INFLUENCE OF LOCAL DISTRIBUTION NETWORK TOPOLOGY ON THE NUMBER OF WIND CONVERTERS

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Abstract:

One of the consequences of restructuring of energy production in countries in transition is an increasing number of wind parks as well as other electricity sources. Energy potentials available in windy regions, especially in coastal regions as well as on islands, open new perspectives for energy supply. The most privileged locations of wind parks in Croatia are the Dalmatian islands in the Adriatic Sea such as the island of Vis. Location of the island as well the fact that electricity is supplied through underwater cables give wind energy a big chance. This island of low population density is located far from any electrical connection point. High capital costs encourage maximum usage of the existing network infrastructure. Long three-phase medium voltage lines characterize the island electricity distribution networks. This paper analyzes the influence of local distribution network topology, capability of the local electricity load and cross-sections of power lines on the number of the connecting wind converters.

Key words: wind farm, load flow, electricity grid, topology

1. INTRODUCTION

Energy potentials available in windy regions, especially in coastal regions as well as on islands, open new perspectives for energy supply. The most privileged locations in Croatia are Dalmatian islands in the Adriatic Sea. The location of islands and electricity supplied through underwater cables give wind energy a big chance. Wind energy may provide a good supplement to hydropower. Wind farm locations and the associated weather conditions represent an enormous challenge for engineers in their attempt to meet wind farm design requirements. Optimization of wind farm electricity systems is constantly being pursued our effort to reduce capital costs and electrical losses at the same time increase flexibility and reliability of the system. Due to prices of wind generated electricity, wind farms are being built at high wind speed sites. These sites are usually areas with low population density and remote from a strong electrical connection point. High capital costs

are encouraging maximum usage of the existing network infrastructure. Long three-phase medium voltage lines characterize the island electricity distribution networks. Voltage magnitude fluctuation, load flows fluctuation, surges in reactive power and other problems are encountered when wind power is generated in such networks. The influence of local distribution network topology and cross-sections of lines, as well as capability of the local electricity load on the number of connecting wind converters is analyzed in this paper.

2. CALCULATION METHOD

The voltage analysis and the power-flow studies are of great importance in planning and designing the future expansion of the local power system, as well as in determining the best operation of the existing system. The principal information obtained from these studies is the magnitude and phase angle of the voltage at each bus and the real and reactive power in each line and transformer.

The power-flow problem is to determine values for all state variables by solving the power-flow equations. The functions of the real power and the reactive power at each bus are nonlinear functions of the state variable voltage angle and voltage magnitude. Hence, an iterative method is used to solve this problem.

3. CALCULATION RESULTS

3.1. Wind farm location

The most privileged locations of wind farms in Croatia are Dalmatian islands in the Adriatic Sea, such as the island of Vis. The planned site for the wind farm is Stupisce, located in the southwest of the island. This location is chosen because it is well exposed to dominant wind directions from the north (Bura), northwest to west (Maestral) and southeast (Jugo). The measurements confirm a good wind potential. It is planned to build plants of 250-300 kW - class. This is the result of logistic considerations and the fact that the Croatian electricity utility company (HEP) has no prior experience with wind energy plants.

3.2. Local electricity grid

Vis is supplied through 35 kV underwater cables from the island of Hvar. Hvar is connected to the mainland grid through 110 kV underwater cable. The local medium voltage grid of the island of Vis operates with 10 kV voltage. From an operational point of view the 10 kV grid consists mainly of six radial branches with, several lines to individual consumers or consumer groups. The 35 kV/10 kV substation with a capacity of 4 MVA is located near the city of Vis. Branches are connected to the 35-kV/10 kV substation Vis. One of them runs across Stupisce and continues as an underwater cable to the island of Bisevo. Maximum power demand of the island of Vis is 2520 kW, cos φ = 0,956 and minimum power demand is 1164 kW, cos φ = 0,957

3.3. Impact of wind energy on electricity grid

Three phase generators are either asynchronous (AG) or synchronous (SG) generators with connections to grid through generator transformers. Asynchronous generators with nominal power rate of 300 kW and synchronous generators of 230 kW are available on the market. Maximum number of generators is 11. In the following analysis it is assumed that each generator feeds the grid with constant maximum power. The local electricity grid of the island of Vis is a relatively weak 10 kV grid. The objective is to determine voltage fluctuation in the local electricity grid (10 kV) and its active power losses including the 35 kV feeding line from Hvar to Vis, depending on the number of connection converters and the grid topology (GT). For this purpose four different grid topologies are considered.

- Topology 1 (T1)

  The wind farm is connected to the radial 10 kV branch Vis-Podstrazje-Podspilje-Ravno-WF Stupisce-Stupisce-Bisevo (length 23.4 km). WF Stupisce is a switchyard of the wind farm.

- Topology 2 (T2)

  The line cross-section Ravno-O. Hum is interrupted near Ravno. The wind farm is connected to the 10 kV radial branch Vis-O.Komiza1-Komiza3-O.Vodovod1-Ravno-WF Stupisce-Stupisce-Bisevo (length 20.6 km).

- Topology 3 (T3)

  The new 10 kV line cross-section Komiza 1-WF Stupisce is built. The Wind farm feeds into 10 kV radial branch Vis-O.Komiza1-Komiza1-WF Stupisce-Stupisce-Bisevo (length 17.5 km).

- Topology 4 (T4)

  This version includes a number of modifications. The most importantly modification is the building-up of a new 35 kV/10 kV substation near Komiza. The line cross-section Ravno-Podspilje is disconnected in Podspilje. The village Hum and Naselje are fed from Ravno. The new radial 10 kV branch (Komiza1-WF Stupisce-Stupisce-Bisevo) exists in this version. The total length is 10.0 km.

Admissible number and optimal number of wind energy converters depends on the grid topology and voltage fluctuations and maximum line loading as well as on grid losses.

In order to increase maximum number of connecting converters we propose to build the disconnectable busbar at WF switchyard as shown in the next figure. The total number of busbar sections depends on grid topologies (Fig. 1).

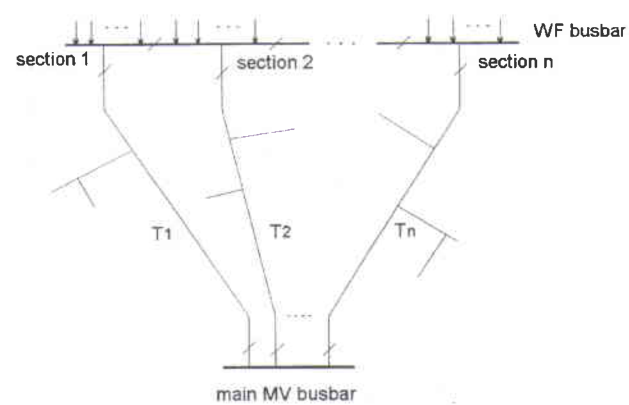

Fig. 1 Connection of converters

3.4. Results

The voltage fluctuation and grid losses depend on the load (maximum and minimum), the grid topology (T1, T2, T3, and T4) and on cross-sections of lines as well as the type and numbers of generators. The largest voltage fluctuations occur in the radial branch, which connects the wind farm. The maximum variation tolerated by IEC 38 is ± 10 % of the nominal voltage. Admissible maximum number of wind energy converters is calculated.

The overhead 10 kV line from Ravno to WF Stupisce has the smallest cross-section (Cu, 16 mm^2). This line limits the admissible number of generators.

Losses in the 10 kV grid of the island of Vis including the losses of 35 kV feeding lines regardless of type and number of generators in the wind farm, are calculated at maximum and minimum load. Active power losses depend on the number of asynchronous and of synchronous generators at maximum and minimum loads. In case of surplus power, electricity of the wind farm is fed back into power system through the 35 kV lines. The differences in grid losses compared to the situation without the wind farm can be of special interest. Admissible limit of the grid losses has to be less than the power rate of generators.

These have to be taken into account when the optimal number of converters is calculated. Applying the disconnectable busbar at WF switchyard, maximum number of connecting converters is increased 1.545 times by AG and 1.364 times by SG. The results of the analysis are presented in the next table.

GT	Admissible number of converters						Optimal number of converters		Maximum number of converters	
	Voltage fluctuation		Max. line loading		Grid losses					
	AG	SG	AG	SG	AG	SG	AG	SG	AG	SG
T1	7	4	7	11	6	8	6	4	17	15
T2	11	4	6	11	7	10	6	4		
T3	11	11	11	11	10	11	10	11		
T4	11	11	11	11	11	11	11	11		

4. CONCLUSION

Maximum number of wind farm units depends on type and power rate of generators and local electricity grid topology. In order to increase maximum number of connecting converters we propose to build the disconnectable busbar at WF switchyard. Applying this idea on the island of Vis, maximum number of connecting converters is increased.

The presented analyses have to be done for each characteristic period in the lifetime of the wind farm. These studies provide the basis for determining the size and profitable calculation of the wind farm.

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