DISPERSED GENERATION AND IMPACT TO DISTRIBUTION NETWORK

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INTRODUCTION

The increasing of the consumption of electricity, the scarcity of conventional energy resources and requirements for environmental protection exert pressure on the use of renewable energy sources. Renewable energy sources are regarded as energy of flowing water, wind, solar, biomass and geothermal heat. Energy contained in these sources can be used to produce heat or electricity. Renewable energy sources other than biomass do not adversely affect the environment. These sources use appropriate local energy sources, and therefore can be spread throughout the country. Renewable sources may be an important source of electricity in remote locations.

These power supply sources are connected mostly to low and medium voltage networks, and foreign literature uses the term Dispersed Generation (DG abbreviation).

THE EUROPEAN LEGISLATIVE FRAMEWORK

In 2009 there was adopted the new Directive 2009/28/ES about support for utilizing energy from renewable sources. The Directive is based on goals to increase the renewable energy's share of total gross final energy consumption in the EU to 20 % by 2020 and increase the share of renewable energy in all modes of transportation to at least 10 % of final energy consumption in transport in each Member State by 2020.

For the Czech Republic the Directive 2009/28/EC states the obligation to raise the share of renewable energy in the total gross final energy consumption in the CR to 13 % by 2020 (from

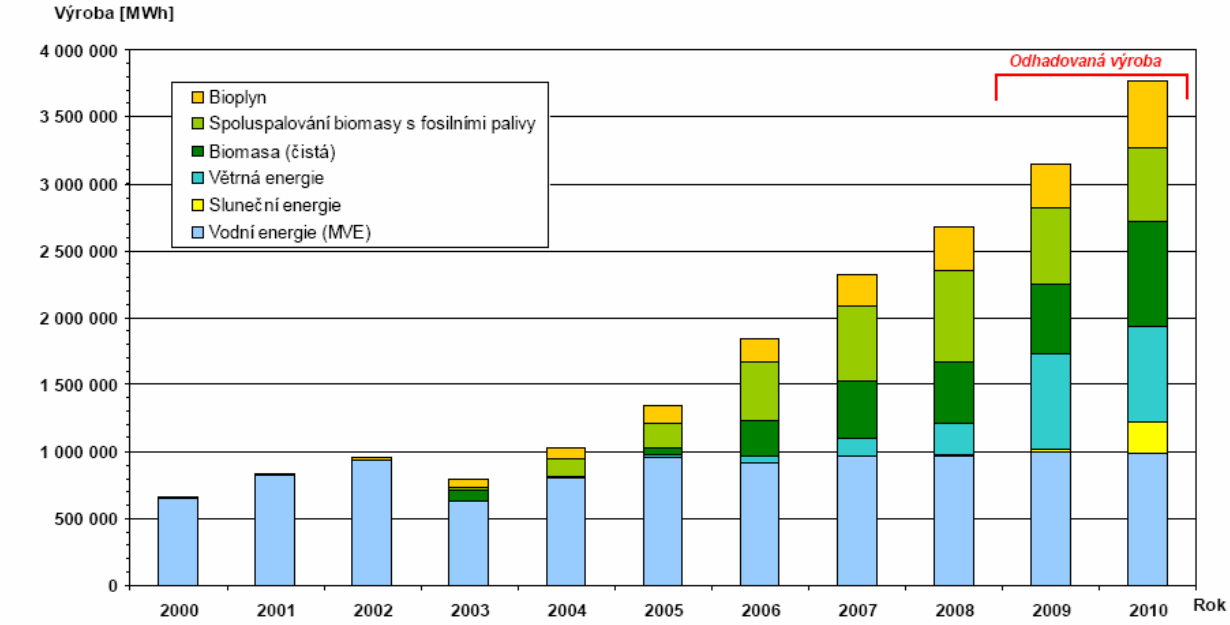
6.1 % in 2005). The 13 % can be covered from the consumed electricity produced from renewable energy sources, from energy used for heating and cooling from renewable energy sources and energy used in transportation that is produced from renewable energy sources. Meanwhile, the increasing of the share of energy from renewable sources in all types of transportation must be, in accordance with the directive, at least 10% of the final energy consumption in transportation in the Czech Republic by 2020.

LEGISLATION FRAMEWORK IN THE CZECH REPUBLIC

In the Czech Republic support for the production of electricity from renewable sources already began in 2002, at that time without any legal obligation. From **graph 1** shows how gradually the share of this electricity production increased over time.

In **graph 1** there is a target set for 2010. It is based on the original directive, and unlike the 2020 target, which is mandatory, this is only recommended.

The basic system for the support of the production of electricity from renewable sources in the CR was set up in 2005 by the Act no. 180/2005 Coll. about the promotion of electricity from renewable sources. The chosen support system and the conditions were and still are considered among the most progressive and liberal in Europe. This has also recently brought several problems, which have to be currently solved. In recent years the network operators have been inundated with requests to connect wind farms, but approximately in the last 2 years the hit has been the photovoltaic power plants.



Graph 1 – The share of electricity production from RES in total electricity production in the Czech Republic

CONNECTING SMALL SOURCES TO THE DISTRIBUTION NETWORKS

During the operation of small electrical producing systems attached to medium or low voltage distribution networks there can occur interferences to customers who are powered from these networks. To reduce reverse-effects of small sources to acceptable levels, it is necessary, when determining the point of connection to the distribution system, to assess if the reverse-effects limit values on the distribution network will be maintained during the basic operating modes of the source. If several such sources will be working in one part of a network, then it is necessary to consider the total sum effect of the interference of all equipment which will be operated simultaneously. Individual production of electricity can then cause only a portion of the total allowable reverse-effect limit.

Several corporate standards of energy PNE 33 3430 - *Power quality parameters* were elaborated, to assess the method of connecting small sources to the distribution network. The Power quality parameters are the subject of international standards and recommendations (IEC Series 1000, EN series 61 000). PNE series 33 3430 also reflects the current status of this issue in Western Europe.

The common material "Rules for parallel operation of energy sources with a power distribution company low or medium voltage network" has been elaborated by the Working Group ČK CIRED, for small productions of electricity, which are connected to the low and medium voltage distribution networks. These rules became the basis for elaboration of Enclosure 4 "Operating rules for distribution systems", which makes up the tertiary legislation in the field of electricity.

VIEWPOINTS FOR CONNECTING POWER LOADS AND SMALL ENERGY SOUCES

According to the PNE 33 3430-0 "Computational evaluation of reverse-effects of customers of distribution systems", the following factors must be checked:

- voltage changes
- voltage fluctuation
- emitted currents harmonics
- influence on ripple control devices (RC)
- short-circuit currents

It is also necessary to check the conditions for ensuring a secure connection of small sources to a network, operation and disconnection in adverse conditions, such as during a loss of voltage in the distribution network, during isolated-network operation.

Voltage change

The connecting of an electricity generating system to a distribution network will increase the voltage at the connection point. This increase in medium voltage networks is allowed up to 2 % of nominal voltage and low-voltage systems can allow a voltage increase of 3 % of the nominal voltage. Compliance to this requirement is difficult if the source is connected to the low voltage by long lines. Therefore, to avoid disturbing other customers by voltage drops during the starting of asynchronous generators, their connections are usually solved by a separate low voltage line from the transformer station.

Voltage fluctuation

The measure and criteria to assess the changes and fluctuations in sources of electricity is the

factor of long-term flicker disturbance A_{lt} (P_{lt}). This is determined either by measuring the actual device or by a calculation. The A_{lt} factor depends mainly on the short circuit power at the given site, the rated output of the generator and the equipment flicker coefficient ***c***.

The coefficient ***c*** indicates the ability of the relevant device to produce a flicker. It characterizes the uniformity of operation of the device for generating electricity. Electric generators powered by turbines or internal combustion engines are favorably evaluated in terms of flicker.

In the assessment of flicker, the generators for wind turbines are less negative. For machines of modern design there is already being achieved a flicker coefficient value of less than 10. With a larger wind power array there occurs a certain compensation for flicker, and the resulting flicker is less than the flicker caused by a single source.

Changes in loads at the customers cause voltage loss changes on the network impedance and thereby also changes of the supplied voltage. Voltage fluctuations in the network can be of periodic or random nature. The sources of voltage fluctuations can be arc furnaces, welding units, starting induction motors, etc.

Short-term flicker caused by operation of the source is limited by the value of $P_{st} = 1$. Long-term flicker caused by operation of the source is limited by the value of $P_{lt} = 0.46$. Inspection must be carried out mainly in wind power plants.

Emitted currents harmonics

Permissible currents harmonics emitted by a source in to the distribution network are stated in ČSN EN 50 160.

Reverse-effects on the RC device

The ripple control device (RC) operates on the principle of superposition of the network voltage tonal frequency pulses. These pulses are used to switch the relays of the RC receivers connected to the network.

Modern RC systems work at low frequencies, typically around 200 Hz. These frequencies spread well over the network because they are close to the network frequency. The transmitting level of the tone frequency pulses lies between 1.8 to 4% U_n.

The customer's connection point to the network is used for assessing whether there is occurred any unallowable influence of the RC by customers' devices. The reducing of the RC signal is often caused by power factor compensation devices, especially in high voltage networks.

Short-circuit currents

Generators connected to the low and high voltage distribution network affect the values of short circuit currents at the connection and in its surroundings. When determining the method for connecting the generator to the distribution network it is necessary to perform an inspection of the short-circuit conditions with respect.

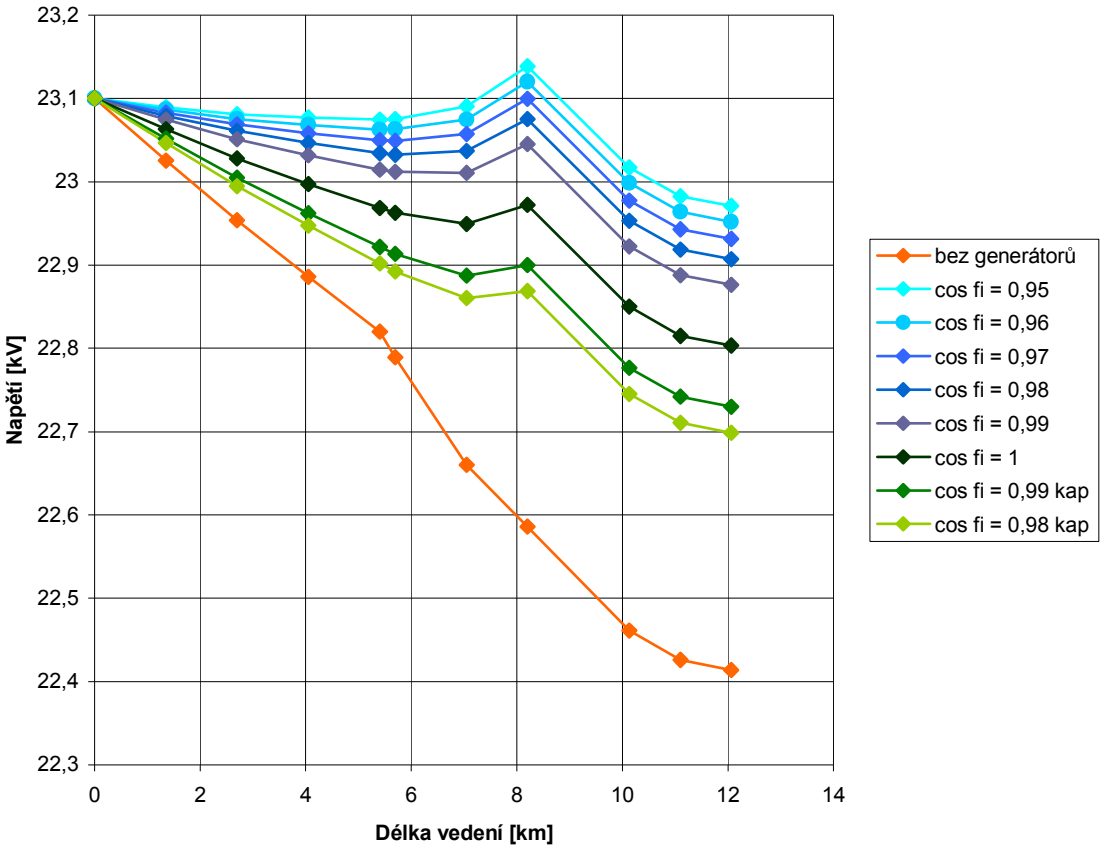
Active Networks

Number of dispersed sources of electricity that are connected to distribution networks is constantly growing. In the areas where there is the highest representation of these resources, we begin to talk about them as so-called active networks. The dominant flow of electricity in

these networks is no longer from power points, but the significant share already belongs to flows of electricity from distributed sources.

Connecting wind power plant to the 22 kV network

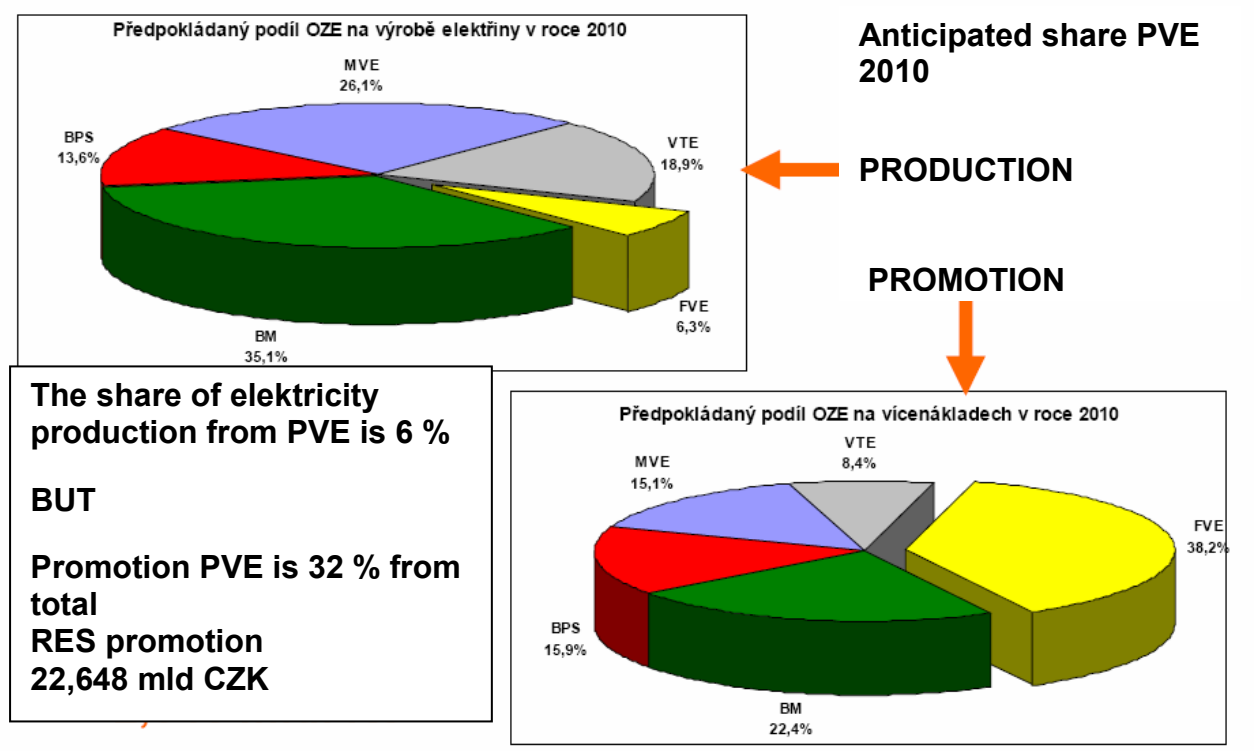
Development of wind power technology leads to an increase in outputs per unit. In the CR it was required to connect the wind power output of 4 MW to the 22 kV distribution network. In **graph 2** it was shown that the connection will be possible only when the electrical generators of wind power plants operate with a power factor in the range of cos phi = 1 to 0.98 capacitive. The accompanying graph shows the results of the calculation of the course of voltage along the 22 kV lines for power factor values from 0.95 inductive to 0.98 capacitive power factor.



Graph 2 –Voltage profile along the 22 kV lines with connection of generators with 4 MW output

CONTRIBUTION TO THE DEVELOPMENT OF RENEWABLE SOURCES, WHICH ARE PAID BY THE CUSTOMERS, IN THE PRICE OF ELECTRICITY

Production of electricity from renewable sources is gradually increasing and year on year there is an increase in the percentage share of this electricity in the total electricity production. Looking at these developments from the perspective of the extra costs paid by all customers in the price of electricity through a contribution to renewable sources and combined production of heat and electricity, and their shares with regards to the various types of renewable sources, and then we see a disturbing trend, as indicated in the **graph 3**.



Graph 3 - The share of electricity production from PVE in 2010 and projected share of PVE in the creation of tariff for customers in 2010

In the years 2002-2009 the contribution price rose gradually from 8 - 9 CZK/MWh in 2002 to 52 CZK/MWh in 2009, yet for 2010 the year to year contribution price will rise by more than 200 % to 160 - 170 CZK/MWh.

The main cause of the significant year to year increase in contribution prices is the extraordinary increase of the newly installed output of photovoltaic power plants. Through the mentioned contribution, all consumers of electricity will pay approximately CZK 3 billion in 2010, for electricity generation from this type of a renewable source. Just for comparison, in 2009, the total contributions paid to promote the production of electricity from renewable sources and combined production of heat and electricity power was a little over CZK 3 billion. Meanwhile the photovoltaic sources is not the most effective way of producing electricity from renewable sources in relation to the price level of contribution paid by all electricity consumers, this is shown in **graph 3**. The graph shows that in 2010 the expected

6 % share of electricity production from photovoltaic power plants consumed 38 % of the total contributions paid by final consumers.

Network operators and the development of renewable sources

The uncoordinated development of electricity generation from renewable sources, primarily from photovoltaic power, does not only have a negative impact on the price of the contribution that is paid by all electricity consumers, but also on network operations.

This rapid development is very quickly depleting the existing available free connectible capacity of the network and further significant investments into energy networks will be needed for further permitting of connection of renewable sources of electricity.

NEGATIVE IMPACT OF THE DEVELOPMENT OF RENEVABLE SOUCES ON THE DISTRIBUTION NETWORKS

There are several specific impacts on the operation of networks. Unfortunately, besides the fact that they all bring problems to network operators themselves, they ultimately affect the increase in prices paid by electricity consumers.

Impact of connecting renewable sources to support services (production = consumption)

The support services are purchased by the operator of the transmission system and are used to maintain a constant balance between production and consumption. Different types of renewable energy sources have different impacts on the needed volume of support services. From the viewpoint of the need of support services, the worst sources for the operator are those whose production of electricity varies over time. It is specifically the production of electricity from the wind and the sun, because here the size of the immediate production depends on whether and how the wind blows and the sun shines. The increased demand for support services can be expected with the significant development of electricity generation from wind and sun. This may bring the need for operators to solve their availability, because the supply of support services is currently limited and definitive. This condition causes an increase in the cost of acquiring support services and a price increase for system services paid by all electricity consumers.

Effects of connecting renewable sources on needed investment into distribution and transmission networks

The high number of requests for connection of photovoltaic power plants to distribution networks has resulted in the fact that the free connecting capacity for new renewable sources has been exhausted to a large extent. Therefore, additional requirements for the connection of new renewable resources inevitably carry with themselves the need for expansions and reconstructions of networks, both in the transmission system, as well as in the distribution systems. On the side of the operators this increases the demands on the funds placed into the networks. Just to connect new renewable sources will require an investment in the networks of about CZK 25 billion. The increase of costs for the construction and reconstruction of energy facilities by the operators will eventually, through regulation rules, be reflected in the increased cost for distribution and transmission, which is paid by all consumers of electricity. Every construction and sometimes also reconstruction of the energy system is preceded by a relatively time-consuming authorization procedure, which is defined by valid legislation.

Impact of connecting renewable energy sources on the operation of distribution and transmission networks

For network operators the rapid development of renewable sources brings entirely new challenges. So far, it was customary for the electricity to "flow" from the manufacturer via the transmission network to the distribution system and then to the consumer, for which the networks were built. The connecting of a large volume of electricity production, from renewable sources, to the distribution networks brings with it the fact that electricity will often "flow" the other way. Specifically, from the distribution network to the transmission network and then from there to another distribution network and to the consumer. Another negative impact of connecting renewable energy sources, particularly photovoltaic sources and the production of electricity from them can be expected in the area of a shortage of idle power, which the non-regulated or problematically regulated photovoltaic sources bring. Lack of idle power then brings problems with the regulation and maintaining of voltage and also possible problems with the operation of rotating machines (motors). The elimination of the mentioned problems will bring with it additional costs and investments on the part of the network operators, which through regulation rules will eventually also be reflected in the increased cost for distribution and transmission, which is paid by all consumers of electricity.

Conclusion

The issuing of Law no. 180/2005 about the promotion for the utilization of renewable energy sources and related pricing assessments of the Energy Regulatory Office create legislative conditions for the development of electricity and heat from energy sources that are friendly to the environment. Another prerequisite is the technological development in the area of wind and solar power plants and other facilities for the use of renewable resources.

Literature

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