itself is significant. As our case intends for remote location and assuming off grid system, load pattern or profile is basic necessity.

A.Load study of the site Population in case of off grid

Based on primary data collected from local communities, the load requirement with four categories like normal, peak, critical and off load; were collected and based on simulation the variation is shown in figure 1. The load data are summarized in table III.

TABLE III SUMMARY OF LOAD DATA OF LOCAL COMMUNITIES

Daily Variation	Hourly Variation	Annual Average	Peak Load	Load Factor
15%	20%	108KWh/day	9.95KW	0.452

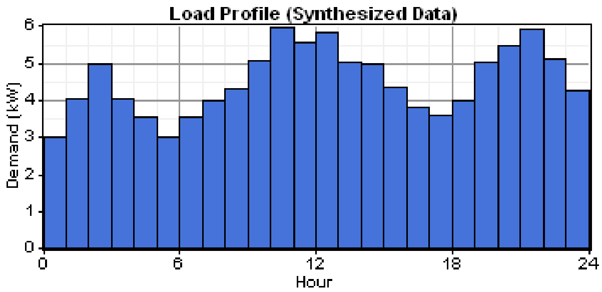

Fig. 1 Load profile of local communities as load requirement

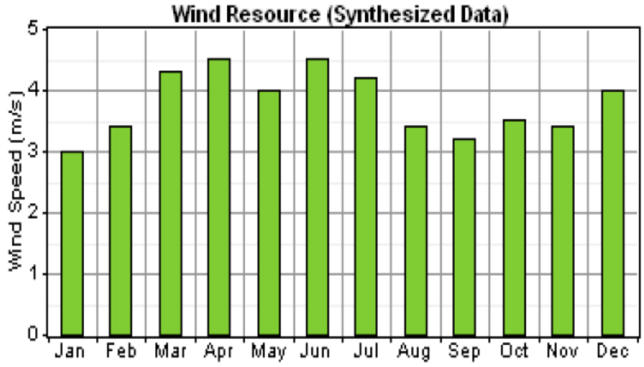

Fig. 2 Simulation based Wind profile of the site

B.Wind Turbine Operational Performance

Based on Homer simulation the configuration for load profile as per figure 1 and load data as per Table 3 the turbine configuration along with Li-on storage capacity are optimized with different sensitivities and alternatives; the optimized ratings and quantities are shown in table 4. It is expected that it will produce excess energy. Related wind farm performance data are presented in table 5, where it is clear that mean generation is 39 kW with capacity factor as 32.28% which is normal and well accepted in the industry. The levelized cost of electricity (LCOE) is INR 10.85 per unit. And wind turbine is operational up to 88.74% of the calendar producing 930 units of electricities per day.

TABLE IV SIMULATION BASED OPTIMIZED CONFIGURATION OF WIND FARM WITH ENERGY STORAGE AS PER LOAD STUDY

Wind Turbine	**Storage Li-on**	**Converter**	**Load**
10kW x10 no’s	1kW x 184 no’s	20 kW	23 kW

TABLE V WIND TURBINE PERFORMANCE OF SITE UNDER CONSIDERATION

Total production kWh/yr	**Rated/Max/mean output KW**	**Hours of operations Hours/yr**	**Capacity factor**	**Wind penetration**	**Levelized cost $/kWh**	**Primary Load kWh/yr**	**Excess Energy kWh/yr**
339324	120/120/39	7774	32.28 %	563.43 %	0.167	58697	277095

For in depth study and comparison, it is worth to include main constructional data of one Wind turbine (WT) model WES-5- in table VI, for a case if single WT is chosen as per correlation of discussion in section V. It is Horizontal Axis Wind Turbine (HAWT) design equipped with speed control and yawing system to arrest during tendency of over speed. Further its operational data are tabulated in table VII and Turbine power performance is shown in Figure 3. Here the cut in speed (<3m) matching at 30 meter hub height has been sufficient to meet the load demand. Thus both option of having single bigger turbine or small turbine is satisfactory in performance but land requirement is substantially larger in case of small turbine population.

TABLE VI CONSTRUCTIONAL DATA OF WIND TURBINE WES-50

Swept Area m^2	**Blade no’s x dia. (m)**	**Flapping angle**	**Gear box ratio, weight**	**Generator Asynchronous**	**Power regulation**	**Tower 3 stage, hot Galvanized steel**	**Yawing system Yaw speed 1, 2°/sec, 4piece friction brake**
327	2x20.3	180-164^0	0.055, 820Kg	72KW, 400V, (40-80) Hz, 4 pole , 400Kg	Blade adjustment	30 m, tubular	0.55 KW motor with gear box

TABLE VII OPERATIONAL DATA OF WIND TURBINE WES-50

Rated Power KW	Rated wind speed m/sec	Specific Power W/m^2	Cut-in speed m/sec	Cut-out Speed (m/sec)	Survival Wind Speed m/sec	Noise Emission (At 100 meter)	Tower Height (meter)/ Weight (Kg)	No. of Blades, Dia.(m)	Rotor Speed rpm/ Weight (Kg)
50	9	220	<3	35	52.5	45dB	30.5/7820	2, 20.3	60-120/1100

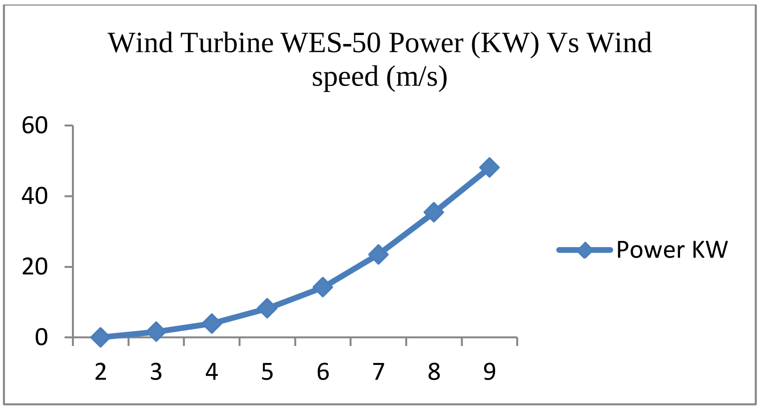

Fig. 3 Simulated data for wind turbine at projected wind speeds

C.Safety & Standards

For a wind plant certain standards which can be interpreted universally by manufacturers, customers and user engineering personnel. The most essential standards referred are: EN1010 (electrical), EN50308 (safety) EN6096 (wind turbines) UL1741 (anti islanding) IEC61346-2000 (cabinet).

D.Safety

First safety system Passive blade pitching activated by: Rotor speed (110 rpm) (2)Second safety system Yawing out of the wind Activated by Rotor speed (>120 rpm) (3)Excessive vibrations and or noise (4)For reduced blade heating, WT blades are preferred with Carbon and fiber glass reinforced epoxy based light weight metals (5)Failure of anemometer or wind vane (6)Failure in power conditioning system or converter (7)Grid failure (8)Too high generator or inverter temperature (9)Fault in yawing system.

E.Certified Testing

The Small Wind Certification Council (SWCC) is an independent, industry-accepted body organized to certify small wind turbines tested for power output, energy production, reliability and sound level [20].

VII.ADAPTIVE CONTROL AUTOMATION FOR ENHANCED PRODUCTION PERFORMANCE AND RELIABILITY

Minimization of Levelized cost of electricity (LCOE), increased performance, life time reliability and enhanced capacity factor are some of the basic universal points and this is directly related to the potential of site and the equipment technology used as per wind profile. Table 8 is pointing automation concepts which when implemented one may get increased efficiency even when wind flow id down. Adaptive controller with State-space control allows the designer great flexibility to deal with multiple inputs (RPM, blade bending, nacelle acceleration, etc.) multiple outputs (shaft torque, individual blade pitch) and ability to dramatically reduce turbine vibrations. One such example is INGECON make “WIND FIX2VAR SPEED” extends asset lifetime by smoothing speed changes, reducing mechanical torque steps caused by wind gusts, as well as by minimizing transients due to start-ups, emergency stops, and grid variations. This helps lower to a minimum the investment cost of transforming to a full converter variable speed topology.

TABLE VIII AUTOMATION CONCEPTS WITH ADAPTIVE CONTROL IN WIND TURBINE

Torque Monitoring	Power Current, Voltage	Mechanical stress Load	Metrol o-gical Data	Wind Velocity	Blade Pitch Control	Speed Variability	Data Acquisition	Noise & Vibrations
High & Low Torque Limit of rotor shaft	For power regulation and optimum perform -ance	Blade root Tower Bending Accelerati-ons Rate-gyros	Up-wind vertical array Temp.	Ultra-Sonic Anemo meter for wind speed & direction	Suitable with constant Speed mode	Full speed variation as per wind velocity	Data sample @ 100 Hz, 90 channels)	dB values at turbine and at100 meter distance

The figure 4 exhibits the fact that efficiency even when wind speed is low can be maintained nearly constant by adapting speed variability in wind turbine. It is important especially for existing wind turbines which can be retrofitted with additional instruments and other components.

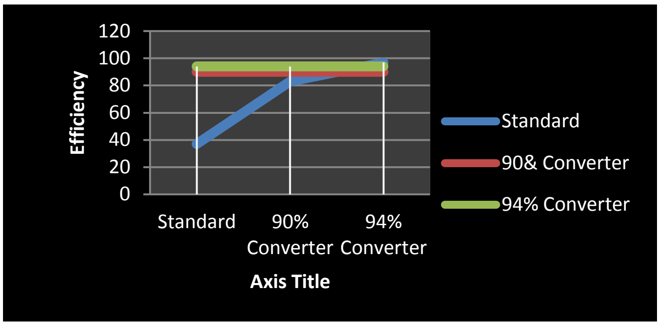

Fig. 4 Variable Speed Converter Efficiency

VIII.TECHNO-ECONOMIC OVERVIEW

The Wind Energy Payback Period and other such details may worked out by Workbook from the National Renewable Energy Labs which is a spreadsheet tool or Homer software that can help us analyze the economics of a wind electric system and decide whether wind energy will work for us. The same intension is shown in table IX.

TABLE IX SHOWING COST FOR A 120 KW WIND PLANT BASED ON LOAD REQUIREMENT AS OFF GRID

Present Capital cost				Annualized cost			
Wind Turbine Generic 10 kW 12	**Storage Generic 1kWh Li-Ion 184 strings**	**Converter System Converter 20 kW**	**System**	**Wind Turbine capital/ O&M**	**Generic 1kWh Li-Ion capital/ O&M**	**Converter capital/ O&M**	**System capital/ O&M**
600,000	55200	6127	661,327	38089/12000	3504/18400	389/0	41983/30400

IX.CONCLUSION

The development of WSRC ranking criteria with score rating has sufficiently demonstrated the wind farm selection criteria at primary stage and validated based on feedback from a profitable running wind site rating 50 kW. Based on Homer software, the matching of wind profile as per load pattern and turbine characteristics is demonstrated. A wide scope discussion in brief for turbine design aspects and other techno-economic based wind farm operation themes are considered in turbine selection process. Automation for safety as per standard guide lines and how a variable speed variation affects the efficiency of over all system including converter; is discussed. A financial and wind turbine energy production projection data of selected wind farm is also presented. In short a WSRC ranking based site selection, assessment of wind potential and how a wind turbine interface should be processed through with advantage of variable speed on in improved efficiency is covered.

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