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Performance Analysis of Wind Turbine and it's Economic Aspects

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ABSTRACT

Wind energy, commonly recognized to be a clean and environmentally friendly renewable energy resource that can reduce our dependency on fossil fuels, has developed rapidly in recent years. Its mature technology and comparatively low cost make it promising as an important primary energy source in the future. However, there are potential environmental impacts due to the installation and operation of the wind turbines that cannot be ignored. This paper aims to provide resource use and emissions generated throughout the life-cycle of wind energy systems can be quantified, in a systematic way, by using the tool Life-Cycle Assessment (LCA). The present paper outlines the status of current LCA studies of wind energy systems. Further, it presents preliminary results from ongoing work on input-output modeling of wind power development. Implications of wind power going offshore, in terms of effects on resource use and emissions, are discussed, and opportunities for improving the environmental performance of offshore wind energy systems are identified.

Key Words: off shore wind power, aesthetics, Life-Cycle Assessment, environmental benefits

I. INTRODUCTION

With the present day's energy crisis and growing environmental consciousness, the global perspective in energy conversion and consumption is shifting towards sustainable resources and technologies. This resulted in an appreciable increase in the renewable energy installations in different part of the world. Wind power could register an annual growth rate over 20% for the past several years, making it the fastest growing energy source in the world. The global wind power capacity has crossed well above 300 GW today and several Megawatts projects-both on shore and offshore-are in the pipeline. Hence, wind energy is going to be the major player in realizing our dream of meeting at least 20% of the global energy demand by new- renewable by 2020.

Assessing the wind energy potential at a particular site and understanding how a wind turbine would respond to the resource fluctuations are the initial steps in the planning and development of a wind farm project. Energy yield from the Wind Energy Conversion System (WECS) at a given site depends on strength and distribution of wind spectra available at the site, performance characteristics of the wind turbine to be installed at the site and more importantly the interaction between the wind spectra and the turbine under fluctuating conditions of the wind regime. Thus, models which integrate the wind resource as well as the turbine performance parameters are to be used in estimating the system performance.

II. METHODS AND MATERIAL

A. Wind farm Site Characteristics

The characteristics of the wind farms can be incorporated in assessing the wind energy potential as well as estimating the output from a wind energy conversion system.

Effect of height of the WECS

The wind turbine performance at a given site depends on the variations in wind velocity due to the boundary layer effect. Due to the frictional resistance offered by the earth surface(caused by roughness of the ground, vegetation etc.) to the wind flow, the wind velocity may vary significantly with the height above the ground shown in fig. 1 below.

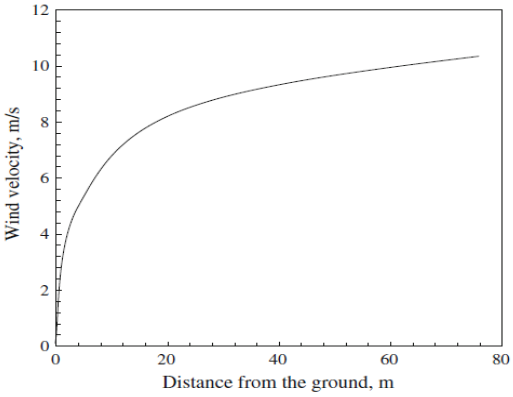

Figure 1: Variation of wind velocity with height

Wind Velocity Distribution

Being a stochastic phenomenon, speed and direction of wind varies widely with time. Apart from the seasonal variations, the differences can be considerable even within a short span of time. These variations can significantly affect the energy yield from the turbine at a given site. A turbine may deliver entirely different amount of energy when it is installed in two sites with the same average wind velocity but different velocity distributions. Similarly, two wind turbines with the same output rating but different in the cut-in, rated and cut-out velocities may behave differently at the same site. Statistical distributions are used to take care of these variations in wind energy calculations. Several attempts were made to identify the statistical distribution most suitable for defining the characteristics of wind regime. The Weibull distribution is well accepted and commonly used for the wind energy analysis as it can represent the wind variations with an acceptable level of accuracy. In some situations, Rayleigh distribution is also being used. Some attempts are also been made by applying the Minimum Cross Entropy (MinxEnt) and Maximum Entropy (ME) principles in wind energy analysis. Figure 2 below depicts the effect of Weibull shape factor on the probability density of wind velocity and the table 1 represents the corresponding Weibull shape and scale factors of some wind farm sites.

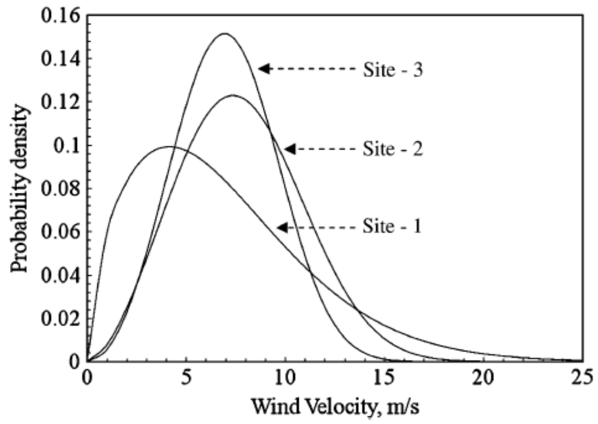

Figure 2: Effect of Weibull shape factor on the probability density of wind velocity

Table 1 Weibull shape and scale factors of some wind farm sites

Site no.	Mean wind velocity, m/s	Standard deviation, m/s	*k*	*c*, m/s
1	6.79	4.11	1.6	7.66
2	7.75	3.11	2.7	8.74
3	6.99	2.50	3.06	7.89

Energy Density

The power available in a wind stream of velocity V, per unit rotor area, is given by

$$P_V = \frac{1}{2}\rho_a V^3$$

Where PV is the power and _a is the density of air. The total energy contributed by all possible velocities in the windsite, available for unit rotor area in unit time (that is energy density, ED) is expressed as:

$$E_D = \int_0^\infty P_V f(V)\, dV$$

III. RESULTS AND DISCUSSION

B. Velocity–Power Response of the Turbine

Power curve of a 2 MW pitch controlled wind turbine is shown in Fig. 3. Table 2 represents the Cut-in, rated and cut-out wind velocities of the turbines. The turbine has cut-in, rated and cut-out velocities 3.5, 13.5 and 25 m/s respectively. The given curve is a theoretical one and in practice we may observe the velocity power variation in a rather scattered pattern. In this curve, it is observed that the turbine has four distinct performance regions:

1. For velocities from 0 to the cut-in (VI), the turbine does not yield any power.
2. Between the cut-in and rated velocities (VI to VR), the power increases with the wind velocity. Though, theoretically, this increase should be cubic in nature, in practice it can be linear, quadratic, cubic and even higher powers and its combinations, depending upon the design of the turbine.
3. From the rated to cut-out wind speed (VI to VR), the power is constant at the rated power PR, irrespective of the change in wind velocity.
4. Beyond the cut-out velocity, the turbine is shut down due to safety reasons. So, the wind turbine is 'productive' only between the velocities VI and VO.

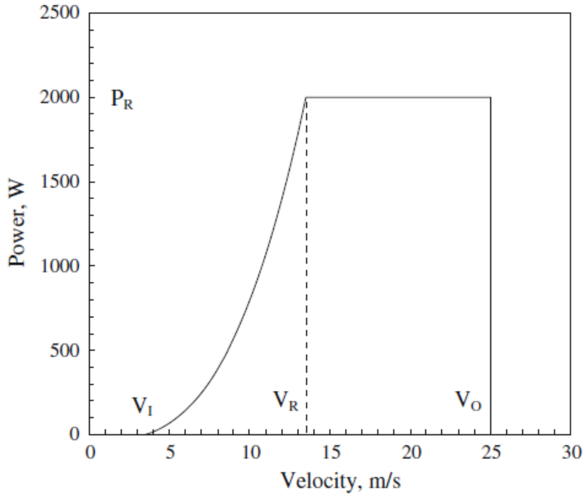

Fig.3 :Power curve of a 2 MW wind turbine

Table 2 Cut-in, rated and cut-out wind velocities of the turbines

Turbine no.	Cut-in velocity, m/s	Rated velocity, m/s	Cut-out velocity, m/s
1	3	12	28
2	4	16	25

The performances expected from the turbines given in Table 2, when installed at the sites described in Table 1are compared in Fig. 4 below.

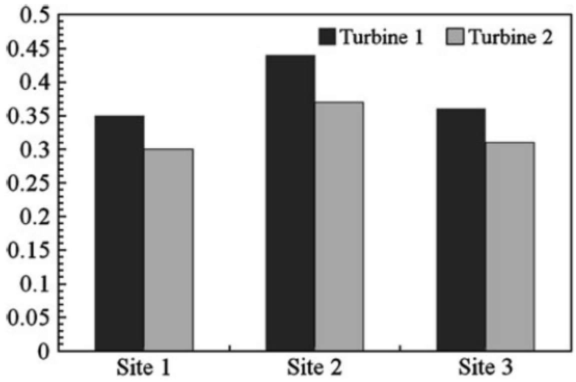

Figure 4: Comparative performance of two 2 MW wind turbines in different wind site

Though both the turbines have the same rated power of 2 MW, the first turbine is expected to generate more energy from all the three sites. This is obvious as (1) the first turbine has lower cut-in and higher cut-out velocities, making it capable of exploiting a broader range of wind spectra available at the site (2) The first turbine shows better power response between the cut-into rated wind speeds.

C. Wind Energy Economics:

There is not a single price and cost of energy for wind farms. Both depend on the location, size and number of turbines, in addition to being influenced by political incentives or subsidies granted by governments. The initial investment costs - cost of equipment, feasibility study, installation, and O&M are essential to determine the final cost of the technology. In general, the main variables that make up the production cost of wind energy are the investment costs of fuel and operations and maintenance.

In the case of wind power there is no dependence of the cost of fuel, but the investment cost is still higher than that of conventional sources. However, the costs of wind farms are decreasing, indicating that this trend is likely to continue due to several factors such as the development of larger turbines and more efficient, technological advancement, reduction in the cost of O&M, among others. An extremely important factor that contributes to raise the cost of wind power is its capacity factor ,generally around 30% to a maximum of 40%, while conventional plants varies between 40% and 80%.
The cost of electricity generation by wind is declined in the last 15 years approximately 80%.At the same time, the installed capacity has increased exponentially in

scale, from less than 100 MWto 34,400 MW in 2010. During the past ten years the price of wind turbines decreased by 5% each year, while at the same time revenue increased by 30% .Despite the reduction on the costs in recent years, some problems still there are hindering investments in wind energy projects. When connecting a wind farm to the electricity grid transmission, it is needed to check the power factor, voltage and final production of harmonics caused by the turbines, and investment costs are still higher than the conventional power plants of oil and natural gas. Moreover, the presence of wind turbines may threaten birds and cause visual and noise impact.

With regard to wind energy production, economic optimization and evaluation of projects in renewable energy, it is also needed on other factors, such as potential exposure from this source in the energy world, especially in regions where wind speeds are expressive. As the output power is extremely sensitive to wind speed, variability significantly impacts on financial investments and O&M costs. Given to this, it is highlighted the importance of developing assessment methodologies for economic and financial evaluation and management for energy projects considering the uncertainties associated with this type of technology .Both onshore and offshore wind energy minimizing the cost per kWh produced it is necessary because when it is going to be sold to the grid, the high and variable cost of wind energy represents a real risk to the investor or wind farm promoter. So when a wind farm is evaluated by deterministic indicator such as NPV, IRR, SPB, DPB and others economic and financial indicator usually applied for it, but such evaluation reflects a set of parameters adjusted and assumptions considered in order to show the results for a unchangeable market situation.

On the other hand, the wind energy system and green energy markets have some inherent features that should be taken into consideration. As renewable energies have been receiving supports by government's incentives such as production tax credits , modified accelerated cost recovery system and others finance supports which become wind energy
technology competitive comparing to conventional ones and other renewable energies technologies. However, given the fast growth of wind power during the last decade and the expectations for the future, wind power penetration levels may increase to levels where engineering and economic optimization for this kind of system starts to be more and more necessary. Note that in this thesis, the optimization model is defined as a suggested methodology able to evaluate a wind farm in both economical and engineering aspects. The main objectives of the optimization design are power reliability and cost. Minimizing the total cost, we can achieve an inexpensive and clean electric power system. In addition, the proposed method can adjust the variation in the data of load, location. Various modeling techniques are developed by researchers to model components of Wind system.

Performance of individual component is either modelled by deterministic or probabilistic approaches.

The economic study should be made while attempting to optimize the size of integrated power generation systems favoring an affordable unit price of power produced. The economic analysis of the wind system has been made and the cost aspects have also been taken into account for optimization of the size of the systems. The total cost of system takes into account the initial capital investment, the present value of operation and maintenance cost, the inverter replacement cost and the wind system replacement cost. The key objectives of this paper are to find the lowest cost and highest reliability design of a wind farm. The importance of using new optimization techniques for short-term energy planning is due to the existence of multiple uncertainties .The investment decision on generation capacity of a wind farm is difficult when wind studies or data are neither available nor sufficient to provide adequate information for developing a wind power project.

It is clear that an economic evaluation by classical economic engineering approach considering deterministic indicator such as discounted cash flow technique would not be sufficient. It is a multivariable problem and engineering aspects must be taken into consideration. The central question for this research work is hence: How to optimize a wind farm economically and technically by the application of nonlinear algorithm theory for minimizing the cost of energy? Is it possible? The answer is yes.

IV. CONCLUSION

A method for assessing the wind energy resource available at a potential wind farm site has been presented in the above sections. Model for simulating the performance of wind turbines at a given site has also been discussed. The performances expected from the turbines when installed at the sites. However, for a final investment decision, apart from a more rigorous technical analysis, economic and environmental dimensions of the project should be investigated. Practical realization of the general methodological approach to financial and economic analysis and efficiency evaluation of the investment projects in renewable energy technologies (wind energy) requires a sufficiently vast database including legal, reference, marketing, technical, and other information about the project itself and the conditions for its implementation. Most of this information (especially that referring to the future) is of prognostic nature and is not sufficiently full and precise, which tells on the feasibility estimates and project efficiency that depend on the realization conditions.

In a real economic sector, practical analysis of projects, unfortunately, is often carried out in an uncertain environment because the available information base is insufficient for determining the probability of one or another event (condition, index, and so on) with the desired precision. Then, informal methods become the main tools to support the decision making.

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