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Analysis of Wind Power Site Performance Evaluation by using MATLAB

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Abstract: Renewable energy sources, especially wind turbine generators, are considered as important generation alternatives in electric power systems due to their non-exhausted nature and benign environmental effects. The main task of a professional wind measurement, used for wind power generation application, are wind measurement for accuracy and reliability of measuring needed for profit prognosis and wind measurement for the monitoring of already installed wind farms.In this paper present Before the installation of a wind turbine or farm it is recommended to analyse the site professionally. The collected meteorological data should accurately describe the wind potential of the site. That is why the measuring systems should meet the highest quantity demand concerning the accuracy and reliabilityThis study shows the probabilistic analysis of wind power generation from wind turbine generators installed at geographic locations.

Keywords: Wind energy, reliability evaluation, WTG, probabilistic model, WECS, LOLE, Wind power generation.

I. INTRODUCTION

The growing consumption of energy has resulted in the country becoming increasingly dependent on fossil fuels such as coal, oil and gas. Rising prices of oil and gas and their potential shortages have raised uncertainties about the security of energy supply in future .Hence, there is a primary need to use renewable energy sources like solar, wind, tidal, biomass and energy from waste material. They are called non-conventional sources of energy. Wind is simply air in motion produced by differential heating of earth's surface and atmosphere by energy from the sun. The earth receives 1.74 x1017 W of power per hour from the sun, from which 1%or 2% is converted to wind energy.In a wind turbine, the kinetic energy of the wind acting on the rotor blades is converted into torque or mechanical energy for rotating the shaft which is then transferred through the gear box to the generator and the generator produce electrical energy. The project reveals a reliability planning method for a generating system with a wind energy system with a wind energy conversion system (WECS).The electricity production by a WECS in a given area is depending on many factors. These factors include the wind speed conditions in the area and the characteristic of the wind turbine generator particularly the cut-in, rated and cut-out wind speed parameters. A wind turbine is not operational when the speed is below the cut-in speed and will be stopped for safety reasons if the wind speed is higher than the cut-out speed. In both the extreme cases, the power output is zero. Different types of wind turbine are commercially available on the market. Wind turbines range from less than 1KW to as large as 5MW or more.

Different authors have focused their research to select best suitable wind turbine generator that maximizes the capacity factor. The capacity factor is defined as the ratio of the expected output power to the rated power of the wind turbine generator. Capacity factor for several WTG were computed having in view the distribution of wind speed. This method gives an idea of characteristic of WTG based on wind speed associated to a given area, but completely ignores the load profile. Having in view this issue, the project aims reliability evaluation method applied to have comparison between different WTG types included in WECS and to evaluate the reliability parameters.

II. RELIABILITY EVALUATION OF ELECTRICITY GENERATING SYSTEM

The basic generating unit parameter used in static capacity evaluation is the probability of finding the unit on forced outage at some distant time in the future in the generation system the total system generation is evaluated to find the system adequacy to meet the total system load demand. The system model in generation is shown in the figure 1.

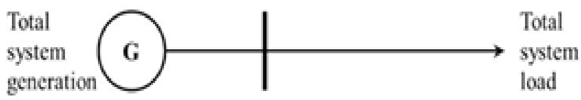

Fig.1Generation system reliability model

III.RELIABILITY INDICES

Reliability has been and always is one of the major factors in the planning, design, operation, and maintenance of electric power system. Generation system reliability

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focuses on the reliability of generators in the whole electric power system where electric power is produced from the conversion process of primary energy (fuel) to electricity before transmission. The generation system is an important part of the electricity supply chain and it is crucial that enough electricity is generated at every moment to meet the demand. Generating units will occasionally fail to operate and the system operator has to make sure that enough reserve is available to be operated when this situation happens.

Reliability of the generation system is divided into adequacy and security. System adequacy relates to the existence of sufficient generators within the system to satisfy the consumer load demand or system operational constraints.

IV. LOSS OF LOAD EXPECTATION (LOLE)

The LOLE risk index is the most widely accepted and used probabilistic method in system reliability evaluation for generating systems. Two models are required and employed. One is the previously studied Load Duration Curve (LDC), and the other is the COPT. These two models are convolved (combined) in the process. The unit of the LOLE is in days per year (d/y) or hours per year (h/y).

The basic reliability index used in this work is Loss of load expectation; it is the average number of hours for which the load is expected to exceed the available generating capacity.

And it is given in the equation.

$$LOLE = \frac{1}{N} \sum Pi\ Ti$$

In addition to this basic reliability index some more indices are used those are described in the equation 1 and 2 respectively in the subsection.

ENERGY INDEX OF RELIABILITY (EIR)

It is the Energy Index of Reliability and is given by,

$$EIR = 1 - \frac{EENS}{EnergyDemand}$$

V. WIND TURBINE PARAMETERS

1.POWER COEFFICIENT: With the help of wind blades the kinetic energy of wind is converted into mechanical energy which is used to drive the shaft of wind generator. The power coefficient C_p converting efficiency is given as:

$$\mathbf{C_p = \frac{P_{me}.Out}{P_w} = \frac{P_{me}.Out}{\left(\frac{1}{2}\right)\rho A V^3}}$$

Where, P_{me}Out – Captured Mechanical, PowerP_w- Available Wind Power – Air Density **,**A – Blade Swiftness

2.POWER CONVERSION EFFICIENCY (η):The total power conversion efficiency from wind to electricity is given by,

$$\eta = C_p \eta_{gear}\ \eta_{gen}\ \eta_{ele}$$

Where,η_{gear} –Gearbox Efficiency;η_{gen} – Generation Efficiency; η_{ele} - Electrical Efficiency.

3.CUT IN WIND SPEED:This is the minimum wind speed at which the turbine blades overcome friction and begin to rotate.

4. CUT OUT WIND SPEED:This is the speed at which the turbine blades are brought to rest to avoid damage from high winds. Not all turbines have a well-defined cut-out speed.

5.RATED WIND SPEED:Wind turbines are most commonly classified by their rated power at a certain wind speed. The rated power is usually defined as the maximum power output and the rated wind speed is the wind speed at which the turbine reaches its rated power output.

6.WIND TURBINE POWER GENERATION EVALUATION: This is the data obtained from the turbine manufacturers installed at the wind site. This data contains the power output of the wind turbine generator at different wind speed and the rated wind speed for the rated power output, cut-in wind speed, cut-out wind speed of the wind turbine. The power generated can be calculated using the power formula given in equation

$$Pm = Cp\left(\frac{1}{2}\rho A V^3\right)\ldots\ldots\ldots\text{watts.}$$

Where, Cp is the capacity factor given by the turbine manufacturer

ρ is air density at the wind site kg/m3

A is area swept by the turbine in m^2

u is the wind speed in m/sec

VI. THREE STATE MODEL FOR WTG SYSTEM

The output of a wind turbine generator (WTG) is a function of the wind speed. In this work the WTG is represented by a three-state model. State Up1, State Up2 and State Down are three states, which represent variable, constant and no outputs, respectively, in terms of wind speed variation. The WTG three-state model is shown in Figure. A wind farm usually consists of many units and therefore the specified wind velocity is assumed to be the same for all the units in the farm. The power output of a wind farm is the summation of the output of all the available units. The probability of turbine being in three different states is calculated according to the state representation and it is described by the relation as shown below. Probability of WTG in state UP1 is,

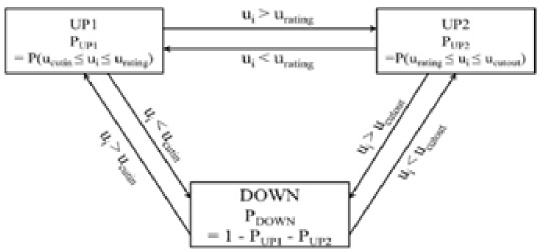


Fig. 2 Three state model for WTG system

A.PUP1 = P(ucutin≤ui≤urating)
B. Probability of WTG in state UP2 is,
C. PUP2 = P(urating≤ui≤ucutout)
D. Probability of WTG in state DOWN is
E. PDOWN = 1 - PUP1 - PUP2 Units

Where, ui is the measured wind speed at the interval.

VII. CALCULATION OF PLANT FACTOR AND PLANT AVAILABILITY FACTOR

Since wind speed is not constant and continuous, a wind farm's annual power production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. Plant factor is the theoretical maximum ratio of actual productivity in a year. Typical Plant factors [4] are 15– 50%; values at the upper end of the range are achieved in favourable sites and are due to wind turbine design improvements.

The plant factor is calculated by the formula given by,

%PLANT FACTOR =

$$\frac{ACTUAL\ POWER\ GENERATED\ IN\ SIMULATED\ TIME}{RATED\ POWER\ GENERATED\ IN\ SIMULATED\ TIME} \times 100$$

The value of plant factor between 15% to 50% is better for wind power generation. When wind is continuous the plant factor will more

The plant availability is the wind turbine generator which is available to generate electric power. This is obtained by following equation

PLANT AVAILABILITY FACTOR =

$$\frac{PLANT\ AVAILABLE\ FOR\ GENERATION\ IN\ HOURS}{TOTAL\ HOURS\ IN\ THE\ SIMULATED\ DATA} \times 100$$

PLANT UNAVAILABILITY = 1- PLANT AVAILABILITY

CALCULATION FOR LOLE:The basic reliability index used in this work is loss of load expectation.it is the average number of hours for which the load expected to exceed the available generating capacity.

And it is given by equation,

$$LOLE = \frac{1}{N}\sum PiTi \ldots\ldots\ldots\ldots\ldots..hours/year$$

VIII. WIND ROSE GRAPH

A wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. Historically, wind roses were predecessors of the compass rose (found on maps), as there was no differentiation between a cardinal direction and the wind which blew from such a direction. Using a polar coordinate system of gridding, the frequency of winds over a time period is plotted by wind direction, with color bands showing wind speed ranges. The direction of the longest spoke shows the wind direction with the greatest frequency.observations for each direction and wind speed class has been specified for each yellow cell, three charts are produced: the wind rose, the wind direction distribution and the wind speed distribution. If the average wind speed for each direction is also specified, then a fourth chart is produced representing the rose of the average wind.

The different wind speed frequencies sum up to give the total length of the arm. The wind rose plotted with the Microsoft Excel or Open Office files does have such feature. If you need more professional wind roses and more complex analysis of your data, you might want to evaluate Wind Rose PRO.

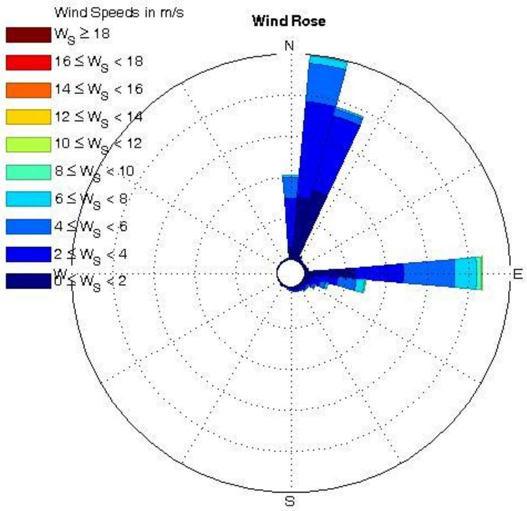
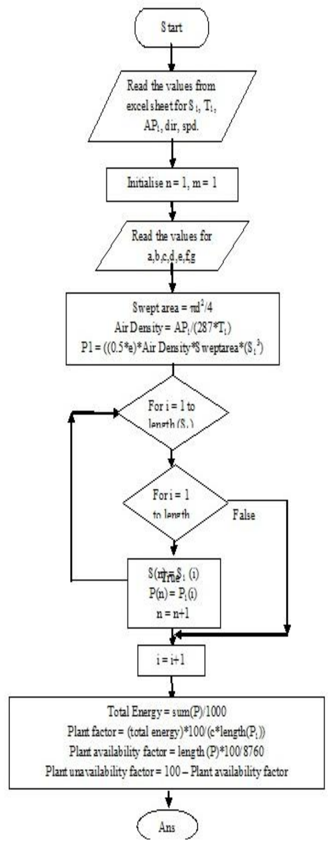


Fig.3 Wind rose diagram

IX. FLOW CHART



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X. INPUT TURBINE DETAILS

Enter the cutInSpeed(in m/s)
a =5
Enter the cutOutSpeed(in m/s)
b =20
Enter the Rated Capacity of Wind Turbine(in kW)
c =600
Enter the Rotor Diameter(in m)
d =40
Enter the Performance coefficient of the turbine
e =0.2083
Enter the rated wind speed of the turbine(in m/s)
f =16
Enter the % load on the Wind Power Plant
g =60

I.

XI. MATLAB RESULT

RELIABILITY EVALUATION OF WIND POWER GENERATION SYSTEM
===
Total Energy Generated in a Year(in kW) = 49022.152480
Plant Factor = 6.621036
Plant availability factor = 14.086758
Plant unavailability factor = 85.913242

===
RELIABILITY INDICES OF WIND POWER GENERATION SYSTEM
===
Loss of Load Expectation (LOLE) = 1234 Hours/Year
Expected energy not supplied (EENS) = 395596.041394 kWhr
Energy index of reliability (EIR) = 0.465700

===
Three State Model for WTG System
===
Probability of WTG in state UP1 is = 0.140753
Probability of WTG in state UP2 is = 0.000114
Probability of WTG in state DOWN is = 0.859132

XII. CONCLUSION

It very important to develop probabilistic reliability evaluation technique useful for electric power industries which are expected to include power form wind. The benefits from wind sources are largely said by the wind organization at the wind farm site.

It is, therefore, very important to obtain suitable wind speed simulation models and appropriate technique **STO** develop power generation model for **WTG** in reliability evaluation. In this work the plant factor is found to be 26.16% and it is very useful to generate power from the wind in that wind site. And the plant available for generation is found to be 67.72%.

Reliability indices LOLE, EENS and EIR are found to be 221.70hrs/year, 59987.28932kWh and 0.9885 respectively. These indices show that the plant installed at the said site work satisfactorily.

This work becomes more valuable, when we consider wind turbine generator and turbine outage models.

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