RATIONAL CABLE CONNECTIONS IN ENERGY WIND FARMS

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ABSTRACT

The article contains a brief analysis of the problem affecting the construction of new wind farms in such a way that the future exploitation of the least expensive due to transmission losses of the towers to the main supply point.

1. INTRODUCTION

Renewable energy sources thanks to the promotion of the European Union are rapidly growing electric energy branches in Poland. This results from the observations of the growth of world energy demand trends and conscious policy of greenhouse gas emission reduction. Moreover, the renewable energy has an important role to play in fighting against the growing dependence on energy imports and in tackling climate change.

The total of actual European electricity production roughly depends on in about 55% from coal and gas/oil, 10% from renewables, 35% from nuclear power. In this situation, there is obvious need for qualitative changes in electricity production by increasing the share of the renewable energy. For this reasons, Europe Union's (EU) (Directive 2009/28/EC) strategic objective is to achieve in any case, at least a 20% reduction of greenhouse gases by 2020 compared to 1990. Poland as a member of the European Union is a part of these efforts by supporting the development of wind energy solutions.

However, the construction of new wind farms, in addition to the legal and economic problems involves difficulties with a choice of the optimal location of towers, generators, equipment, cables and the optimal location of a main point of power, (switchgears), etc.

2. THE DEVELOPMENT OF WIND ENERGY IN POLAND

The European Union, through the Operational Programme Infrastructure and Environment for Poland granted substantial funds for the construction of units producing electricity from renewable sources. Introduction to Law "Energy Law", in 2010, the provisions requiring the electric distribution companies to repurchase and distribution of energy generated from renewable sources and a program to support the power sector in the form of "green certificates" resulted in the rapid development of wind energy in Poland. Table 1 shows the increase of installed capacity of wind power plants in Poland in the last eight years.

Table 1. Increase of the installed capacity of wind power in Poland in 2005–2012

	2005	2006	2007	2008	2009	2010	2011	2012
	Power (MW)							
Wind turbines	83,30	152,00	287,90	451,00	724,68	1180,27	1489,72	2341,31

The data presented in Table 1. predicts a strong growth of wind power sector in the coming years. Over the eight years this power has increased nearly 28 times. Unfortunately, a significant increase in installed capacity is not synonymous with the production of electricity due to the instability of wind. At the same time we observe the development of wind farms in areas with the lack of stable electricity from conventional generation sources. This results in a number of technological problems and affects the stable and secure operation of the power system. But there are also positive aspects of participation in the policy of reduction carbon-intensive emitting energy sources, which include: employment, environmental studies, changes in legislation, etc.

3. REQUIREMENTS FOR THE WIND FARM INVESTMENTS

To conduct a successful investment in a wind farm growth in Poland and in other countries there should be designated a large area away from residential buildings, as to fulfill the criteria necessary to obtain a building permit. These relate to environmental conditions, planning, acquiring rights to land and power connection parameters. Failure to meet even one of the conditions excludes the completion of the investment.

Obtaining the conditions of power connection is the greatest challenge for investors. Connection terms, in a later stage of a connection agreement, guarantee that the electricity system will be able to accept produced by a wind farm energy, even under disturbed operation of power network.

Properly designed wind farm requires the implementation of construction projects in various industry branches like architecture, roads, design, electrical, etc. Electrical designer of the wind farm deals with the following issues:

- Choice of the type of wind turbines,
- The parameters of the main supply point,
- Cable connection parameters,
- The parameters of the power line transmitting power from the wind farm to the specified port.

Selection of cables transfer power from wind turbines to the main supply point of the wind farm should be made on the basis of their load, short circuit parameters and loss of energy. Optimization criterion assumed as the minimum power loss in power cables can be met by considering its convenient location and determining the optimum cross-section of the cable, taking into account economic parameters.

4. RATIONALIZING THE USE OF CABLES WITH SPECIFIED PARAMETERS IN WIND FARM POWER

Multi-criteria analysis of cables connection, methods and main point of the wind farm power supply makes it necessary to study the feasibility of different cable routing of the same section. According to the assumptions, the best location of the subscriber substation is considered as for which the costs of transmission and distribution losses of electricity will be smallest, while the cost of the additional investment will be economically viable.

In the wind farm study there were used cables XRUHAKXS type because of their good technical parameters, favorable price and widely use in similar projects. The used cable cross-section should be chosen so that for given operating conditions, the cable load value should not be higher than the long-term load and short-circuit current does not cause over-temperature specified by the manufacturer. In cases where there are different heat dissipation of the cable tray cable cross-section must be selected for the worst.

In the study of power wind farm there are used cables XRUHAKXS with cross section $3\times185/50\ \text{mm}^2$ and $3\times70/50\ \text{mm}^2$ and different lengths (of 1300 m to 3500 m).

For cable cross-sections used there were calculated active power losses resulting from the current load based on the formula:

$$\Delta P = 3 \cdot I^2 \cdot R \quad [\text{W}] \tag{4.1}$$

R – cable resistance [Ω],
I – current [A].

Power loss is a loss of energy at a given time:

$$\Delta A = \Delta P \cdot t \quad [\text{MWh}] \tag{4.2}$$

t – time [h],
Δ – active power losses [MW].

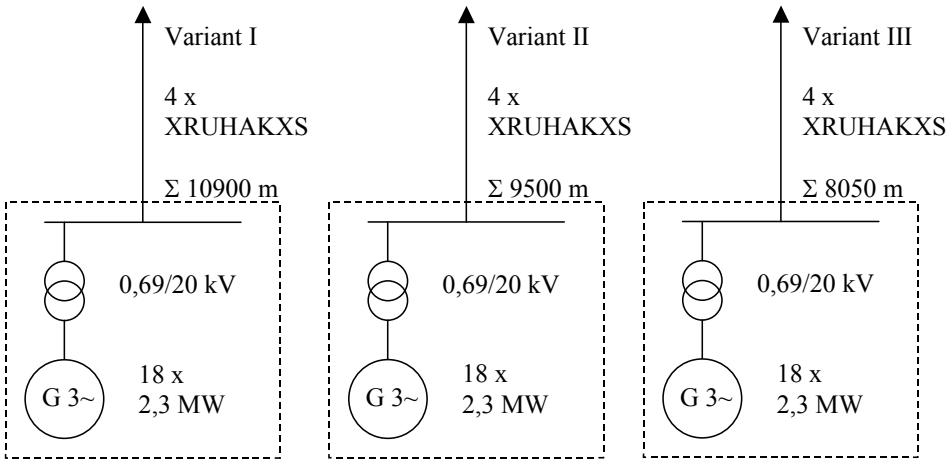

Fig. 1. Diagram of the possible combinations of wind power plants with medium voltage cables

Table 2 shows the results of the economic analysis calculations in the choice of cable in the wind farm.

$$PV = FV \cdot a_t = FV(1+p)^{-t} \quad [\text{zł}] \tag{4.3}$$

PV – present value [zł],
FV – future value [zł],
a_t – compound interest,
p – the discount rate.

Table 2. Results of calculations Grey – option realized

	Variant I			Variant II			Variant III		
Cable section	Cable length	Loss of energy	Cost of losses	Cable length	Loss of energy	Cost of losses	Length cable	Loss of energy	Cost of losses
[mm²]	[m]	[MWh]	[thousand PLN]	[m]	[MWh]	[thousand PLN]	[m]	[MWh]	[thousand PLN]
70	3500	149,57	389,97	3000	128,20	334,26	1300	55,55	144,85
185	3000	134,74	351,33	3000	134,74	351,33	1750	78,60	204,94
185	3000	134,74	351,33	2000	89,83	234,22	2000	89,83	234,22
185	1400	62,88	163,95	1500	67,37	175,66	3000	134,74	351,33
		481,93	**1256,58**		**347,50**	**1095,47**		**358,73**	**935,34**

The analysis found the average electricity production at 30% of nominal power (derived from the mean wind speed). On this basis, there was made calculation of power and energy losses during operation of the power wind plant. The relevant costs are based on the discounted present value of the energy loss from the formula 4.3. (time: 25 years, discount rate: 5%).

5. CONCLUSIONS

The application of analytical study of appropriate cable length generating the smallest transmission losses within the wind farm has been completed on the basis of consideration of the three optional substation location (main point of power wind farm) (variant I, II, III). The input data for the calculations included the elements allowing for present situation to choose the optimal option, in which there were taking into account a number of parameters: the length of the cable, cable diameter, nominal current, loss of energy.

Analyzing the results of calculations presented in Table 2 it can be concluded that, variant of the wind farm carried out will generate the largest losses. Energy losses resulting from the application are not optimal, for present location of the main supply point.

The choice of cable cross-section must be reasonable, meet the requirements of both technical and economical points of view. However, during the construction of wind farms, the investment costs and the local community have a key role. Different policy leads to the implementation of technical projects that use a suboptimal solution, or even harmful ones.

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