

## THE ASPECTS RELATED TO THE GRID CONNECTION OF THE WIND FARMS INTO NATIONAL POWER SYSTEM

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*Centralele electrice noi bazate pe surse regenerabile, cum ar fi parcurile eoliene, prezintă unele probleme cu privire la stabilitatea sistemului electroenergetic. Instabilitatea sistemului electroenergetic poate fi cauzată, printre altele, de pierderea capacității de generare a energiei electrice, modificarea circulației de puteri etc. Pentru a preveni astfel de probleme, înainte de instalarea parcului eolian, trebuie efectuate studii cu privire la determinarea potențialului eolian, verificând dacă un anumit loc este potrivit pentru construirea unui parc eolian, având în vedere faptul că alegerea tipului de instalații eoliene depinde de viteza anuală a vântului. De asemenea, trebuie luată în considerare și configurația rețelelor electrice existente. Există diverse metode de determinare a potențialului eolian. De exemplu, prin intermediul unei aplicații în Matlab, bazată pe distribuția Weibull, adaptată la utilizarea formulelor necesare pentru calculul vitezei anuale a vântului se poate determina energia anuală. Această lucrare prezintă rezultate obținute prin metoda mai sus menționată și subliniază aspectele principale referitoare la conectarea turbinelor eoliene.*

*New power stations based on renewable resources, such as wind farms, present some problems related to power system stability. The instability of the power system may be caused, between other things, by the possibility of losing the capability of generating the electrical power and modification of power flow. In order to prevent such problems, before the installation of the wind farm, some studies regarding the wind energy shall be carried out. It should be verified whether a given site is suitable for building a wind farm by having in mind the annual average wind speed when choosing the type of wind turbine. Moreover, the configuration of existing grids shall be taken into account too. There are different methods to determinate the wind energy. In this paper, the wind energy is determined by the means of a Matlab application, based on Weibull distribution, adjusted for the necessary formulas that calculate the annual wind speed. This paper shows some results obtained by the above mentioned application and highlights the main aspects related to the grid connection of wind turbines.*

**Keywords:** power system, power quality, wind farm, grid

### 1. Introduction

Today, the scarcity of fossil fuel, drive governments to take action to reduce the dependence on it and consequently, the electricity produced by

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renewable energy sources becomes one of the priorities of the European countries. The primary aim of power supply system is to meet the demands for energy imposed by the customers, namely to secure a continuous power supply. Thus, the security of power supply depends on the ability of power plants to provide a cushion against forced system outages or loss of energy supplies. Satisfying and responding to customer demands, on one hand and taking the directives of the governments on the other are important features of the electricity market. The construction of wind farm connected to the power system has to take into consideration the following three main components: power generation units, grids and consumers.

## 2. Determination of annual wind speed and suitable output

The wind turbines are subjected to geographical and electrical conditions that may affect their loading, durability and operation. In order to establish what type of turbine is best suited to a given site, it is necessary to study the wind conditions and the features of the landscape. The implementation of a wind turbine project depends on the climate condition of each country, and therefore intensive measurements, at the intended site, of factors such as wind speed and wind direction could last for months. The wind direction is principally used to determinate how the turbines are to be positioned in relation to each other. The necessary distance between the turbines and rows is in fact heavily dependent on both the wind speed and the wind direction. An optimal distance ensures that the turbines do not generate turbulence or block the wind for each other [1]. Wind turbines operate at partial loads most of the time, depending on the wind speed. The amount of the energy provided by wind turbines is proportionally related to local wind prediction and consequently, before the erection of a wind farm, shall be chosen a suitable site that offers the best wind speed for obtaining a power factor of at least 30 % of installed wind capacity [2]. The output power of a wind plant depends on the wind speed due to the fact that the wind turbines use the kinetic energy of the wind to produce mechanical power which is transformed by the generator into electricity. Some of the available power in the wind is converted by the rotating blades, which are acting on the rotor shaft of the wind turbine, to mechanical power. For example, the mechanical power -  $P_{\text{mech}}$  can be determined by the formula below:

$$P_{\text{mech}} = \frac{1}{2} \rho A_r C_p(\lambda, \beta) \omega^3 \quad (1)$$

$$\lambda = \frac{\Omega_r r_r}{\omega} \quad (2)$$

where:  $C_p$  is the power coefficient,  $\beta$  is the pitch angle,  $\lambda$  is the tip speed ratio,  $\omega$  is the wind speed,  $\Omega_r$  is the rotor speed,  $r_r$  is the rotor-plane radius,  $\rho$  is the air density and  $A_r$  is the area swept by the rotor [3].

The connection of wind farms to the national power system has technical and economical implications due to the fact that wind turbines' performance depends on the characteristics of the site where are erected.

This paper shows some results of the annual wind speed obtained by the means of a MATLAB [4] application that could be used for determination of the annual wind speed in all areas. For evaluating the performance of the future wind farm someone should measure the wind speed (at 50 m above the ground) at each 10-minute bin, over a year (i.e. about 52560 measurements during 8760 hours).

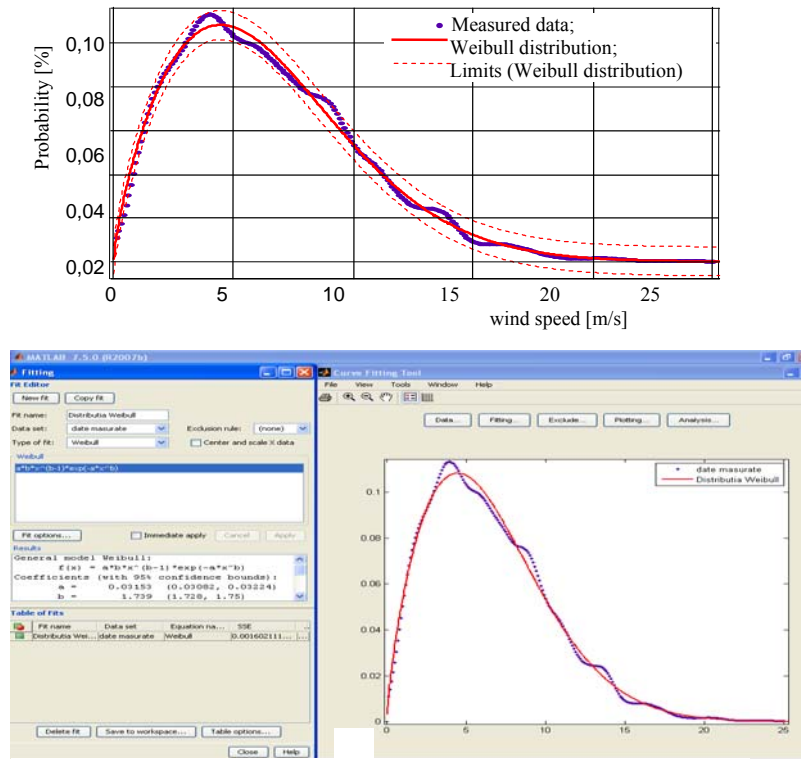


Fig. 1. The wind speed occurrence probability

All data is registered in an Excel file and then these will be imported into the MATLAB application. This calculates by using the Weibull distribution for the annual wind speed of the given wind speed sample.

See the wind speed occurrence probability shown in figure 1 and the print screen underneath. In this example, the annual wind speed is 4.5 m/s and the suitable output power is given in figure 2. The total energy that is obtained equals to 3304.6 MWh.

In Romania, for instance, the annual average wind speed is about 3 m/s in the middle of Transylvania, and it rises from 4 m/s in southern-east part of Moldavia to 6 m/s in Dobrogea, and this may reach 8 m/s to 10 m/s by the Black Sea coast. Subsequently, the most suitable sites for building the wind farms are the onshore and offshore areas of the Black Sea.

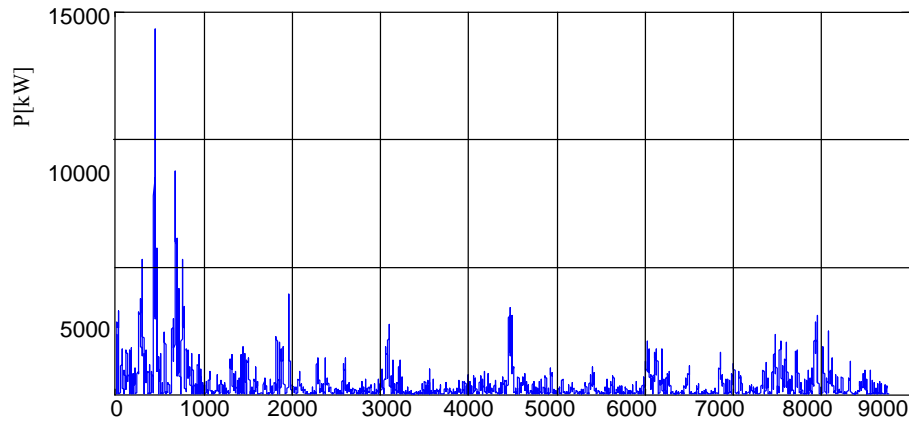


Fig. 2. Power curve depending on time [h], suitable for annual wind speed of 4.5 m/s

### 3. Grid code requirements for connection of wind farms

In the traditional network design approach, the errors in the performance of the medium and low voltage networks have a dominant impact on the quality of service seen by the end users, however, faults in high-voltage distribution and transmission grids do not normally affect the continuity of energy supply for the customers that are connected to medium and low-voltage networks. Therefore, additional high voltage grids are needed when the new wind farms are connected to the grid. One way to describe a grid is by referring to a number of characteristic grid parameters. The first and most important parameters are the voltage level and the kind of source, either direct current or alternating current. Two other characteristic parameters are the apparent short circuit power and the short circuit angle. On the local level, voltage variations are the main problem associated with wind power. Normal static tolerances on voltages levels are  $\pm 10\%$ . The short circuit power level at a given point in the electrical network is a measure of its strength and has a heavy influence. For any given wind power installation of installed capacity  $P$  (MW) the ratio  $R_{sc} = S_{sc} / P$  is a measure of the

strength. The grid is strong with respect to the installation if the ratio  $R_{sc}$  is above 20 to 25 times and weak for  $R_{sc}$  below 8 to 10 times [5]. Major discrepancies between the generated active power and consumption, that exceed the action capacity of the automat control systems and/or planned power reserve, lead to: fast and major frequency variations, significant change of active/reactive power flow on elements and/or on specific areas of transmission grids, deterioration of unit's regime of operation, deterioration of some sensitive consumers etc.

The new wind farms, as conventional power plants, are generally of similar size, and consequently they must at least meet the same grid connecting rules to maintain the power system stability. The requirements for connection to the grids are given in the grid codes, that differ often significantly from country to country, and consequently, the connecting rules should basically be harmonized across Europe. Having in mind the assurance of power system stability, the connecting rules are related to: the behavior of wind power plants in normal network conditions; the behavior during and after network disturbances; frequency response / active power control; voltage control / reactive power; verification and testing and all site-related aspects [6]. In order to prevent the occurrence of grid congestions, new management methods and FACTS are required. The long-term voltage stability is influenced by the replacement of the large synchronous generators connected to the high voltage grids, with small generators integrated into voltage distribution networks. Thus, the reserve of reactive power, without adequate measures, can be considerably reduced. Having in mind the experience of the other countries, an additional support of reactive power (SVC, STATCOM, etc.) is necessary. The connection of wind turbines to the distribution networks may affect the power quality offered to the consumers. The most important aspect refers to the quality of the voltage supplied to the customer, and includes both steady state variations, like voltage regulation, harmonic distortion and flicker, but also disturbances, such as transients, voltage dips and swells that could lead to interruptions of supply.

The increase of the installed wind capacity in the transmission systems necessitates that all wind power plants remain in operation in the event of grid disturbances. For this reason, the grid codes issued during the last years require that all wind farms shall withstand voltage dips to a certain percentage of the nominal voltage and for a specified duration; this requirement is known as "the fault ride through capability"- FRTC of wind turbines, as given in figure 3, in conformity to the grid code requirements in different countries [7]. Due to the fact that wind power field is new in Romania, the grid code might be changed in the future; in conformity with national grid code is stated that the future wind turbines must withstand voltage dips of 10% of nominal voltage for maximum 750 ms (see the green line in figure 3). The reinforcement of the old grids and development of new grids are the main objectives of national power system planning. According

to the last studies in Romania there are mainly 110 KV grids. In the near future it will be finished in Dobrogea the building of two wind farms that both sum up at about 500 MW installed capacity.

#### 4. Conclusions

The continuity of power supplies depends on the capability of power plants to provide suitable power quality. A part of technical and economical problems are related to the transfer capability of the grids. As most of the existing grids are weak, it is needed to be done some infrastructure reinforcement in order to come up to the installed capacity of new wind farms. Currently, more grid operators carried out extensive work on reviewing the interconnection rules for wind farms. This paper shows some results on the calculation of the annual wind speed by simply taking a full year measurements of wind speed and feeding those numbers into a Matlab application accustomed to the wind farm theory. The annual average wind speed once calculated will help to finally find the output power. The power calculated together with the grid connecting rules indicates whether the analyzed site is suitable for building a wind farm.

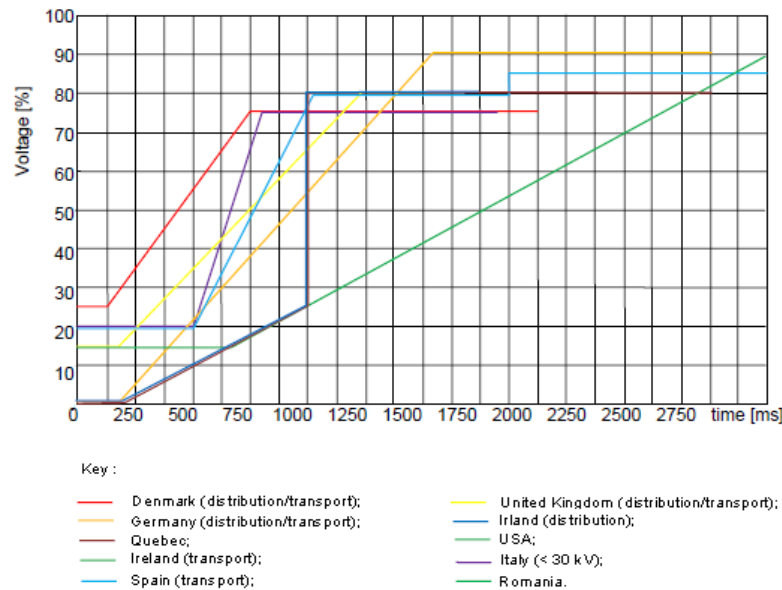


Fig. 3 - Fault ride through capability for grid connected wind turbines in conformity with grid codes of different countries.

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