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A review on reliability characteristics of wind energy: a case study of M.P. India

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1. Introduction:

The major sources of electrical energy, in India, are the fossil fuels and water. There are no immediate prospects for large scale utilization of alternate sources of energy like sun, wind, tides etc. for generation of electrical energy. The three types of fossil fuels used in power plants are coal, oil and gas. As it common to know, coal is the predominant source of energy in India and many other countries. Coal contains moisture, carbon, hydrogen, sulphur, nitrogen, oxygen and ash.

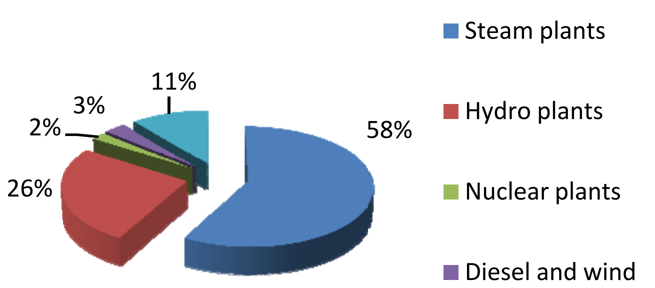

Figure.1 - Plant Distribution

The liquid fuels are obtained by refining the crude oil which contains about 84 to 87% carbon, 11 to 16% hydrogen, and oxygen, nitrogen, sulphur etc. Gaseous fuels are either natural gas or manufactured gas (water gas or producer gas). The manufactured gas is costly and, therefore, not used for power generation. The fuels used in nuclear reactors are natural uranium, lightly enriched uranium dioxide and plutonium.

During the past few decades the advanced technological nations of the world have been engaged in an energy and resource race that has brought us to the position of energy crises. Solar energy is the most abundant and constant stream of energy. It is available directly (solar isolation) and indirectly (wind energy, ocean thermal energy, geothermal energy, tidal energy, wave energy etc.).

Wind power generation, the most promising renewable energy, is increasingly attractive to power industry and the whole society and becomes more significant in the portfolio of generation systems. However, because of the unfavorable features of wind power, it affects all aspects of traditional processes of power system planning and operation. Power systems primarily planned for providing reliable and economic electric power to their customers. Therefore, it is critical to assess and understand the impacts of wind power on power system.

Energy consumption is loosely correlated with gross national product and climate, but there is a large difference even between the most highly developed countries, such as Japan and Germany with 6 kW per person and United States with 11.4 kW per person. In developing countries particularly those which are sub-tropical or tropical such as India the per person energy use is closer to 0.7 kW. Bangladesh has the lowest consumption with 0.2 kW per person.

Installed wind power capacity (MW)					
Nation	**2005**	**2006**	**2007**	**2008**	**2009**
United States	**9.149**	**11,603**	**16,819**	**25,170**	**35,169**
Germany	**18,428**	**20,622**	**22,244**	**23,903**	**25,777**
China	**1,266**	**2,599**	**5,912**	**12,210**	**25,104**
Spain	**10,028**	**11,630**	**15,145**	**16,740**	**19,149**
India	**4,430**	**6,270**	**7,850**	**9,584**	**10,925**

Table-1.1- Installed wind power capacity (MW)

The US consumes 25% of the world's energy with a share of global GDP at 22% and a share of the world population at 5%. The most significant growth of energy consumption is currently taking place in China, which has been growing at 5.5% per year over the last 25 years. Its population of 1.3 billion people (20%of the world population) is consuming energy at a rate of 1.6 kW per person.

Wind energy scenario in India- The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the US, India has the fifth largest installed wind power capacity in the world.

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States	Power Generation
TamilNadu	8256.00 MW
Maharashtra	2976.25 MW
Gujarat	3093.61 MW
Karnataka	2130.23 MW
Rajasthan	2355 MW
Madhya Pradesh	386.8 MW
Kerala	35.5 MW
West Bengal	1.10 MW
Others	3.20 MW

Table no. 2 – Power generation capacity in India (MOP,iNDIA)

Wind power generation Pros and Cons:

A conventional generator can be understood as a controllable generator, such as thermal units. From system economic viewpoint, wind generation is the “must-taken” energy whenever it produces. Therefore, this portion of load demand that used to be served by thermal generation is now provided by wind generation. In result,

- Overall system production cost will reduce from the reduction of high cost thermal generation, while assuming proper operation procedure is taken place.
- The amount of emission, such as CO2, SO2, NOx, released from coal and gas power plants before wind power integration will diminish. This will be greatly beneficial for already deteriorative environment.
- The consumption of major fuels by thermal generation, such as coal, natural gas and oil, will decrease.
- In addition, development of a wind power project can be implemented much easier and faster than building a thermal or hydro plant. It is also a potential and economic solution for providing energy around remote areas that cannot be reached by major transmission networks.\
- Meanwhile, wind generation brings a series of difficulties to the traditional power systems due to the unfavorable build-in natures.
- Uncontrollability: With regard to a generating unit, controllability means that the generation can be fully governed at any level from minimum capacity to maximum

capacity by a system operator. Wind generation mostly depends on wind availability. Only if wind blows, wind turbine produces electric power.

- Intermittence: Wind generation shows irregularly fluctuating and intermittent behavior. Fast ramp up and down of wind generation created by intensive fluctuation of wind will potentially lead to operational difficulties and endanger system reliability. For security consideration, when wind speed exceeds the “cut out” speed, like a gust, wind turbine will totally stop generating instead of keeping at maximum capacity. Consequently, all of a sudden, system may lose a group of generating resource and sufficient emergency actions must be taken in respond to such contingency.

- Poor predictability: Due to the random and irregular behavior of wind, it is very hard to accurately forecast wind generation. Long-term from seasons to years, mid-term from hours to days and short-term from seconds to minutes of wind forecast are typically used for wind project planning, daily resource scheduling and real-time operation, respectively. In a power system with high wind power penetration, mid-term wind forecast that predicts the hourly wind generation for a time horizon of 1–48 hours has great value for daily system operations. Unfortunately, state-of-the-art wind forecasting methods only show a Mean Absolute Error (MAE) of 10–15% of installed capacity of a wind project.

- Unfavorable seasonal and daily pattern: Around some wind farm locations, seasonal and daily wind patterns are out of phase with the patterns of local load, which means heavy wind generation happens during low load period and poor wind generation happens during peak load period. The worst scenario is that a wind project is sited where wind is rich at night during winter season; meanwhile, system load peak takes place in daytime during summer season. An area load profile and an aggregated wind generation of several wind farms for 24 hours in a day in the western region. It is obvious that the trends of load shape and wind generation deviate from each other.

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Impact of Wind Power on Power system planning and operation :

In power system operations, the main goal is to ensure the reliability of an electric power supply system which continuously faces anticipated and unanticipated changing conditions. Comprehensive processes of long-term planning and short-term operation are carried out to resolve the issues in the time frame from multiple years to milliseconds. In a traditional power system, operator dominates all available controllable resources to reliably serve the primary independent uncontrollable variable, system load.

Wind generation, as an undispatchable generating resource, almost entirely relies on wind availability. Integration of wind generation into existing power systems will definitely impact system planning and operation process in all time frames. The time frames from long term to short term for planning and operation. Investigation of wind generation integration must be carefully performed to accommodate to system's needs for different time frames in the long-term planning time frame, expansion decision of system infrastructure including resource and transmission are made with looking several years ahead to meet demand growth and satisfy reliability requirement. Wind generation, depending on geographical location and climatic condition, varies a lot from season to season and from year to year. Development of wind generation needs collaborate with generation and transmission planning, especially for the conventional generating units, to satisfy resource adequacy.

During day-to-day scheduling, available generating resources are scheduled beforehand based on the predicted upcoming load demand and wind generation, as well as other system conditions, such as transmission constraints and maintenances. Not like system load that conforms to diurnal cycle, availability of wind is largely unpredictable. To some extent, forecast error of wind generation is much greater than that of load, particularly for mid-term and long-term forecast. Logic of unit commitment considering operation reserve requirement needs be adjusted under high wind penetration condition.

During an operation day, also known as real-time operation, economic dispatch determines the minute-to-minute generation from the generating units that are committed based on unit commitment decision in the past, typically previous day. Unit commitment is potentially refined to accommodate the deviation between the forecast and actual value of load and wind generation and any other types of contingencies.

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In the fastest time frame, minute to second level, generating facilities are handled by automatic generation control and governor action without much operator intervention in response to system variations to meet system frequency and scheduled interchange among control areas. Large and high frequency variations of wind generation barely happen in such short period. Therefore, impact in this time frame is relatively small and could be negligible.

Reliability cost and reliability worth :

Due to the complex and integrated nature of a power system, failures in any part of the system can cause interruptions which range from inconveniencing a small number of local residents to a major and widespread catastrophic disruption of supply. The economic impact of these outages is not necessary restricted to loss of revenue by the utility or loss of energy utilization by the customer but, in order to estimate true costs, should also include indirect costs imposed on customers, society, and the environment due to the outage For instance, in the case of the 1977 New Year blackout, the total costs of the blackouts were attributed as:

*	Consolidated Edison direct costs	3.5%
*	Other direct costs	12.5%
*	Indirect costs	84.0%

in order to reduce the frequency and duration of these events and to ameliorate their effect, it is necessary to invest either in the design phase, the operating phase, or both.

The major discussions point regarding reliability is therefore, “is it worth it?’. As stated a number of times, costs and economics play a major role in the application of reliability concepts and its physical attainment. In this context, the question posed is: “Where or on what the next pound, dollar, or franc should be invested in the system to achieve the maximum reliability benefit?" This can be an extremely difficult question to answer, but it is a vital one and can only be attempted if consistent quantitative reliability indices are evaluated for each of the alternatives.

It is therefore evident that reliability and economics play a major integrated role in the decision - making process. The principles of this process are discussed in Engineering Systems. The first step in this process is illustrated in Fig. 1.14.1, which shows how the reliability of a product or system is related to investment cost; i.e., increased investment is required in order to improve reliability. This clearly shows the general trend that the incremental cost ΔC to achieve a given increase in reliability ΔR increases as the reliability level increases, or, alternatively, a given increase in investment produces a decreasing increment in reliability as the reliability increased. In either case, high reliability is expensive to achieve. The incremental cost of reliability ΔC/R, shown in Fig. 1.14.1 is one way of deciding whether an investment in the system is worth it. However, it does not adequately reflect the benefits seen by the utility, the customer, or society. The two aspects of reliability and economics can be appraised more consistently by comparing reliability cost (the investment cost needed to achieve a certain level of reliability) with reliability worth (the benefit derived by the customer and society.)

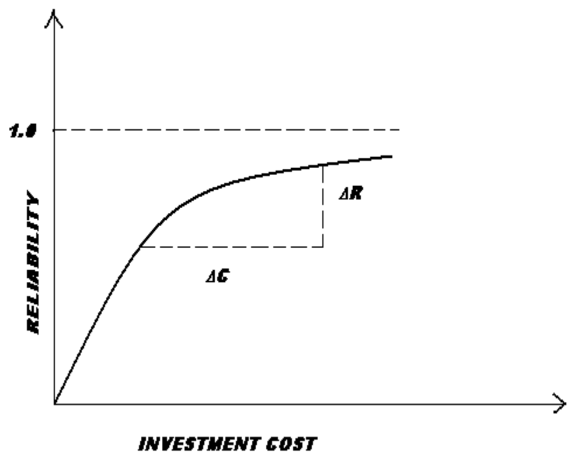
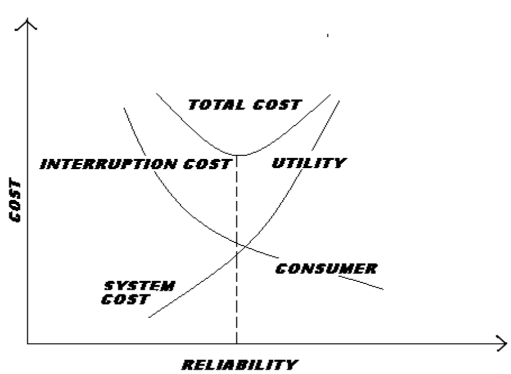


Figure 2.- Reliability Vs Investment Cost

This extension of quantities reliability analysis to the evaluation of service worth is a deceptively simple process fraught with potential misapplication. The basic concept of reliability cost/reliability worth evaluation is relatively simple and can be presented by the cost/reliability curves of Fig. 1.14.2 these curves show that the investment cost generally increases with higher reliability. On the other hand, the customer costs associated with failures decrease as the reliability increases. The total costs therefore are the sum of these two individual costs. This total costs exhibits a minimum, and so an "optimum" or



Various Cost Vs Reliability Figure

target level of reliability is achieved. This concept is quite valid. Two difficulties arise in its assessment. First, the calculated indices are usually derived only from approximate models. Second, there are number of studies and surveys have been done including those conducted in Canada, United Kingdom, and Scand via.

Conclusion: wind energy is the path growth of Indian energy need. Movement of wind energy occupied great role compare to conventional approach. Justification is given in terms of a review of these, together with a detailed discussion of the models and assessment techniques associated with reliability cost and worth evaluation. The function of a modern power system is to satisfy the system load requirement as economically as possible and with a reasonable assurance of continuity of the supply. The determination of just what is reasonable assurance continuity is an extremely difficult problem. The utilization of probability technique permits all the pertinent parameters to be in cooperated into the analysis of system reliability. The reliability evaluation can take two distinct forms it can serve as a prediction of average system performance over a relatively long period of time or it can be considered means of obtaining a consistent quantitative assessment of alternate facilities.

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