CONNECTION OF RENEWABLE RESOURCES TO POWER GRID

Ing. Michal Adamec, Prof. Ing. Miloš Beran, CSc.

Abstract

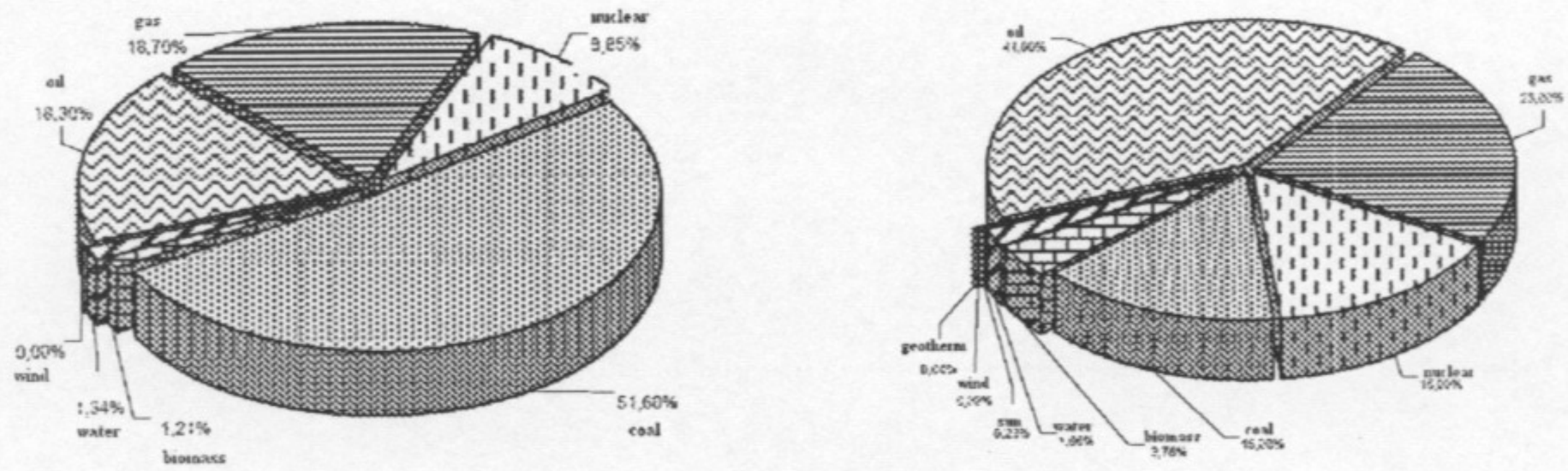
This paper deals with the connection of distributed resources. It is divided into two parts. The first is devoted to renewable energy resources. The review of these resources will help to determine if they could reduce the global warming and if they could play a significant role in electricity generation over the course of a decade. The second part deals with problems of blackouts, overcurrent coordination and voltage sags in distributed generating systems.

Key words

renewable resources, distributed generation system, overcurrent protection, voltage sag, islanded mode

1. Renewable energy resources

Almost 98% all of energy in the Czech Republic is generated from nonrenewable resources (52% coal, 8% nuclear, 19% natural gas, 18% oil and 1% from hydropower). The remaining 2% is generated from renewable resources. The total amount of energy generated from renewable resources in the EU is bigger, nearly 6%. This means that there are reserves in renewable energy resources. There is a real chance to increase the amount of energy generated from them in the future. The share of renewable and nonrenewable resources in the generation of electric energy in the Czech Republic and in the EU is presented in Fig.1.



the Czech Republic the European Union

Fig. 1: Generation of electric energy in CR and EU according to resources

1.1. Wind Energy

For a preliminary analysis of a wind power plant output it is possible to use the formula

$$P = k \times D^2 \times v^3 \qquad (1)$$

where **D** is the length of the vane of the rotor wheel [m], **v** is the velocity of the wind [m/s], and **k** is the coefficient depending primarily on the nature of the scenery and on the efficiency of the wind turbine. The value of 5 m/s is usually considered to be the minimum economic limit for the exploitation of wind power.

Despite the fact that our country does not abound in favorable conditions for development of the wind power, some convenient localities with relatively high average velocities of the wind can be found. However, these localities are situated at higher altitudes, where construction of wind power plants is often forbidden by nature protection regulations. For this reason, wind power engineering does not play a very significant role in the energy balance of the Czech Republic.

1.2. Water Energy

The turbine output can be determined by applying the following formula

$$P = Q \times H \times k \qquad (2)$$

where **P** is output [kW], **Q** is water discharge [m^3/s], **H** is turbine effective head [m] and **k** is the dimensionless constant (from 6.5 to 8.5).

Hydroelectric power stations participate in the total installed capacity in the Czech Republic by 17 %, and in production, by less than 4 %. The hydropower potential of rivers in the Czech Republic, utilizable from the technical point of view is 3,380 GWh/year, out of which the hydropower potential utilizable in the small hydroelectric power stations is 1,570 GWh/year. The hydropower potential currently utilizable in the small hydroelectric power stations is approximately 30 %, i.e. about 500 GWh/year. This shows that the Czech Republic still has a number of localities for the development or restoration of small hydroelectric power stations.

1.3. Biomass

Biomass consists of:

$$h + A + W = 1 \qquad (3)$$

where **h** is the weight of the combustible [kg.kg-1], **A** is the weight of ash [kg.kg-1], **W** the weight of water [kg.kg-1]

The source of biomass energy in the Czech Republic could be primarily the wood waste produced by the wood-processing industries and forest exploitation. In addition, it is possible to use by-products such as cereal and colza straw and other waste of caulocarpic plants, wooden containers and, in the future, even energy forbs (such as cultivated sorrels and hop-trees) and the fast-growing energy crops (such as willows, poplars, and various sorts of ash).

1.4. Solar Energy

The Czech photovoltaic (PV) industry has shown considerable growth in the past few years. Unfortunately, the total installed PV capacity is still small even when compared to other renewable energy resources. Most of the growth of the PV installed capacity and in fact the overall increase in the utilization of renewable energy resources was brought about significant government' subsidies, see Chart 1.

Sort of renewable energy resources for electricity generation	Redemption price [Kč] for 1kW
small hydroelectric power stations	**1,50**
wind power stations	**2,70**
biomass combustion	**2,50**
biogas combustion	**2,50**
geothermal energy	**3,00**
solar energy	**6,00**

Chart 1: Renewable energy resources and their redemption price

Green city

The development of renewable resources in the Czech Republic is too slow. The situation could, however, be better, as the development in other coutries shows. A suitable example is Chicago. Chicago is a city which supports the development of solar power, wind energy and, in point of fact, everything green in-between.

The whole system is based on green certificates. The green certificate represents the environmental attributes of the renewable energy resource. Customers buy these certificates to help the development of additional energy resources. A considerable amount of the profit from green certificates is put into a special fund that is used to promote new renewable resources, for example to purchase solar panels for zero energy houses.

A considerable number of roofs were already used, it was necessary to find an alternative way of the photovoltaic solar panel location. The panel was embedment in the photovoltaic solar panel into the glass facades on the outside surface.

2. Overcurrent Protection and Voltage Sag in Distributed Generating Systems

Overcurrent protection and voltage sag coordination are based on the upstream impedance of the point of common coupling or system impedance. The voltage sag magnitude is obtained by taking into account the voltage drops across system impedance. Sag duration depends on the operation time of the overcurrent protective device. Under normal system conditions, system impedance is constant, but in the case of distributed generation it can change from a low value to a high value. This situation should be considered, since sensitive equipment will be operating under emergency conditions.

Installation of new types of power sources is promoted by the utilities due to the advantage construction of new distribution and transmission infrastructure. Each of the power generators in a distributed system, such as wind turbines, photovoltaic cells and combustion engines, has its own advantages [easy installation, fast start] and disadvantages [voltage distortion generator, subharmonics, flicker, voltage sags and voltage swells]. Distribution generation carried out by utilities concerns related with potential distribution system and the customer interest.

One of the important issues is the new concept of overcurrent protection, where there will be changes in system behavior and the flow of power under short-circuit conditions. The distribution systems, which were considered as radial circuits, have now become double or multiple-feed circuits bringing about important changes in operation and having safety consequences. The most important is the verification of the protective-device breaking capacity, which might not be sufficient due to the increase in the available short-circuit power. The short-circuit study characteristic will change from considering the fault as an event taking place far away from the source to a near occurrence, where the subtransient and transient impedances will be included in the calculations.

Induction generators directly connected to the supply will show a special behavior when a short-circuit takes place. Since the induction generator gets its excitation from the mains, it is unable to maintain short-circuit currents for a long time. The short-circuit currenthort-circuit

The islanded mode operation is a situation in which the main supply is disconnected from the power system and the distributed resources continue operating with its own sources. The voltage sag is considered as nonpermanent voltage reduction values [10% - 90%] of the rated voltage. Another aspect that will be studied is the coordination between overcurrent protection and the voltage sag.

A circuit with distributed resources [see Fig. 2.] may be represented by more than one single device. When the islanding circuit breaker is closed, the source impedance is the parallel combination of the utility [power system] and distributed resources impedances. When the islanding circuit breaker is open, the source impedance jumps to a higher value. In the case of fault, a short-circuit fault current will be greatly attenuated and the operating time of the protective device will be increased. The coordination study must be done only for two branches on the distributed resources side of the islanding circuit breaker, with maximum and minimum protecting device rated currents.

Legend

PC - Point of common coupling

Z_1 – system impedance

Z_2 – line impedance

ZDR – distributed resources impedance

PS – power system [synchronous generators]

IG – induction generator

IM – induction motor

SE – sensitive equipment

ICB – islanding circuit breaker

DR – distributed resources

CF – case of fault

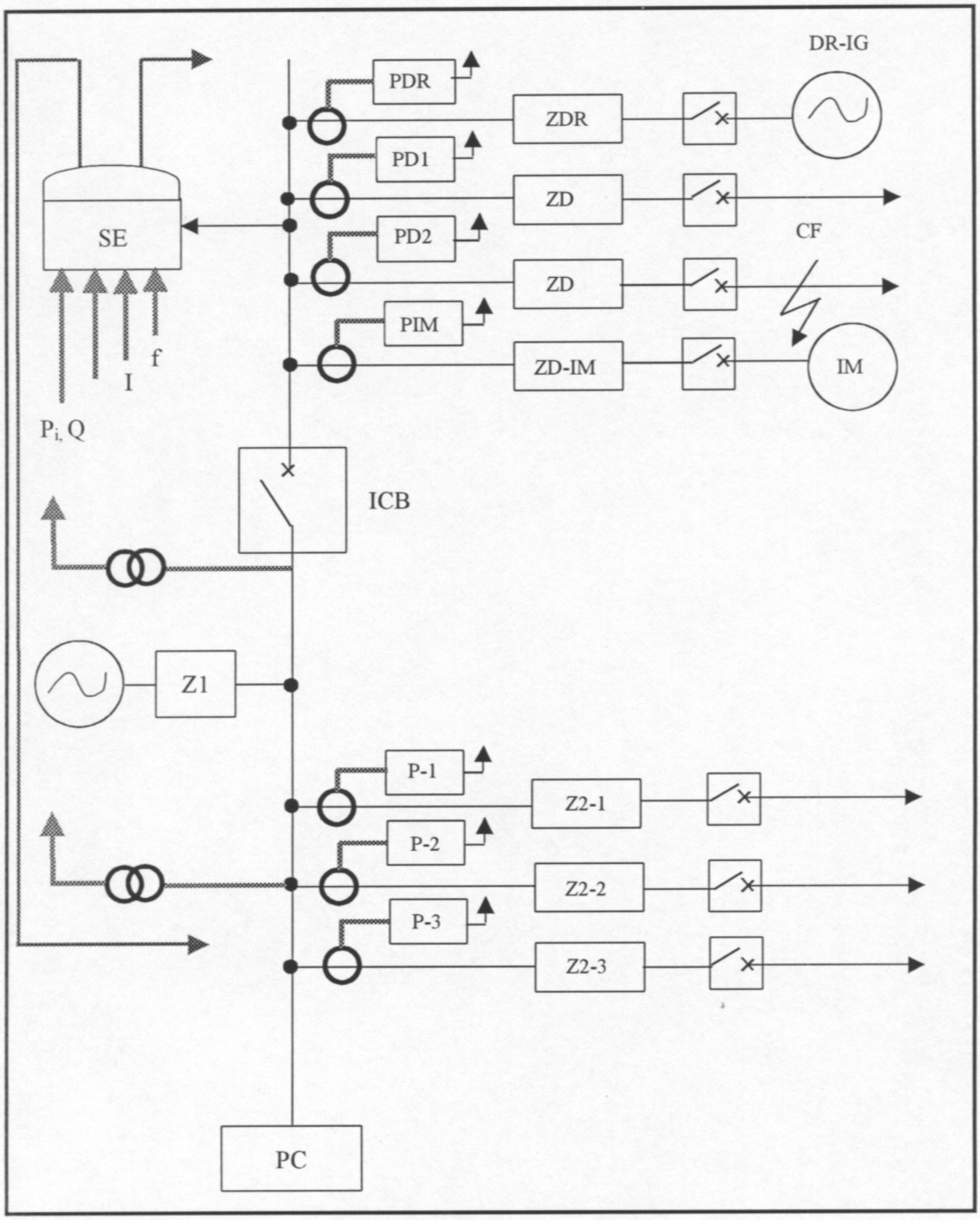


Fig. 2: System with utility and distributed resources

3. Conclusion

The development of renewable energy resources is not fast enough. The main problems are the location of the Czech Republic and the cost of these resources moreover the people and organizations are not ecology-minded. There are, however, ways of increasing the utilization of these resources by introducing support redemption prices. It is estimated that the renewable energy resources could compete with the common nonrenewable resources in the future.

By the year 2010, approximately 20% of the new generation of electric energy is predicted to come from distributed generation. The inclusion of distributed resources in a distribution system leads to an important change in the coordination procedure. The new scenario implies that the time-voltage characteristic of the protective device changes into a zone that modifies the previous methodologies and increases the dropout susceptibility of sensitive equipment.

4. Bibliography

[1] J.C. Gómez, M. M. Morcos: Coordinating Overcurrent Protection and Voltage Sag in Distributed Generation Systems, IEEE Power Engineering, February 2002

[2] Gabriela Martin: Renewable Energy Gets the "Green" Light in Chicago, IEEE Power Engineering, December 2003

[3] Andrew Hanson: Power from the people, IEEE power & energy magazine, June 2004

[4] Ekowatt [online] 1.4.2005. Accessible:

http://www.ekowatt.cz/library/infolisty/index_en.php3

Ing. Michal Adamec

University of West Bohemia in Pilsen, 26 Univerzitní, 306 14, Pilsen, http://web.fel.zcu.cz/

phone.: +420 377 634 385, e-mail: adamec@kee.zcu.cz

Prof. Ing. Miloš Beran, CSc.

University of West Bohemia in Pilsen, 26 Univerzitní, 306 14, Pilsen, http://web.fel.zcu.cz/

phone.: +420 377 634 319, e-mail: beran@kee.zcu.cz