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Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

# 13. Production and distribution of electrical energy

13.1 Possibilities of electrical energy production

13.2 Renewable resources of electrical energy

13.3 Distribution of electrical energy, electric energy system

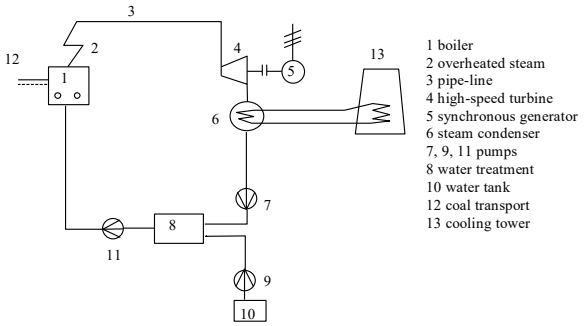
Doc. Ing. Stanislav Kocman, Ph.D.
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## 13.1. Possibilities of electrical energy production

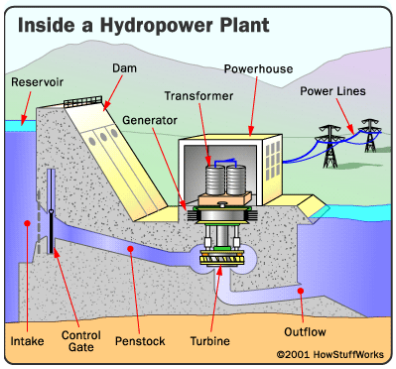
13.1.1. Power stations

Electric energy is mostly produced in electric power stations (https://en.wikipedia.org/wiki/Power_station). According to the primary (input) energy it is possible to classify the power stations as follows:

- fossil-fuel power stations: the electric energy is getting from the energy of a fuel (coal, gas, oil). It utilizes a heat getting by burning e.g. the coal in a boiler where steam is produced from the water. The steam leaving the boiler is more warmed and under a high pressure is feeding into a turbine which drives the synchronous generator with a speed of 1500 or 3000 rpm. The steam leaving the turbine is changing into the water in a steam condenser. Next the water is cleaned and completed in a water treatment and after this process is again supplied into the boiler.




- nuclear power stations: the electric energy is getting from the energy of the nuclear fission. The principle of the nuclear power station is close to the thermal power stations. The difference is in getting the heat energy: here from the nuclear fission in a reactor.
- hydroelectric power stations: the electric energy is getting from the potential energy of the water. The power stations can be built on a dam which holds the water. The water flows under a pressure from the reservoir to the low-speed turbine to drive it. The turbine is connected with the synchronous generator with the salient-pole rotor. The pumped storage plant has two reservoirs, lower one and upper one. Usually at night when there is a surplus of electric energy in the supply network, they draw the water from the lower reservoir into the upper one. At the time of a peak load they work as the power stations. It means the water is released from the upper reservoir to the lower one across the turbine driving the synchronous generator to generate the electric energy.



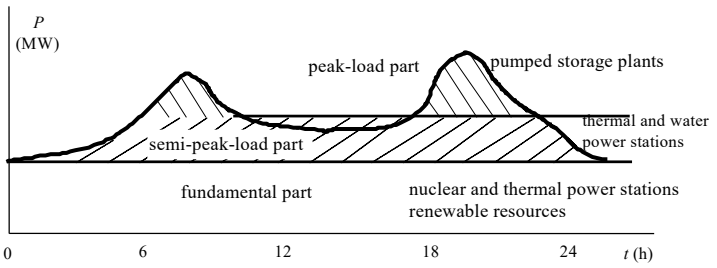

- unconventional power stations: wind, geothermal, solar energy power stations, etc... These power stations together with the hydroelectric ones are also classified as the renewable resources of the electrical energy (https://en.wikipedia.org/wiki/Power_station).

13.1.2. Supply of the electric energy to the mains

According to their mode of the electric energy supply to the mains it is possible to classify them as follows:

- fundamental-load power stations: thermal and nuclear power stations, renewable resources
- semi-peak-load power stations: thermal and water power stations, renewable resources
- peak-load power stations: pumped storage plants

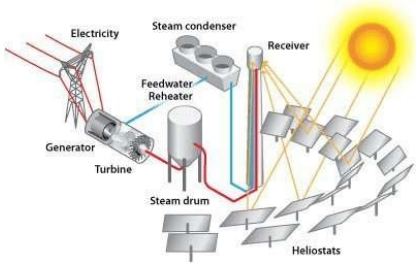
A consumption of the electric energy by factories, plants, inhabitants in their places of residence, office buildings, etc. is not constant within a whole day, but it is changing as it can be seen in figure.



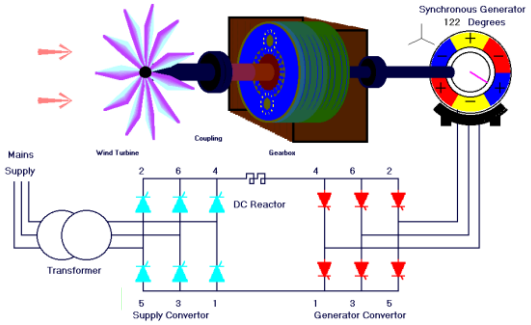
## 13.2. Renewable resources of electrical energy

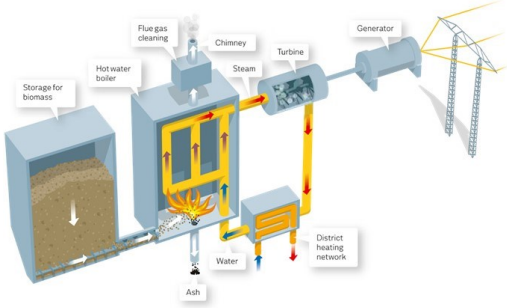
Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat and heat generated from biomass (https://en.wikipedia.org/wiki/Renewable_energy). The energies used for generating electricity can be classified as:

- Solar energy: there are two possibilities of the conversion of the solar energy into the electrical energy. A solar photovoltaic power plant converts sunlight into direct current electricity using the photoelectric effect, after it is changed into alternating current for connection to the electrical grid. Solar thermal power plants use e.g. heliostats to direct sunlight onto a pipe containing a heat transfer fluid, such as oil. The heated oil is then used to boil water into steam, which turns a turbine that drives an electrical generator (https://en.wikipedia.org/wiki/Power_station).




- Wind energy: using wind turbines to generate electrical energy in areas with strong, steady winds. It includes electrical generator, gear box, adjustable speed drive (rectifier, DC reactor, inverter) (or continuously variable transmission component), control electronics, rotor, blades and other construction elements.
- Marine energy: energy carried from ocean waves  tides, salinity, and ocean temperature differences. The movement of water in the world's oceans creates a vast store of kinetic energy, or energy in motion. This energy can be harnessed to generate electricity to power homes, transport and industries (https://en.wikipedia.org/wiki/Power_station).
- Geothermal energy: energy carried from hot steam from underground.
- Biomass energy: energy carried from green natural waste being fueled. It contains a storage for biomass, a hot water boiler where the steam is produced from the water flowing in a pipeline into it. The steam leaving the boiler is regulated and feeding into a turbine which drives the generator.




## 13.3. Electric energy system, distribution of electrical energy

### 13.3.1. Electric energy system

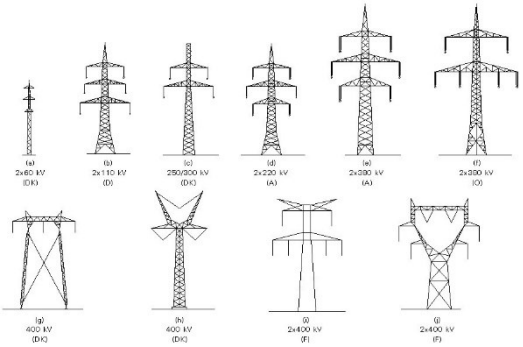
The electric energy generated by synchronous generator is transformed in power station transformer to a higher level of voltage (e.g. from 10 kV on 400 kV) which is more acceptable for electric power transmission. After the electric power is transmitted from the electric power stations by transmission lines to the transformer stations in main buses of the electrical network, and then by distribution systems to the transformation stations and distribution points in the points of electric energy consumption.

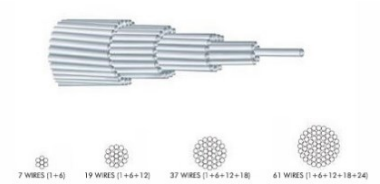
Transmission system is used to transmit very large power among main nodes of power system (400, 220 kV). Distribution system is used to distribute electrical energy from supply node into industrial, traffic networks and into tertiary branch (110 kV, 35 kV, 22kV, 10 kV...). The voltage levels for defined types of supply voltages are in figure. The values are prescribed for line voltage.

| Voltage Level | Value Level Mark | System | Valid Section |
|---|---|---|---|
| Low Voltage Level | Below 1000V | AC | Secondary distribution |
| Medium Voltage Level | 1000V to 69kV | AC | Primary distribution |
| High voltage Level | Below 100kV | AC | Secondary transmission |
| Extra High Voltage level | 230kV to 800kV | AC, DC both | Primary Transmission |
| Ultra High Voltage Level | 800kV to 1000kV | AC, DC both | Primary transmission |
| | Over 1000kV | HVDC is preferable | Primary Transmission |

13.3.2. Distribution of electrical energy

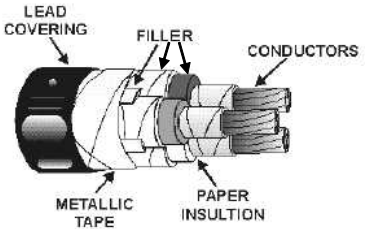
The distribution of electrical energy can be projected as open-wire (overhead) power line or underground (cable) power line. The open-wire transmission system is with uninsulated conductors designed as an aluminum alloy made into several strands (e.g. 4 or 6) and reinforced by steel core to improve a mechanical strength of the line. The task is to solve the weight of the line, the wind speed or icing on overhead lines, etc… The overhead line is used to transmit very high levels of electrical power at ultra high voltage (UHV), extra high voltage (EHV), high voltage (HV), and medium voltage (MV), low voltage (LV) of power lines of electric traction and in sparsely built-up areas. The conductors are fixed wit usage of insulators on transmission tower https://en.wikipedia.org/wiki/Electric_power_transmission).





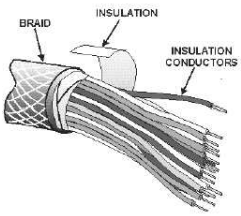

The electric power is also distributed by power cables which can be undergrounded. The underground cable lines have advantages: they take up less right-of-way, are safer, have lower visibility and are less affected by bad weather. But their insulations and a need of an excavation cause their much higher costs than the open-wire line. The disadvantage is a limitation of their thermal capacity, which permits less overload than the open-wire line, and at AC cables their capacitance causing potential worse transmission effectiveness at higher power cable line length beyond c. 80 km (https://en.wikipedia.org/wiki/Electric_power_transmission). The power cable lines are used in distribution systems of HV, LV in urban and industrial agglomerations, public networks of LV.






To transmit low level of power the communication line is used in the area of communication, telecommunication, computer networks and instrumentation and control. To protect the signals flowing across the cable wires against ambient electromagnetic field a metallic braid is used, and also coaxial cables are used. To avoid negative influences of radiating electromagnetic disturbance optical cables are also used.






Requirements on electrical power lines:

- good electrical conductivity
- economy
- allowable warming (wire insulation is sensitive)
- mechanical strength and ruggedness
- insulation of sheathing or covering
- permissible voltage drop
- immunity against short-circuit currents

Problems associated with operation of the power lines

- losses, power factor
- capacity (power sent over the power line is limited)
- system stability (sets the limit of the transferred power)
- load balancing (to avoid overload conditions)
- failure protection
- maintenance