STUDY OF 6 KV NETWORKS WITH DISTRIBUTED GENERATION

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Abstract: *This report examined the networks of average voltage 6kV with connected to them generation distribution systems. The maximum power of renewable energy source plants, that could be connected to the power line with voltage 6kV according to the nominal capacity of the power transformers, their number, the cross section of overhead electric transmission network and the regulations in our country had been determined.*

Key words: *generators and renewable energy source plants, overhead average voltage network.*

Electricity generation from renewable energy sources is one of the latest trends in the development of modern electric power engineering. Wind and water are power sources not resulting in pollution and climatic anomalies. The transformation of these primary energy sources into electric power is not attractive. Operating costs make them particularly desirable to investors as power source. Wind power cannot be a source of electricity produced on schedule according to the needs of the electric power system. It has been working in this direction by establishing centers forecasting speed and wind direction, and hence the probable electricity production. In Bulgaria there is also potential for building wind power plants along the coastal line and in areas with an altitude above 1000 m. The future development in suitable mountain areas and in zones with lower wind speeds depends on the development of new technical solutions. The operation of wind-power generator depends on the wind speed and turbulence, the tower height and the air density, so it is important the potential in the chosen area in the country where it would be conditions under which the data were collected. In recent years the photovoltaic systems for electricity generation connected to low, average, and those with higher capacity to high voltage networks became extremely popular.

Development of small hydropower stations in our country also marked growth. The encouragement of renewable energies in many countries has led to great rise of the installed capacity for power generation in them. This process started quite intensively in our country too. Most of the wind-power generators, small hydro power stations and photovoltaic plants are built in areas with extended electricity distribution grids and thus they are connected to the power system. Wind farms and photovoltaic plants with a capacity over 5MW generate much more power and therefore are connected to the transmission grid. The high voltage (HV) networks are not as dense as the average voltage (AV) networks meaning that the distance which should be covered for connecting these plants to the grid, is longer.

Photovoltaic and wind power generation

installed to be known as well as the synchronous generators directly connected to the network, commonly used in conventional power plants. Due to their different features these generators interact differently with the power system compared to synchronous generators. This means that they can lead to a disturbance such as a change in the terminal voltage and frequency or in the primary driving source, in a different way, and that their ability to participate in the control of the supply voltage may be low. Furthermore, certain aspects of the interaction between the wind-power generators and the network are specific for the used type of generator, especially in wind-power generators with or without power electronic converters, i.e. with constant and variable speed.

While electricity generated by wind and solar energy in the total production is small, the mode and the behavior of the power system will continue to be determined by the synchronous turbo and hydro generators that still produce most of the consumed electricity. Therefore, the behavior of such system will not be significantly different from the power system without generators powered by sources of renewable energy. However, when a large number of wind-power generators and photovoltaic plants are connected to the system and they replace a significant portion of power produced by conventional synchronous generators, they will begin to affect various aspects of the system behavior. At the moment the balance between power generation and power consumption to a great extent is maintained by adjusting the generation up to the load. The reason for this is that the inclusion of the load in the balancing of the system is difficult, since the power consumption is not greatly varying, and therefore the load is rather unchanging. While the energy produced in power plants can be controlled, this is not a major problem, although impeding the dispatch of generating capacity, i.e. determining which plants need to work to cover the loading most efficiently and economically, taking into account the cost of systems are distinguished from the standard generators which output power cannot be regulated is a major problem for the current procedures to balance the system, because such generators cannot contribute to the maintenance of the system balance.

Generators, which output power is not regulated, can of course cover part of the power consumption without causing problems for the balance of the system. The level to which generators which output power is not regulated, can contribute to covering the load without additional measures, and of course the extent at which additional measures should be taken to allow a further increase in the contribution of these generators depend on factors such as: load schedule of the system; the ratio between the load and the availability of primary energy source used by not adjustable generators; the specifications of the remaining adjustable stations and the network topology. It is therefore not possible to make a general proposition with respect to the quantity of non-adjustable output power, which can be connected to the electric power system, without taking additional measures, either as regards the precise steps to be taken for the further increasing the level of their application. However, it is clear that increasing the number of non-adjustable generators such as wind-power generators and photovoltaic plants, eventually lead to problems in maintaining the system balance.

The operational requirements for the connection of wind power plants (WPP) to the average voltage electrical network in Bulgaria are regulated. These requirements could be used for other RES plants. Here are some of them:

• The total installed capacity of wind power plant (WPP) at the point of connection to the power system should not exceed 5% of the power in h. p. in this unit;

• It is not permitted WPP to be in island operation mode;

• The allowable voltage unbalance caused by WPP at the point of connection to the transmission network is 2.0% and 3.0% to the fuel and the performance of power plants. However, the significant participation of frequency at the point of connection of WPP during normal operation are (49.5Hz ... 50.2Hz);

• The total harmonic distortion from WPP at the point of connection to the electricity grid is THD ≤ 8% (for AV networks);

• The total flickers from WPP at the point of connection to the electricity grid (short-term flicker indicator; long-term flicker indicator) are Pst = 0.8; Pit = 0.6 (for HV networks) and Pst = 0.9; Pit = 0.7 (for AV networks);

• The power factor range of each wind-power generator of WPP should be at least 0.98 (CAP) ... 1 ... 0.96 (IND);

• WPP must be equipped with frequency protection that shuts it from the network at frequency deviation beyond the range 47.5Hz ... 50.3Hz, with a delay of 0.2s;

• It is not permitted automatic resynchronization of WPP to the transmission grid, after the automatic shutdown of the frequency protection. Such synchronization can be done only after permission of the operational staff of ESO (EDC);

• The power quality generated by WPP should be in conformity with BDS IEC 61000-2-2 and BDS EN 50160. When the generated power does not meet the quality criteria ESO or EDC are entitled to terminate the access of the respective producer to the power network;

WPP should allow transitory decreased and increased values of the voltage, without impeding their synchronous operation with the power system as follows: lowering the voltage below 75% Un up to 0.08s and rising the voltage over 120% Un up to 0:08s;

The total installed capacity of all power plants from renewable energy sources in the power system of Bulgaria should not exceed 20% of the registered maximum gross electrical load of the country in the previous year. The quantity of the total allowable capacity of all plants from RES in the power system of Bulgaria is proposed annually by ESO and is approved by the State Commission of Energy and Water Regulation distribution network;

• The limit tolerances of the nominal EN50160, which stated that the requirements for producers of electricity in some cases are more severe. In Germany according to the prescripts for connection of power generating sources of 2008 the maximum power that could be connected to the network is calculated also by the increase in the voltage at the point of inclusion using the formula:

$$\Delta U_{aV} = \frac{S_{Wmax}}{S_k}.\cos\left(\psi_k + \varphi\right) \qquad (1)$$

where: S_k – short-circuit power at the point of connection; ψ_k – angle of the impedance of the short circuit at the point of connection; S_{Wmax} – maximum power of the generating source at the point of connection; φ– angle of the phase shift between voltage and current at the point of connection.

This increase of voltage should not exceed 2%. In Bulgarian prescripts that maximum increase of the voltage may be up to 5%. According to German regulations [3] the power factor could be 0.95 (CAP) ... 1 ... 0.95 (IND). Thus further increase of generating capacity could be achieved so that it is involved in the regulation of the voltage. The German prescripts allow regulation of the active power of wind and photovoltaic plants, and in some cases participation in the frequency control of the network as in failures in the network it is not required mandatory shutdown.

The average voltage networks of 6kV in our country are few and mainly they are auxiliary, as in general they are powered by step-down substations of 110kV/6kV. The average excess transient short-circuit power in the country is 110kV within the range of 3500MVA. Most often, the number of transformers used in these substations is two. The rated power of these transformers could be 6.3, 10, 12.5, 16, 25, 31.5 and 40 MVA. When these transformers of average voltage are operating in parallel higher powers of short-circuit are obtained as follows 116.02, 180.65, 222.93, 280.35, 419.15, 512.195, 580.03 MVA. When the transformers are

(SCEWR).
Some of the connection requirements are in contradiction with the European standard
follows 58.99, 115.13, 146.02, 222.92, 276.315, 316.38 MVA. A model of power network with connected power plant of RES (renewable energy source) at the end of AV overhead line has been developed using the program Digsilent Power Factory. Plants from renewable sources (photovoltaic and wind) are modeled by power and consist of an inverter with respective power connected to the electric transmission line. The specified maximum power for plants from renewable energy sources that can be connected to the electric grid is provided that the requirements for the voltage quality of SCEWR are observed, i.e. the deviation is within +/- 10% and the condition for not exceeding the ratio of generating capacity to power of h. p. of 0.05. Using the prescriptions of SCEWR the operating separately the excess transient powers of short-circuit are obtained as

obtained maximum capacity of wind power plants connected to buses of 10 kV,depending on the rated power and the number (1 or 2) of power transformers are presented in Figure 1. In Figure 1 the values of the maximum possible power in parallel operation of transformers are marked with a square and those operating separately – with a triangle.
Usually the substations are at considerable distances from places with high average wind speeds. It has been examined the connection of plant powered by renewable energy source by means of electric transmission line of average voltage 6 kV with different length and cross section of the electric transmission line (overhead and cable) depending on the mode of operation and capacity of the power transformers.

Figure 1

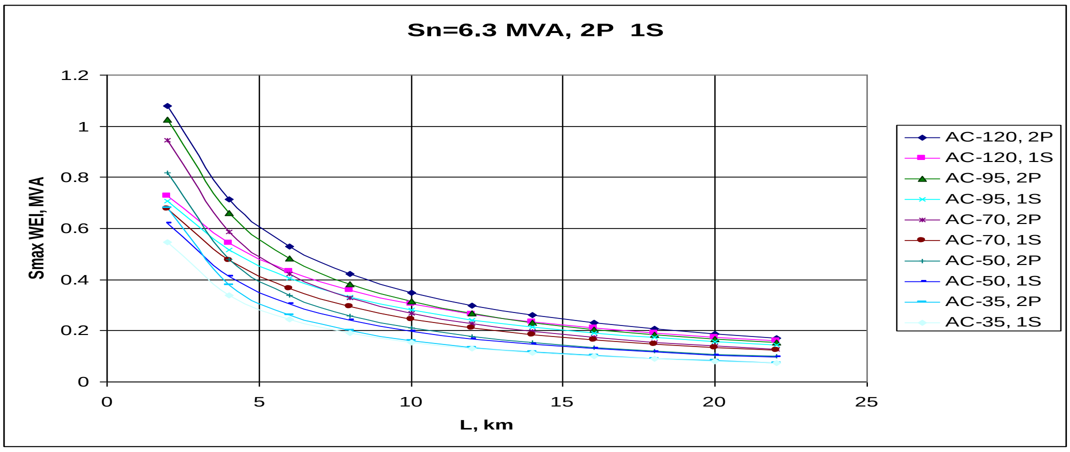

Figure 2

Figure 2 presents the curves of variation of maximum power of plant from renewable energy sources that can be connected to overhead electric transmission line with aluminum-steel conductor and cross section within the range from 25 to 95mm^2 connected to 6 kV buses of substation with two power transformers with rated power 6.3 MVA. Both options of parallel (2P) and separate operation (1S) of the transformers are also presented. Figures 3, 4, 5, 6, 7 and 8 show the curves of variation of maximum power of plant from renewable energy sources that can be connected to overhead electric transmission line with aluminum-steel conductor and cross section within the range from 35 to 120mm^2 connected to 6 kV buses of 110kV substation with two power transformers with rated power 6.3, 10, 12.5, 16, 25, 31.5 and 40 MVA. Both options of parallel and separate operation of the transformers are calculated. These curves could be used for determining the maximum installed capacity of RES plant joined to the electric transmission line connected to the high voltage distribution substation with different capacities and number of step-down transformers.

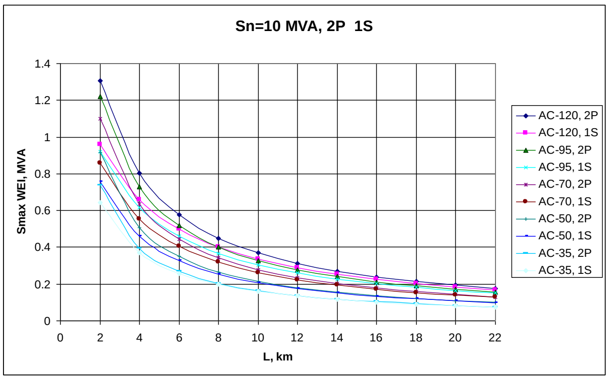

Figure 3

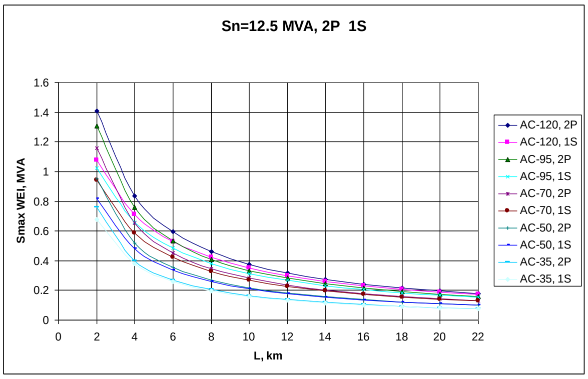

Figure 4

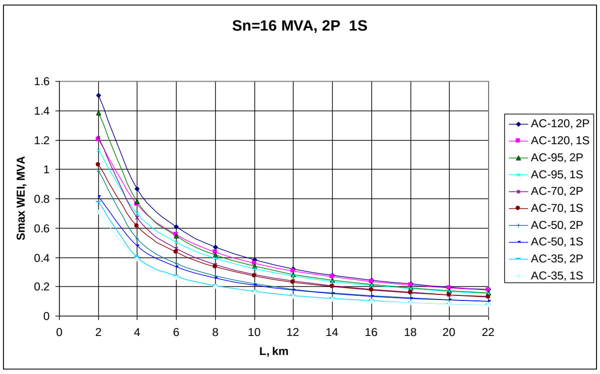

Figure 5

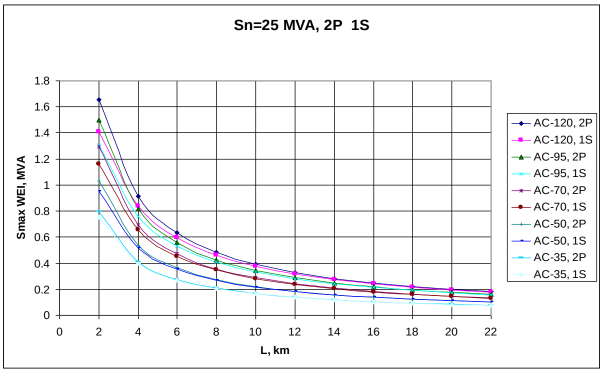

Figure 6

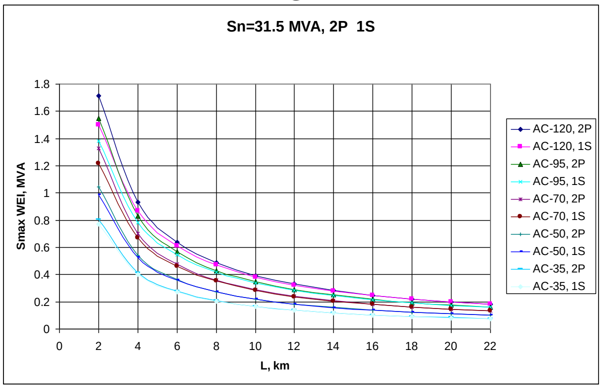

Figure 7

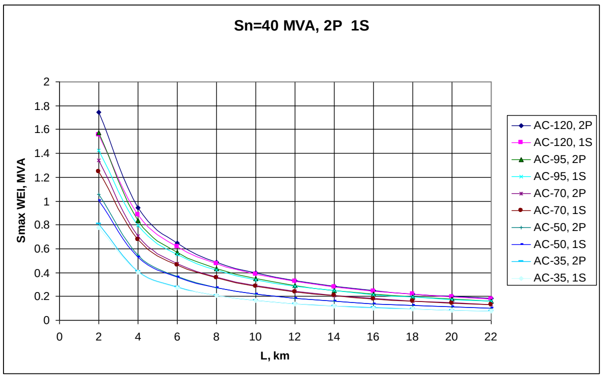

Figure 8

The loss of voltage in the electric transmission line with RES plant and maximum power presented in the diagram does not exceed 4% assuming that the generated power is fully active. The uninterrupted current of the conductors is not exceeded either.

CONCLUSION

In Bulgaria there are suitable conditions for the construction of RES plants. Determining the maximum capacity of these plants that are connected at the end of electric transmission line 6 kV was the main objective achieved in studying the possibilities of substation of high (110 kV) average voltage with power transformers of different power and number. The researches were carried out using the program Digsilent Power Factory and are presented graphically.

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