International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 03 | Mar 2023 www.irjet.net p-ISSN: 2395-0072

# RELIABILITY EVALUATION OF A WIND POWER PLANT IN THE MID REGION OF KARNATAKA STATE USING MATLAB

**Basawaraj Hebbale[1], Tejaswini C. Kamble[2]**

[1]*Assistant Professor, Dept. of Electrical Engineering YSPM's YTC Satara, Maharashtra, India*
[2] *Assistant Professor, Dept. of Electrical Engineering YSPM's YTC Satara, Maharashtra, India*

***

**Abstract -** *The goal of this study is to create a more straightforward technique to assess the dependability of electric power output from a system that combines conventional and wind energy conversion (WECS). As wind doesn't hurt the environment, it is a clean source of electricity. Yet, the results from using wind resources are not assured. The WECS produces a variable amount of power. So, the primary goal of this research is to create a method for assessing the dependability of the output power from a wind electric conversion system. The method employed the streamlined dependability model for the wind energy conversion system is in play here. Four variables are calculated using this methodology: the wind availability factor, the constant power output factor, the variable power output factor, and the mechanical failure factors. The height of the tower and station which is shape factor (β), the scale factor (α), and other turbine design elements must be taken into account in order to determine these variables. MATLAB is used to plot sensitivity graphs for the various important parameters.*

***Key Words***: wind energy conversion, Forced Outage Rate,

## 1. INTRODUCTION

The use of renewable energy sources is increasing popularity as a result of worries about global warming, the security of energy supply, and the resulting effects on the economy and environment(1). This is particularly clear in the case of converting wind power to electricity due to rapid technological advancements and large reductions in production costs. Globally, more and more multi-megawatt size units—both on-shore and off-shore—are being erected, and the rise in penetration levels that has followed has made numerous technical and financial issues public for serious thought and investigation.

An essential infrastructure for a country's general growth and development is provided by electricity. Hence, it is envisaged that the power system will continually produce and supply electricity in the required quantities, at competitive costs, and with approximately 100% reliability. Yet, the inconsistencies in the supply of electric power are caused by the mismatch between power generation and load characteristics (2). From an economic standpoint, achieving high reliability with extra generation capacity compared to load is not the best course of action. Because of this, probabilistic analyses are performed for the power systems throughout the early planning and operating phases in order to obtain the highest level of reliability while staying within budgetary restrictions.

Due to a lack of data, an absence of practical dependability approaches, and misconceptions regarding the importance and relevance of such evaluations, probabilistic evaluations of power systems were not conducted until the middle of the 1960s. Since the significant US Northeast blackout of 1965, much has altered. On November 9, 1965, the loss of electricity affected over 80,000 square miles and nearly 25 million people for almost 12 hours. Ontario in Canada and Massachusetts, Connecticut, New England, Rhode Island, Vermont, New York, and New Jersey in the United States were among the states without access to electricity. Reliability Councils were established in the US to define standards, communicate information, and improve power coordination in order to prevent the recurrence of such disasters in the future.

The building of new power plants using coal, natural gas, nuclear, etc. was prompted by the high energy needs brought on by the usage of sophisticated electrical equipment and changes in human lifestyle brought about by technical advancements. Issues including greenhouse gases, acid rain, an increase in the amount of CO2 in the atmosphere, and global warming were caused by the increased use of harmful resources to generate power (3). The need to deliver grid-friendly electricity utilising renewable energy sources resulted from this. Power has been generated since a few decades ago utilising both conventional energy sources and green energy sources like wind and solar. The amount of electricity produced by wind has significantly increased during the last 20 years. The cost of generating electricity from wind has dropped from 38 cents per kWh to 4 cents per kWh since 1980.

## 2. RELIABILITY OF WIND POWER

The success of wind-electric conversion system projects depends critically on the general stability of the electric power supply due to the increased penetration of wind-generated electricity into power systems. Low WECS unit dependability increases O&M costs, reduces system availability, and has a direct impact on project revenue. Loss of load probability, often known as LOLP, is a widely used metric to assess the dependability of the electric power supply (6). Since the availability of electricity from WECS is lower than that from traditional units, LOLP will rise as wind energy becomes more integrated into conventional power systems. This chapter discusses some of the significant causes of the decreased availability of electric power from WECS. By taking into account all of the primary elements affecting the availability of wind turbine electric power, a simplified technique to assess the forced outage rate is offered.

### 2.1. Forced Outage Rate (FOR)

One of the most crucial factors in the estimation of component reliability is the forced outage rate. When a component is forced out of service due to emergency circumstances, this is known as a forced outage (4). The term "forced outage rate" (FOR) refers to the component's long-term probability of being found in the down state.

### 2.1.1. Rate of Forced Outages for Conventional Generators

The "unavailability" of a generating unit is a common term used to describe FOR. According to its definition, it is the likelihood that the unit will experience a forced outage while running under certain conditions at some unspecified point in the future (6). Emergency situations may develop in the case of conventional generating units as a result of stochastic weather conditions, system behavior, customer demand, or component breakdowns.

If a generating unit has constant failure ( $\lambda$ ) and repair (µ) rates of and, respectively, and its forced outage rate is established by reliability studies, then

$$\text{FOR} = \frac{\lambda}{\lambda+\beta} = \frac{\sum down\ time}{\sum up\ time + \sum down\ time} \ldots\ldots\ldots\ldots 1$$

### 2.2. WECS Output Characteristics- Factors Influencing Electric Output Availability

A typical curve for power output from a WECS is shown in Figure 1. A wind-electric system begins producing electricity at what is referred to as the "cut-in speed" (Vci). As seen in Chart 1, it generates rated power (Pr) output over "rated wind speed" (Vr) (7). Wind turbines keep producing at their maximum capacity until the wind speed reaches the "cut-out" mark (Vco). The turbine is totally turned off after Vco to prevent any harm to its parts (6).

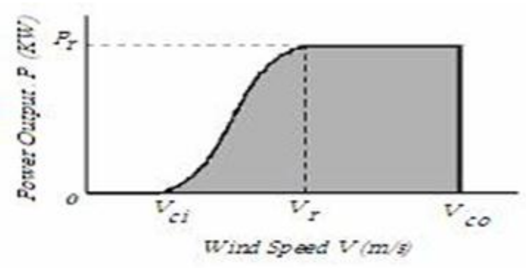

**Chart -1**: Power Output Curve

The following is a list of the main variables influencing the availability of WECS and, consequently, the availability of its power output:

1. A WECS can produce electricity only at wind speeds between Vci and Vco.

2. Only wind speeds between Vr and Vco are capable of producing the required amount of electricity.

3. A fluctuating power output that is less than the rated output is caused by the power curve's non-linearity from Vci to Vr.

4. Extreme weather causes mechanical failures by placing an excessive amount of electrical and mechanical stress on the system's components. Moreover, some components will malfunction due to regular wear and tear and strain. Severe mechanical failures cause the turbine to shut down, which prevents power output until the problem is fixed.

5. Beyond Vco, the grid is cut off from the wind turbine to prevent undue electrical and mechanical strain on system components.

### 2.3. WECS Power Output Curve Approximation

The approximate power output curve of a wind-electric system is shown in Chart 2. A straight line can be used to roughly represent the non-linear portion of the curve between Vci and Vr. The power output equation so becomes.

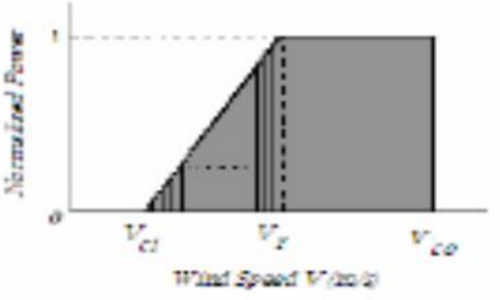

**Chart -2**: Power Approximation Curve

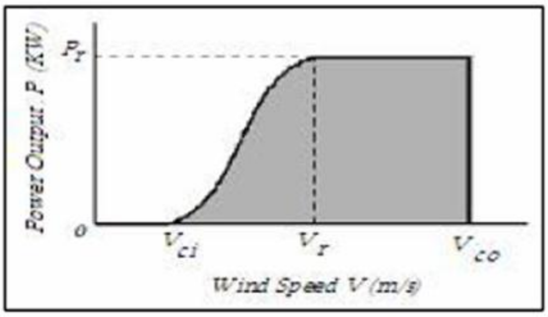

**Chart -3**: Expected Power Output Calculation for Variable Portion

## 2.4. WECS Power Output Curve Approximation

To account for their effects on the FOR value for WECS, every aspect that influences the availability of wind-powered systems must be assessed.

**(1) Wind Availability Factor ($P_{WA}$):** It is explained as the likelihood that the wind speed will fall between the cut-in and cut-out numbers.

$P_{WA}$ =P (Vci ≤ V ≤ Vco)

$$P_{WA} = \exp\left[-\left(\frac{Vci}{\alpha}\right)^{\beta}\right] - \exp\left[-\left(\frac{Vco}{\alpha}\right)^{\beta}\right] \text{.............. } 2$$

**(2) Constant Power Output Factor ($P_{Const}$):** The projected normalised power output in this speed range will be the likelihood of the wind speed lying in this speed range since rated power output occurs for wind speeds between Vr and Vco. Hence,

$$P_{cons} = \exp\left[-\left(\frac{Vci}{\alpha}\right)^{\beta}\right] - \exp\left[-\left(\frac{Vco}{\alpha}\right)^{\beta}\right] \text{...................3}$$

**(3) Variable Power Output Factor (PVar):** The following equation can be used to compute the expected value of normalised power output over the speed range from Vci to Vr. As depicted in Chart 3, the region from Vci to Vr is separated into n discrete intervals. The likelihood that the wind speed will be between any two numbers, such as V1 and V2 (Figure 2),

$$a_1 = P = (V_1 < V < V_2)$$

$$P_{Var} = \exp\left[-\left(\frac{Vci}{\alpha}\right)^{\beta}\right] - \exp\left[-\left(\frac{Vco}{\alpha}\right)^{\beta}\right] \text{...................4}$$

Next, for the speed range between V1 and V2, the anticipated normalized power output will be,

$$E(P_{1,2}) = a_1 * \frac{\left(\frac{V_1+V_2}{2}\right) - V_{ci}}{V_r - V_{ci}} \text{...............................5}$$

$$P_{WA} = \exp\left[-\left(\frac{Vci}{\alpha}\right)^{\beta}\right] - \exp\left[-\left(\frac{Vco}{\alpha}\right)^{\beta}\right] \text{.......................6}$$

The region from Vci to Vr's expected normalised power output can be computed by adding the expected normalised power outputs that were previously estimated in this manner for each brief interval in the variable section. Thus,

$$P_{Var} = {}^{\Sigma E}(P_{1,2}) \text{................................................7}$$

**(4) Factor for mechanical failures (PMech):** Given a mechanical component with a constant failure rate of "λ" per hour and a mean repair time of "r" hours, the forced outage rate is calculated as follows:

Forced Outage Rate ≡ λy ..................................................8

The mechanical components that make up a wind turbine have varying rates of failure and repair. The wind turbine stops working when one of its major components fails. Hence, all of the components can be viewed to be logically in sequence from the perspective of reliability. The FOR of the mechanical system will then be the total of the FORs of each component.

$$FOR_{Mech} = \Sigma\lambda_i r_i \text{.............................................9}$$

Hence,

$$P_{Mech} = 1 - FOR_{Mech}$$

The dependability R for a WECS can be written as the sum of all the factors mentioned above.

R = $P_{WA}$* E ( P )* $P_{Mech}$ ................................10

Where

$$E(P)\_P_{var} + P_{const}$$

## 3. RESEARCH EXAMPLES

The chapter assesses the impact of integrating wind energy into a conventional generation system using the ideas of FOR and WECS' expected power production. The utilisation of publicly accessible failure data for wind power facilities owned by Suzlon Global Services Limited, Harappanahalli, Jajikalgudda, Chitradurga, Gadag, and Hassan is used in the example studies.

### 3.1. FOR and WECS's Estimated Power Output

Three distinct wind regimes—low; moderate, and high—with the appropriate Weibull parameters are selected for the investigation and are listed in Table 1. Cut-in, rated, and cut-out wind speed values are chosen to be 3.6 m/s, 8 m/s, and 21 m/s (1 mile/hr 2.24 m/s), respectively. Data on component failures are shown in Table 2 and are drawn from published literature. The predicted power production, wind availability factor, and WECS reliability values are shown in Table 3 for three distinct wind regimes with the same component failure. As can be observed, depending on the wind regime, predicted power output ranges from 31% to 87% of the rated power (8). Higher predicted power output values, greater unit reliability, and lower FOR values are produced by improved wind regimes. The FOR values in particular are a great deal higher than the corresponding values for traditional generators.

**Table -1:** On the harapanahalli site, weibull distribution factors

| Wind Speed | α (m/s) | β |
|---|---|---|
| Low | 5.07 | 1.31 |
| Moderate | 9.7 | 2.00 |
| High | 15.55 | 3.10 |

**Table -2:** On the Chitradurga site, weibull distribution factors

| Wind Speed | α (m/s) | β |
|---|---|---|
| Low | 3.17 | 1.77 |
| Moderate | 9.00 | 2.10 |
| High | 14.4 | 3.11 |

**Table -3:** On the Kappatagudda site, weibull distribution factors

| Wind Speed | α (m/s) | β |
|---|---|---|
| Low | 2.84 | 1.7 |
| Moderate | 9.6 | 1.8 |
| High | 15.55 | 2.91 |

**Table -4:** Calculated outcomes for the location of Harapanahalli

| Wind Speed | Low | Moderate | High |
|---|---|---|---|
| E(P) | 0.3159 | 0.6867 | 0.8709 |
| $P_{WA}$ | 0.5265 | 0.8621 | 0.9118 |
| $FOR_{Mech}$ | 0.0059 | 0.0059 | 0.0059 |
| R | 0.1653 | 0.5885 | 0.7892 |
| $FOR_{Pow}$ | 0.8347 | 0.4115 | 0.2108 |

**Table -5:** Calculated outcomes for the location of Chitradurga

| Wind Speed | Low | Moderate | High |
|---|---|---|---|
| E(P) | 0.0579 | 0.5553 | 0.8351 |
| $P_{WA}$ | 0.3021 | 0.8695 | 0.9476 |
| $FOR_{Mech}$ | 0.000379 | 0.000379 | 0.000379 |
| R | 0.0175 | 0.4827 | 0.7911 |
| $FOR_{Pow}$ | 0.9825 | 005173 | 0.2089 |

**Table -6:** Calculated outcomes for the location of Kappatagudda

| Wind Speed | Low | Moderate | High |
|---|---|---|---|
| E(P) | 0.0482 | 0.5892 | 0.8243 |
| $P_{WA}$ | 0.2724 | 0.8511 | 0.9107 |
| $FOR_{Mech}$ | 0.000216 | 0.000216 | 0.000216 |
| R | 0.0131 | 0.5013 | 0.7505 |
| $FOR_{Pow}$ | 0.9869 | 0.4987 | 0.2495 |

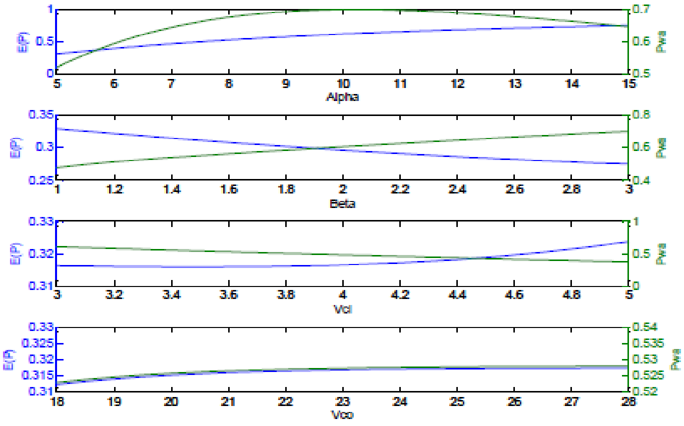

**Chart -4**: High-speed charts for the Harappanahalli Site

## 4. CONCLUSIONS

Repair times for mechanical components and approximations of output characteristics determine the forced outage rate for WECS. Key factors are established and mathematically stated using weibull parameters. These factors' sensitivity studies to changes in various parameters are looked at. Data on forced outage rates are used to assess the wind power system's dependability. Failure information for wind energy conversion systems is gathered from a number of locations. Considered are elements including expected power output sensitivity, wind availability, and other design parameters like cut-out speed, rated speed, and cut-in speed. Findings are displayed graphically. High wind regimes produce greater predicted output power values, lower forced outage rate values, and good reliability as expected.

## REFERENCES

[1] R. Billinton and M. P. Bhavaraju, “Generating Capacity Reliability Evaluation”, Transactions of the EIC, Vol. 10, No. C-5, October 1967.

[2] World Wind Energy Association, New World Record in Wind Power Capacity: 14,9GW added in 2006 – Worldwide Capacity at 73,9 GW, Press Release, Bonn/BuenosAires/Cape Town/Melbourne/New Delhi, 29th January

[3] R. G. Deshmukh and R. Ramakumar, “Reliability Analysis of Combined Wind-Electric and Conventional Generation Systems”,Solar Energy28(4), 345-352, 1982.

[4] Sami H. Karaki,Riad B. Chedid and Rania Ramadan, “Probabilistic ProductionCosting of Diesel-Wind Energy Conversion Systems”,IEEE Transactions on Energy Conversion, Vol. 15, No. 3, September 2000.

[5] P.W. Carlin, A.S. Laxson, E.B. Muljadi, “The History and State of the Art of Variable-Speed Wind Turbine Technology”, Report, NREL/TP-500-28607, February2001.

[6] Ramakumar R., “Wind-Electric Conversion Utilizing Field Modulated Generator Systems”, Solar Energy, 20(1), pp.109-117, 1978.

[7] Blaabjerg Frede, “Photovoltaic and Wind Energy in Distributed Power Systems”, PELINCEC tutorial, Warsaw, 18th December 2003.

[8] Ryan Wiser and Mark Bolinger, “Annual Report on US Wind Power Installation,Cost, and Performance Trends: 2006”, an Annual Report by U.S. Department of Energy,May, 2007.