Studies regarding the use of renewable energy sources to produce electricity

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***Abstract*—** Due to prolonged use of wind turbines they must be characterized by high reliability. This can be achieved through a rigorous design, appropriate simulation and testing and proper construction. The reliability prediction and analysis of these systems will lead to identify critical components, increase operating time, minimizing failure rate and minimizing maintenance costs. The Monte-Carlo simulation of parameters of helical wind turbine with vertical axis includes elements of reliability theory and notions of probability and statistical inferences. To estimate the produced energy by wind turbine, an evaluation approach based on Monte Carlo simulation model is developed which permits us to estimate the probability of minimum and maximum parameters. In our simulation process we used triangular distributions.
The case study consists on determination of statistical parameters of assumed distribution, in order to estimate the reliability and unreliability functions, probability density function (pdf) and hazard rate (failure rate) of the helical wind turbine with vertical axis. Based on experimental tests, it was calculated the variation of power produced for different wind speed, respectively it was calculated the Weibull distribution of wind probability and the power which is generated. The analysis of experimental results indicates that this type of wind turbine at low wind speed is more efficient than other wind turbine with horizontal axis and with three blades.

***Keywords*—**About four key words or phrases in alphabetical order, separated by commas.

I. Introduction

ENVIRONMENTAL pollution, greenhouses effect, intensification due to the wide ranging of organic fuel, as well care of energy supply to the future generations caused the accelerator development of technologies oriented to the realization of renewable energy sources. Environmental concerns are growing, interest in environmental issues is increasing and the idea of generating electricity with less pollution is becoming more and more attractive. Unlike conventional generation systems, “fuel” of the solar photovoltaic energy and wind energy is available at no cost.

Wind power is today the fastest growing electricity generation technology. Impressive annual growth rates of more than 35 % between 2001 and 2010 have made Europe into frontrunner in wind energy technology development. All around the world there is a number of small isolated communities, like island and rural villages without access to a large electricity grid. Further, in many places, due to remoteness and cost, it is unlikely that a main grid connection will ever be established, as telecommunications stations, inquiring centers, etc.

According to rough estimates, a significant number of isolated consumers are spread all over Europe, including mainly country houses, inaccessible farms, shelters, telecommunications stations, small islands, light houses, etc.

In Romania, a remarkable number of remote consumers possess an outstanding wind potential. Unfortunately, the absence of an electrical network in their major area or the prohibitively high consumers cost –due to large distances and peculiar topography – force the remote consumers to cover their urgent electrification needs to use small diesel electric generators, with all the known problems of pollution of environment and noise.

In this respect, an alternative can be the wind turbine. Wind turbine systems are rapidly becoming an economically viable source of renewable energy. Two key elements of wind turbine technology are turbine performance and availability.

Turbine performance – energy produced is a function of design variables and a highly stochastic operating environment. Machine availability is a function of system reliability, and it is impacted by design, operating environment and maintenance considerations.

Most wind turbine manufacturers include failure analysis as an essential part of their continuous quality improvement process.

Evaluating the root cause of a major component failure is essential to determining if the failure is due to manufacturing quality, product misapplication, design error, or inappropriate design assumptions..

The traditional method of measuring wind turbine performance under laboratory conditions in ideal circumstances will always tend to be optimistic and rarely reflect how the turbine actually behaves in a real situation:

- local wind conditions, nearby obstructions, power demand, etc.

There will also be deterioration in performance with time due to wear and tear.

II. Characteristics of wind turbine

The helical wind turbine with vertical axis, that will be analyzed and tested for Romanian regions in order to estimate the reliability (unreliability) function and hazard rate, it was designed to generate 1000 W.

This type of wind turbine is easy to mount on the roof of a house, having the main advantage of don't need to be pointed into the wind direction with a system as other types of wind turbines. In the same time it works without any noise and the shape of the rotor make these turbines to be with any damage for the birds [1]. The rotor of this wind turbine was made by the FINEX Company, patented in Romania, and it is with three blades with fiber glass material (Figure 1), [2].

Fig. 1 Analyzed wind turbine with vertical axis helical type

The rotor was mathematically designed and tested in experimental conditions on the car adapted as a mobile laboratory, where it was measured the next parameters:

- output power of turbine [W];
- wind speed [m/s];
- rotational movement of rotor shaft [rpm];
- air temperature [°C]

Also, it was measured the following parameters:

- turbine rotational speed;
- wind speed;
- system voltage;
- system current.

Because the rotational movement of the rotor shaft is of maximum 120 rpm, it was needed to use a device that increase the rotation movement and ensure optimum conditions of working for the permanent generator magnet. The electric current is three fazed and it is needed to use a device to modify it in order to be measured as good accuracy as possible the current generated at different number of rotor shaft rotation.

One rotor can generate a power of 600 W, at the wind speed of 12 m/s, and by mounting on a common axle of two rotors it is obtained a total power of 1200 W.

3 Monte-Carlo simulation of parameters of helical wind turbine with vertical axis

Since the beginning of the Seventies XX century, an intensive development of the use of Monte Carlo method has taken place due to a massive increase of the new generations computers' processing power. At the same time, the formalism linked with the Monte Carlo method application has been intensively developed [4].

Particular role in learning the reality could be attributed to the methods using occurrences treated as random, but only a development of sciences associated with random processes, provided rational basis to evaluate methods and the results of examining these processes. It turned out that, rational treating of the occurrences, whose natures - as random - is essentially irrational, can be the source of useful knowledge about objectively learned reality. Formalized approach to learning the reality – thanks to the random reality created by people – found its place in science under the name of Monte Carlo method, which can be associated not only with a world's hazard capital, but also – what is important – also with elegance, as the Monte Carlo method itself, and eternal longing of people for power, either material or intellectual [4].

In Monte-Carlo method calculations are repeated several times using the same, deterministic model of a physical phenomenon, but each time for different, randomly selected values of particular arguments, from among uncertainty range given a priori.

The Monte-Carlo technique is a device for modeling and simulating processes that involve chance variable [4].

By studying the distributions of results, we can see the range of possible outcomes and the most likely results. Using simulation, a deterministic value can become a stochastic variable. We can then study the impact of changes in the variable on the rest of the spreadsheet.

Recent popularity of the triangular distribution can be attributed to its use in Monte Carlo simulation modeling and its use in standard uncertainty analysis software. The triangular distribution is also found in cases where two uniformly distributed errors with the same mean and bounding limits are combined linearly [3].

Uncertainties may be modeled by the distribution where Johnson and Kotz (1999) discuss the asymmetric triangular distribution. Suppose that:

$$x_i = \begin{cases} a + \sqrt{z_i \cdot (b-a) \cdot (m-a)}, a < x_i \le m \\ b - \sqrt{(1-z_i) \cdot (b-a) \cdot (b-m)}, m < x_i \le b \end{cases},$$

(1)

where $\hat{a}$ is lower estimate, $\hat{m}$ is most likely estimate value and $\hat{b}$ is maximum estimate value.

The mean and standard deviation are given by:

$$\mu = \frac{a+m+b}{3}, \quad (2)$$

$$\sigma = \sqrt{\frac{a^2 + m^2 + b^2 - am - ab - mb}{18}}. \quad (3)$$

The distribution emerges in numerous papers [1], [2] and the probability density function for asymmetric three-parameter is given by:

$$f(x) = \begin{cases} \frac{2(x-a)}{(b-a) \cdot (m-a)}, a < x \le m \\ \frac{2(b-x)}{(b-a) \cdot (b-m)}, m < x < b \\ 0, elsewhere \end{cases}. \quad (4)$$

The development of simulation program was based on predefined statistical functions in Excel and MathCAD software. The Monte-Carlo simulation program comprises the steps described in Fig. 2.

Cumulative distributions functions are usually presented graphically in the form of ogives, where we plot the cumulative frequencies at the class boundaries. The resulting points are connected by means of straight lines, as shown in figure 3, figure 5 and Fig. 6.

Cumulative distribution function is defined by:

$$F(x) = \begin{cases} 0, x \le a \\ \frac{(x-a)^2}{(b-a) \cdot (m-a)}, a < x \le m \\ 1 - \frac{(b-x)}{(b-a) \cdot (b-m)}, m < x < b \\ 1, x \ge b \end{cases}. \quad (5)$$

If the relative frequency is plotted on normal probability graph paper, the ogive will be a straight line for a normally distributed random variable.

The normal probability graph paper is a useful device for checking whether the observations come from a normally distributed population, but such a device is approximate. One usually rejects normality when remarkable departure from linearity is quite evident [2].

The Monte-Carlo simulation of parameters of helical wind turbine with vertical axis includes elements of reliability theory and notions of probability and statistical inferences. In our simulation process we used triangular distributions because the input data can be obtained very easily and it does not require laborious investigations.

The most important parameter that influence the reliability of wind turbine with vertical axis it is wind speed. In this case, interesting results may be expected from the implementation of the Monte-Carlo simulation.

Considering the wind speed between 4 m/s and 6 m/s for Romanian analyzed region.

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Considering the wind speed between 4 m/s and 6 m/s for Romanian analyzed region, it can be determined the cumulative probability expressed by cumulative frequency curve (ogive chart).

Another measure of helical wind turbine reliability is the annual energy production. In a similar manner, it can be simulated the daily and annual energy output.

It can be observed that the probability to exceed the maximum value of wind turbine parameters it is approximately 10% for wind speed, 4% for daily energy and 9.7% for annual energy. These percentages are obtained for different intervals set as acceptable limits.

III. Conclusions

As it has been proved by a lot of researchers and energy engineers, it will be a very positive and economic solution the replacement of bigger part of diesel generators with stand-alone hybrid energy systems, especially in medium and high wind and solar potential locations. Power systems which can generate and supply electricity to such remote locations are variously termed -"Remote decentralized, autonomous, or stand alone".

The main advantages of this type of wind turbine with helical rotor which main rotor shaft runs to the flow streamlines, from other type of wind turbines with horizontal axis are:

- high reliability;
- in isolated area, with no connection to national network, it can be used with good results a wind turbine with vertical axis helical type;
- simplicity in construction and good rigidity;
- smaller cost with 20 % as similar turbines;
- specific power bigger on the active surface;
- high torque moment at starting;
- at the wind speed bigger than 20 m/s is self-breaking without mechanical components, due to its original shape of rotor;
- it doesn't need orientation after the wind direction;
- it can works to high wind speed, as 50 m/s;
- it is only one wind turbine that is accepted by environmental agencies, because it doesn't kill birds;
- doesn't make noise during its function;

Application of Monte-Carlo simulation allows us to determine the cumulative distribution curve and it helps to estimate the probability to obtain the daily and annually energy output with a specified wind speed. These charts can be used to establish upper and lower specification limits on energy production and this information can be very useful to optimize the parameter and components of wind turbine. Based on simulation principles, it was performed the statistical processing of experimental data. By this means, it were determined the wind speed, the output power and annual energy output.

Considering this parameter, it was estimated the reliability function, unreliability functions, and failure rate. So, the Cumulative distribution curve indicates the probability that it will be obtained the daily or annual energy output. Each time when the simulation is executed, the cell will be updated to show a random value drawn from the specified distribution.

reliability modeling and analysis of wind turbine permits us to understanding and minimizing wind turbine operation and maintenance costs. Information derived from these measurements can help to identify where the problems are. Further interpretation of the data could help to optimize the wind turbine and it could assess if it has been chosen the optimum parameters of the system. After the tests results was demonstrated the advantages of this type of wind turbine with vertical axis, against the other types of wind turbines patented in the world. In the time that will follow, based on the tests in laboratory and in aerodynamic tunnel, we intend to improve its performances.

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