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INFLUENCE ANALYSIS OF SMALL REPOWERED WIND POWER PLANTS ON THE RELIABILITY OF THE LOCAL GRID

Key words: wind power plants; repowering; renewable energy sources

Summary: The paper discusses problems of the influence of small wind power plants on the reliability of the local system of electrical power engineering. The authors point out to the necessity of adjusting Polish legislation after joining the European Union in reference to the share of renewed energy sources in the general Polish energy balance and among specific distribution companies. The anticipated change in Polish legal system, referring to the promotion of the renewed energy sources, may contribute to the pace of wind power plant energy development. The expected side effect of the development will be, among others, the wind power plants repowering, connected with the implementation in Poland of the formerly used wind power plants. The authors have estimated the scope of this process in terms of valid procedures and standard technical norms.

1.INTRODUCTION

World trends in searching and popularizing alternative energy resources are considerably related with wind power energy and its development.

As the evidence of the leading wind energy producers (i.e. Germany, Spain, Denmark) shows, wind power plants, with the increased unit power, can be seen as the equipment that can negatively affect the operation of the energetic system.

The necessity to increase the use of the renewable energy sources (RES) in the energy balance of Poland and of particular distribution companies will most probably lead to such legislative changes which would make the pace of wind energy development increase. This, however, may result in negative phenomena in Polish transmission system due to the fact that the system is not adjusted to the changing power spread.

Since 2002 in Poland wind power plants giving their energy to the industrial power engineering network have been treated as regular enterprise participating in balancing the market, which is the country basis for exchange and accounting of energy trade. In practice it means that 48 hours before the energy supply to the power energy network the Transmission System Operator (TSO) has to be informed about the amount of energy to be transmitted. Wrong evaluation of amount of the transmitted energy supplied to the system, exceeding a small allowed error margin, may result in higher costs covered by the wind power owner due to the necessity of covering the difference between the anticipated and actual amount of the supplied energy.

In the planned for the year 2004 in Poland The Instruction of Traffic and Exploitation of the Transmission System there are regulations which determine that under normal circumstances of the wind power farm exploitation, and during planned starting and breaking, the median gradient of the change of active power of the farm, measured for 15 minutes, must not exceed 10 per cent of the rated power per minute. The median gradient within a minute should not exceed 30 per cent per minute.

The above mentioned legal regulations used so far, result in complete stagnation instead of fast development in wind power energy. The only wind power plants, which are more and more often installed, are the machines commonly referred to as repowering machines. Used for years, not meeting the required technical parameters, wind power plants brought from the West instead of being utilized, are bought by Polish business which still plans to use them. At the same time small generating systems, which by assumption should correspond to the positive features of the dissipation system, can completely destroy possible advantages of the dissipated generation.

2. EQUIPMENT FAILURE

Wind power plants, both the new and the used ones, consist of many components that can fail due to a variety of reasons. The experience of the countries that have been using wind power energy for a long time shows that the most often fallible equipment is the one of the most primitive technological level.

Presently obtained rates of average wind turbine fallibility are between 0,5–3, and depend mainly on the method of data collection. Figure 1 shows the levels of the average fallibility of wind turbines in Germany and Denmark.

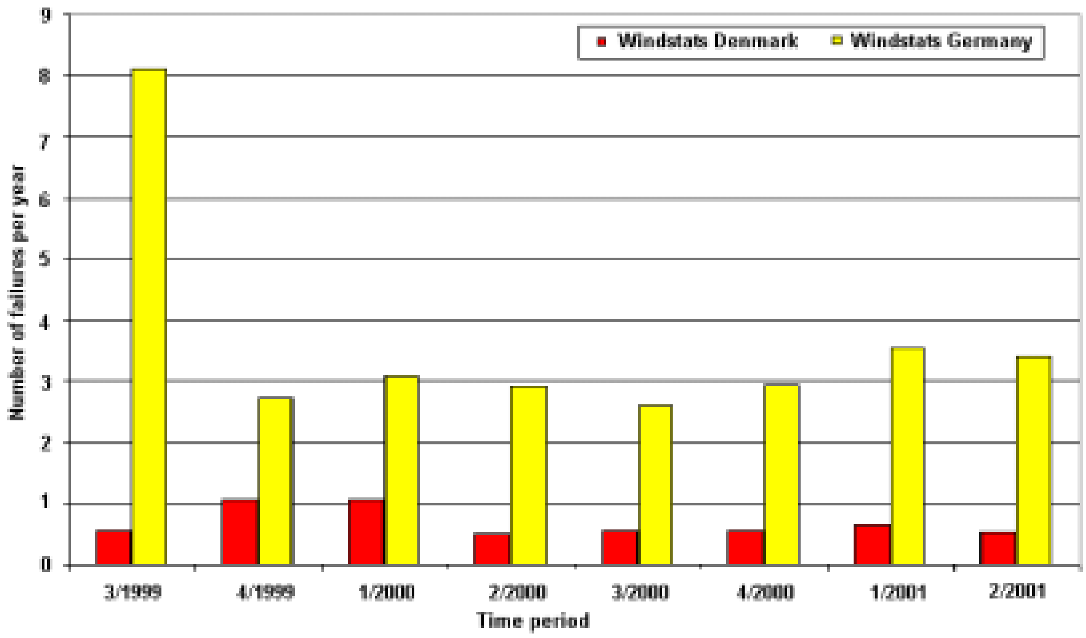

Fig. 1 Comparison of average failures of wind turbines in Germany and Denmark

As it can be easily observed, the number of failures is relatively stable (in the above mentioned countries) when noted every three months. However, in longer perspective, it can be observed that the number of failures is decreasing.

Between the years 1986 – 1987, according to EPRI California, the average failure rate for wind turbines of power ranging from 40 to 600 KW was as high as 10. It should be mentioned here that this, most fallible equipment, is to be installed in Poland.

Wind power plants failures result from breaking one single component that is installed in them. Figure 2 shows an example of the percentage distribution of particular components in wind power plants failure.

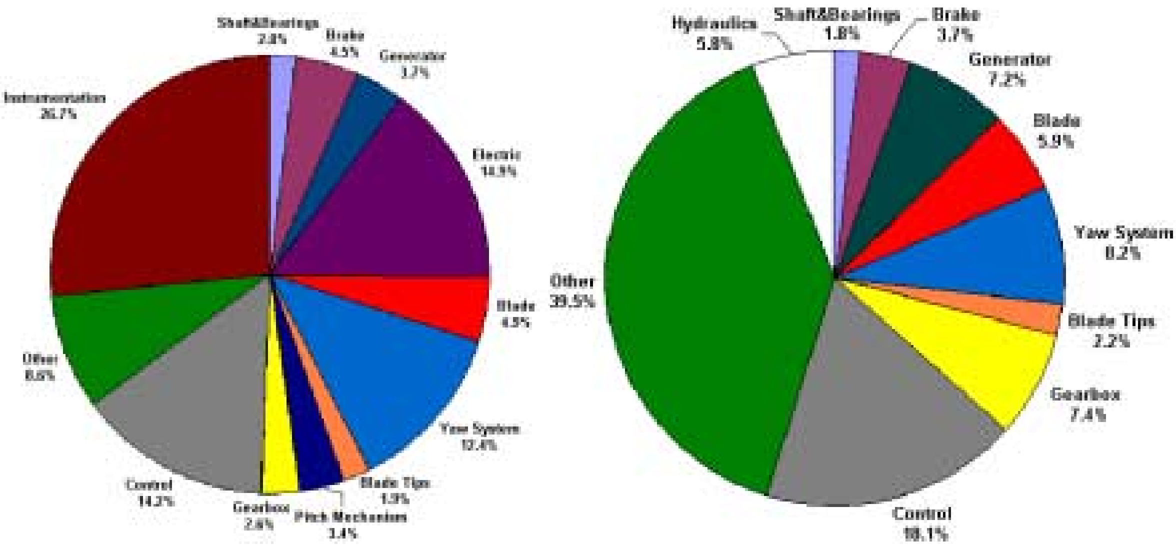

Fig. 2 Failure rates distribution
Left: according to EPRI California, Right: according to Danish Windstats

Presented diagrams in Fig. 2 show partially different quantities which makes that their comparison is not too obvious. The differences result from various classifications of particular elements in European and American standards.

However, it should be mentioned that the wind power plant failure can occur due to various potential causes whose number and frequency increase significantly with the age of the analyzed equipment. Sometimes failures occur because of the age of the equipment (and its regular exploitation) and sometimes because of the kind applied technology, especially the kind of the used materials for the production of particular components.

Failures of wind power plants cooperating with the power industry system decidedly influence the changes of, among others, current voltage and distribution conditions in that system. The scale of these changes can be intolerable, which often is neglected in case of small wind power plants.

3. INFLUENCE ON LOCAL POWER INDUSTRY SYSTEM

Power industry system can view wind power plants not only as a source of energy, but also as the source of disturbances. These disturbances are introduced into the system not only because of the working factor, i.e. the wind (wind velocity and changeability), but also because of their construction features.

These are some of more important causes that influence the quality of produced energy:

- Connecting a wind power plant with the industry power system occurring a few times within 24 hours and related with it changes in generated active power and wattles power absorbed in a given node of the electrical power engineering system
- Changeability of wind velocity and related with it wind engine wing operation to maximize and to limit power generation ($v_n<v<v_{max}$). Frequency of these pulsations can be estimated on the level 0.02 ÷ 0.04 Hz, and their amplitude on several, even up to 20 per cent of the power plant rating
- Wind wheel torque changeability induced by periodic covering of the wing blades by the tower. Frequency of this disturbance is between 1÷1.5 Hz
- Torque changeability resulting from uneven wind velocity on different heights. Frequency of such a disturbance at average angular velocity of the wings is estimated to be 1÷1.5 Hz. The amplitude of the wind wheel changes induced by this and the above mentioned cause ranges between a few to twenty per cent of the plant power rating
- Torque changeability resulting from the elasticity of the wind shafts, blades, and tower of frequency of singular hertz. Generally, pulsations of such frequencies are significantly suppressed. However, there are possible local resonant phenomena strengthening the vibration whose frequency is, for example, 7 Hz.

The above mentioned causes and the value of particular deformations constitute a general description. In fact, every wind turbine operates differently, which in practice enforces individual approach in estimating the parameter quality of the energy produced in a given wind power plant.

The quality of wind power plants operation is estimated on the basis of the prepared report analysis which includes the calculating elements required by the energetic system operator. It is most often assumed that for the right influence analysis of the connected wind power plant on the energetic system, and for further preparation of the analyzed results, the suggested methodology is recommended in a technical report DEFU CR 111-E and based on the norm IEC 61400-21. The above mentioned norms are congruent with the Polish norm PN-EN 50160 and the regulation of the Minister of Economy from 25.09.2000, and they determine the possibilities of cooperation of the analyzed wind turbines in their particular local installation.

The simplified parameter analysis refers to qualities characterizing the quality of energy, such as:

- rms value, frequency and voltage fluctuation,
- the level of higher harmonics in voltage and current (with the established ratio of voltage and current distortion)
- voltage asymmetry
- quick changes in voltage drop and overshooting
- flickering of the light sources (the so called ‘flicker’ effect)

Negative influence of the wind power plants with asynchronous generators on the energetic system results most often from wrong level of shorting power in relation to the installed power of the generators. In systems with wind turbines in the attachment points voltage increase has been noticed which, with little shorting power of this point, can exceed the permitted value.

In order to determine the influence of a small wind power plant on the energetic system, using a typical engineering program Neplan 4.2 ®, there has been presented the model of an exemplary energetic system with given its shorting parameters. (Fig. 3). The modeled fragment of the energetic system structurally corresponds to medium voltage grid 15kV radially connected to energetic knot of 110kV. To the knot, indicated on the Figure 3 as EWI, is connected a wind power plant whose power is 150kW.

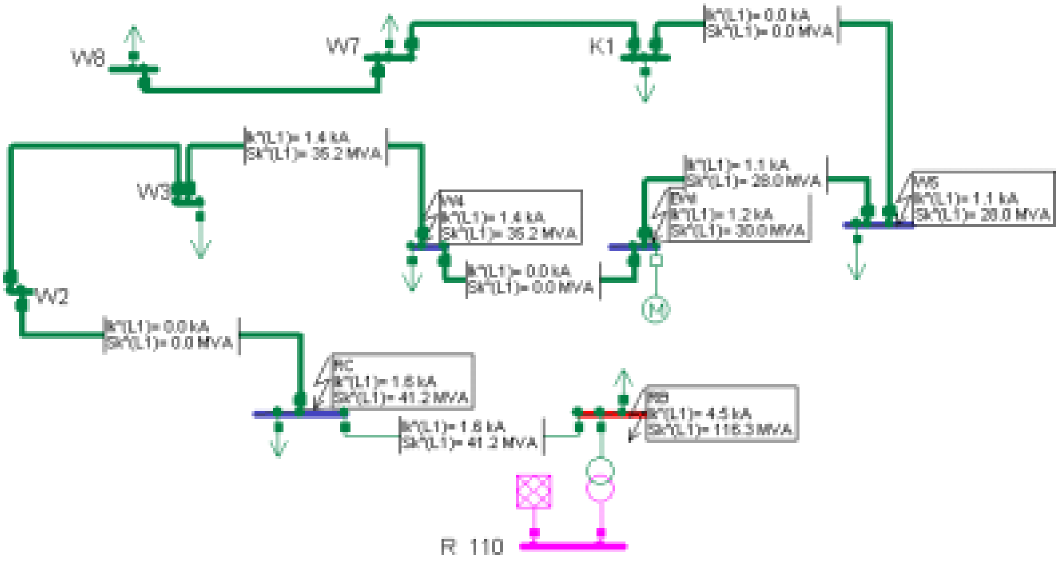

Fig. 3. Shortage parameters of the modeled fragment of the energetic system before connecting wind power plant

The presented scheme of connections serves to analyze the active and passive power spreading introduced to the system. The analysis allows to determine the voltage level fluctuation in the point of connecting the wind power plant.

Assuming that the connected wind power plant can, in different moments of its operation, generate active power from 0 kW (when off) to 150kW (its nominal power), the levels of voltage fluctuation in the connecting knot have been determined.

Typically used nowadays solutions concerning the construction of wind power plants coming from repowering are connected with the installation of al least a few wind power plants in the same connecting point.

Fig. 4 analyzes the influence of power changes introduced to the system in the connecting point on the voltage quantity in this point. Because of the above mentioned reason, the analysis was made for the changes in generated power ranging from 0 kW to 1600 kW (connecting 11 wind power plants corresponds to 110 per cent in Figure 4).

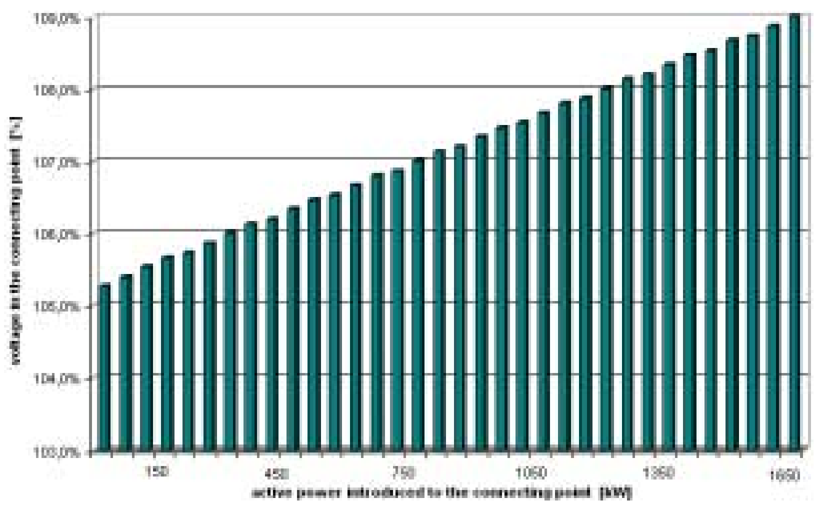

Fig. 4 Relation of voltage in the connecting point and quantity of power generated in a system of wind power plants

The analysis results have been referred to relative quantities which enable their comparison with existing legal regulations in the discussed matter. At present it is assumed that the allowed fluctuation in voltage level in energetic system grids should not exceed 2.5 per cent.

Analyzing Fig. 4 it can be stated that within the range of power changes introduced to the connecting point from 0 kW to 1100 kW corresponding to them changes of voltage level are within permitted legal limits. In other words, for practical configuration of the energetic system connections, taking into account the voltage criterion, it is possible to connect not more than 7 wind power plants of unit power of 150 kW each.

4. CONCLUSIONS

The described above situation is quite likely to occur. Majority of Polish Distribution Companies, owners of medium voltage networks, when granting the permission to connect generating installations, use the shorting criterion which determines the relationship of shorting power in the connecting point to nominal power quantity of the installed wind turbines. It is commonly assumed that the ratio cannot be lower than 20. As concluded from the above presented situation, for the shorting power of the connecting point (30MVA), theoretically accepting the assumed relationship, one would expect a permission to connect even 1.5 MW (30 : 20 = 1.5). However, when the nominal power of the connected generators exceeds 1100 KW, as it is pointed in Fig. 4, one can expect exceeding permitted voltage requirement. (max. 2.5 per cent).

In the presented information in point 2 it can be concluded that wind power plants installation that come from repowering are characterized by greater than new ones fallibility. It means that standard, theoretical approach to wind turbines connection, especially of those coming form repowering, has to be replaced with careful individual analysis.

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