A STATISTICAL ANALYSIS OF WIND SPEED DATA FROM A SPECIFIC SITE IN ORDER OF OPTIMAL OPERATING OF WIND TURBINES

Alexandru-Mihnea SPIRIDONICĂ[1], Cornel IFTIME [1]

Email: aspiridonica@ee.tuiasi.ro

Abstract

The surprising evolution from the last decade in the area of renewable energy has triggered the emergence of the new technical challenges for both the power system operators and for the project developers of this area. One of this challenges refer to the analysis, from the statistical view, of the wind parameters (speed, direction, frequency, amplitude) on relevant time intervals. A detailed analysis of the wind speed values recorded in a specific site leads to the generation of results that can lead to the determination of optimal values for the electric power generated at each time point by the wind turbine located in that area. Very important is the identification of sign changes and hence the time intervals during which the wind turbine does not work because these has a major importance in the stage of initial estimation of power energy generated and also for the estimation of average lifetime of a wind turbine on a specific site with various variation regimes of wind speed.

Key words: wind turbine, wind speed, power systems, roughness coefficient

The continuous integration of wind power plants in the power systems determine the occurrence of important problems for transport and distribution operators which must ensure the operations in a completely safety manner of the system, keeping the energetic parameters in permissible limits. Much of these problems are partially or totally solved through mandatory conditions to be met by any wind turbine that operates in an integrated system.

Unlike the conventional power plants, where the electric generated power can be controlled or modified in any time through direct intervention in the values of the inputs, in generating plants using renewable energy, especially wind turbines, the control of the amount of flow energy can be exercised in a lesser extent, only by limiting the output power. The main factor that contributes to this limitation of human intervention is continuously variability of wind speed, which is the raw material of the wind turbines. Therefore, a more complex and detailed analysis of how this parameter varies on short, medium and long time allow optimal decisions on the operation of a wind turbine in an integrated system of wind turbines.

These integration regulations specially adopted for wind turbines were established because of high variability degree of energetic parameters of the wind potential and electrical power produced, and because the complexity, diversity and innovation of the used conversion systems (synchronous of asynchronous electrical generators, with or without gearbox, with voltage converter).

As a response to, the fully justified, more severe integration conditions, wind generator manufacturers and operators must be able to comply at any time requisite quantity and quality parameters. These parameters can be respected only by a very advanced technical design, but also by a proper choice of the wind turbine type. This choice can be made through the technical features of the turbine and the specific parameters of the site in that the wind turbine is installed. Among general methods for the analysis of statistical databases, for this application it has been chosen a method of descriptive statistics, the determination of some intervals regarding the wind speed variation. The determination of these intervals has been the basis of the development of an algorithm that determine the typical values (the length of the interval, the number of sign changes, the length of some subintervals from the intervals) of the databases for doing the analysis.

MATERIAL AND METHOD

The data used for this statistical analysis were received from the Faculty of Electrical Engineering, Mathematics and Computer Science of Technical University of Delft, Holland. The data were recorded from 1st of January 2006 to 31st December 2008 and with a sampling interval of one minute at the height of 18 meters, by using an

[1]"Gheorghe Asachi" Technical University of Iasi, Faculty of Electrical Engineering

anemometer installed on the faculty. A first step was the realization of an estimation algorithm of wind speed values at the height of 70 meters. For testing and presentation of the algorithm we considered the month of January 2006, but the algorithm can be implemented for each month of a calendar year.

For establishing the wind value at the height of 70 meters we used the formula (1), with which it is possible to calculate the wind speed at desired height by knowing the measured speed by anemometer at the height of 18 meters and by using a value of the roughness coefficient:

$$\frac{v_1}{v_2} = \left(\frac{h_1}{h_2}\right)^{\alpha} \quad (1)$$

Using the data processing at the height of 70 meters it can estimate a minimum of wind energy potential of the site and therefore a minimum of electricity generated. If the wind turbines would be installed at over 70 meters then the resulting production would be higher than that from the present analysis.

As we said above, the data were recorded with a sampling interval of one minute and the minutes at the data were recorded were converted into times. We established that the lower limit at which the wind turbine operation starts is 4m/s, the next step is established at 7.5 m/s, the nominal value at which the wind turbine produces maximum of the energy is 10.5 m/s and the step of 13 m/s is the upper limit at which the wind turbine is used without major requests and can produce energy at nominal power in normal working conditions. For speeds over 13 m/s the wind turbine is more used so that it must be equipped with more performance equipment that implies much higher costs. In the next figures are presented the specific operating curves that work with fixed or variable speed:

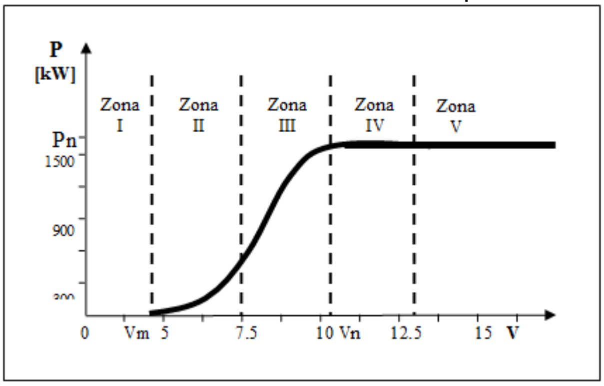

Figure 1 **Characteristic power curve for variable speed wind turbines**

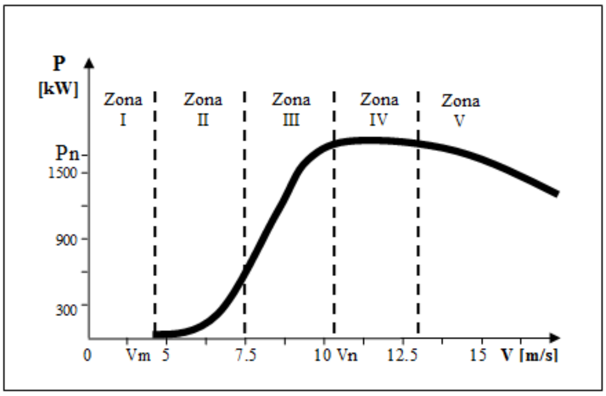

Figure 2 **Characteristic power curve for fixed speed wind turbines**

After establishing the reference values from above, the program determines the times for that the values of wind speed are within the specified intervals. So, it can be identified the time intervals for that the wind speed lies in a certain domain and depending on the length of that interval it can be determined the time for that the wind turbine was in a particular operating regime (zone I - V). Next, it were determined the intervals for that it was registered a certain minimum number of operating times. This minimum number was chose as 30, representing the time (30 minutes) for that the wind turbine runs without interruption in a certain regime. The results of these operations realized by the algorithm are highlighted through graphics that are then interpret in order to identify of those functioning areas with high density. Identifying the high density areas it may define a specific of wind speed evolution for the chose interval of time (one month) and can be also observed the period from interval (number of times) for that the wind turbines runs with a certain specific (low, medium or high production). From the intervals with a minimum of 30 run times with the wind speed values between 4 and 13 m/s, we determined these subintervals with the consecutive values between 7.5 and 10.5 m/s, identifying so the time periods for that the wind turbines run at high parameters, nearly to nominal value.

Also, in this algorithm we determined the number of sign changes to the lower limit and upper limit of the chosen interval. These sign changes represent for the wind turbine the passing from one operating regime to another, a fact that may positively or negatively influences his functioning in an integrated system. For wind turbines integrated in power systems it is desired that the number of sign changes to be as small as possible and also the interruption period to be very short. The sign changes that represents the passing in operating area I and II are not desired nor by the distribution system operator, nor by the owner of the wind farm. Also, the sign change that leads to operating in the V-th area may be or not beneficial for the wind farm owner, depending on the type and on the performances of turbines used.

RESULTS AND DISCUSSIONS

The results of the analysis regarding the sign changes are given explicitly in Table 1, noting that due lack of space we present the results only for the first 8 days of the model month, January 2006.

Table 1: The intervals of wind speed values between 4 and 13 m/s for the month of January 2006

Ianuarie 2006				
Ziua	**Intervale dorite (cu valori între 4-13)**	**Schimbări de semn**	**Număr de timpi în care viteza este în intervalul [4,13]**	**Număr de timpi în care viteza nu este în intervalul [4,13]**
1	[135 183] 49 valori [233 275] 43 valori [740 1206] 467 valori	187 (147+40)	969	396
2	[277 317] 41 valori [322 351] 30 valori [432 470] 39 valori [845 921] 77 valori [959 1009] 51 valori [1011 1069] 59 valori [1120 1185] 66 valori [1187 1232] 46 valori [1234 1365] 132 valori	214 (0+214)	1180	185
3	[1 1146] 1146 valori [1181 1249] 69 valori [1251 1326] 76 valori	24 (0+24)	1349	14
4	[127 275] 149 valori [329 377] 49 valori [379 421] 43 valori [428 532] 105 valori [534 566] 33 valori [654 1198] 545 valori [1200 1364] 165 valori	80 (0+80)	1304	60
5	[1 142] 142 valori [288 341] 54 valori [369 412] 44 valori [683 712] 30 valori [779 833] 55 valori [835 1347] 513 valori	144 (142+2)	1213	151
6	[104 531] 428 valori [546 611] 66 valori [613 750] 138 valori [752 888] 137 valori [890 1363] 474 valori	82 (80+2)	1331	32
7	[1 156] 156 valori [169 203] 35 valori [205 264] 60 valori [296 580] 285 valori [582 654] 73 valori [1151 1198] 48 valori [1200 1365] 166 valori	180 (0+180)	1137	228
8	[1 62] 62 valori [64 166] 103 valori [326 355] 30 valori [1074 1115] 42 valori [1213 1302] 90 valori [1315 1364] 50 valori	284 (0+284)	879	485

In this table we presented only the intervals with values in the range 4 – 13 m/s (the number of times for the wind turbine has run optimal), but in this application we determined also the subintervals with the values of wind speed between: 4 - 7.5 m/s, 7.5 – 10.5 m/s, 10.5 – 13 m/s and over 13 m/s, subintervals related to the area I – V, for that the wind turbine has been in an optimal running regime. Also, we determined the subintervals with values of wind speed between 0 and 4, when the turbine has not run or has run with a minimum of energy (the number of times for that the turbine has not run at optimal parameters). It is observed that we also determined the sign changes, which are very important for a correct running of the turbine. The program used for the development of this algorithm is MATLAB, a very efficient program in determining of such intervals, this program having also the mathematical and statistical integrated function. Below we present a small part from the code used for development of this application:

```
l = length(V);%search the number of times
Tmic = find(V<=4); % search the times for that the
%speed is maximum 4
Tmed = find(4<V<13); search the times for that
%the speed is between 4 and 13
Tmare = find(V>=13); % search the times for that
%the speed is minimum 13
N = length(V)-length(Tmic)-length(Tmare)
% the number of times when the turbine has work
N1 = length(V) - N
% the number of times when the turbine has not
%work
[h,p,stats] = runstest(V,4)% the number of sign
%changes
[h,p,stats] = runstest(V,13) % the number of sign
%changes
%the percentage of times when the turbine has
work %at optimal parameters (values between 4
%and 13)
Procent = (N/l)*100
%the percetange of the times number in that the
%speed was between 7.5 and 10.5 m/s
Procent1 = (260/l)*100
%the percetange of the times number in that the
%speed was between 7.5 and 13 m/s
Procent2 = (407/l)*100
%the percetange of the times number in that the
%speed was between 4 and 7.5 m/s
Procent3 = Procent - Procent2
%the percetange of the times number in that the
%speed was between 10.5 and 13 m/s
Procent4 = Procent2 - Procent1
%the percetange of the times number in that the
%speed was between 0 and 4 m/s
Procent5 = (330/l)*100
%the percetange of the times number in that the
%speed was minimum 13 m/s
Procent6 = 100-(Procent5+Procent)
```

As a future direction, based on the intervals obtained in this application, we want to determine certain categories in that will be framed the days of the interval, so:

- the percentages determined for each day to be considered points that will be allocated to that day for the established interval;
- for each interval will be determined influence coefficients;
- using the coefficients and the allocated points it will be established the final score for each day;
- the days will be grouped into several categories, depending on the available technical potential.

CONCLUSIONS

The identify of sign changes and therefore the intervals of time in that the wind turbine not runs has a major importance in the stage of initial estimation of generated electrical energy and the average continuous operation time of a wind turbine in a specific site with different wind variations regimes. From this point of view this algorithm has determined precisely the number of interruptions and re-operation of the turbine. Also, we determined the number of times for that the wind turbine has work in a regime in which the mechanical request was high (intervals with values of wind speed higher than 13 m/s).

The continuation of this analysis and the determination of the categories in that the interval days will be framed, in order to determine the specific of each day for that it is analyzed the existing data will make that this application to be more complete and very useful for every owner of the wind farm. This will make with high precision the quantity of energy that can be incorporated within the grid and in the same time the period in which the wind turbines operate or not.

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