Chapter 01 : General techniques of electricity production

Lecture 01

1.1 Introduction

Electricity is produced by an energy source provided by nature. This operation is carried out using different means of production, depending on the quantities produced and on the essential evolution of the current mode of production and energy consumption towards low carbon solutions to fight climate change. In this context there are two different types of production:

Centralized production: Electricity is produced centrally, throughout the country and in large quantities, by power plants using different energy sources (fossil, fissile and renewable) and making it possible to supply consumers through a transport and distribution networks.

Decentralized production: Electricity is produced in a decentralized manner, directly at the consumers and in small quantities, by equipment using renewable energy sources, for immediate self-consumption.

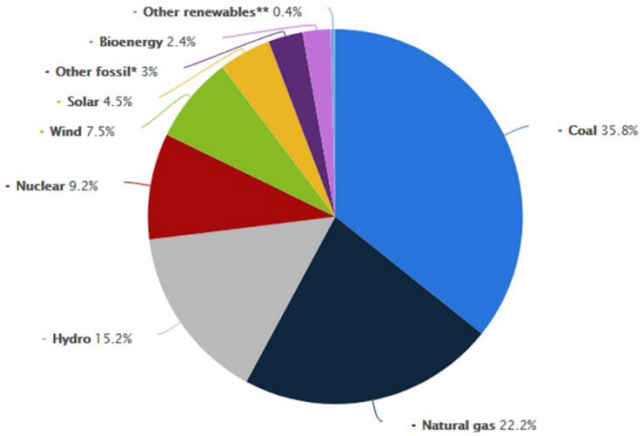

Figure.1. Distribution of electricity generation (2022)

1.2 Sources of energy

1.2.1 Non-renewable sources

- Coal
- Natural gas
- Oil
- Nuclear energy

1.2.2 Renewable sources

- Solar energy
- Hydraulic energy
- Wind energy
- Geothermal energy
- The biomass

1.3 Centralized electricity production

To meet the demand for electricity from consumers of different types (individuals, industrialists) and distributed across an entire territory, it is necessary to use industrial means of production making it possible to produce electricity in large quantities.

This operation is carried out in power plants by rotating a turbine which drives an alternator using the force of wind, water or water vapor.

There are different types of power plants depending on the energy used:

Thermal energy: In this type electricity is produced from fossil fuel sources (coal, fuel oil, and gas).

Nuclear energy: Electricity is produced from a fissile energy source: uranium (an ore contained in the Earth's subsoil).

Renewable energy: electricity is produced from renewable energy sources, which nature constantly renews: water, wind, sun, underground heat, organic matter (wood, waste, etc.), and marine energies.

As electricity cannot itself be stored, its production is the result of a combination of different complementary means of production, each having a role in the consumption curve.

1.3.1 Thermal energy

Fossil-fired thermal energy is a source that depends on fossil fuels (coal, gas or oil), elements contained in the Earth's subsoil

Figure.2. Thermal power planet

It is possible to produce electricity in flame-fired thermal power plants, (also called flame-fired power plants or classical thermal power plants), thanks to the heat released by the combustion inside these plants.

Fossil-fired thermal energy is the most widely used in the world because coal is abundant, but it emits a lot of greenhouse gases.

1.3.1.1 flame-fired thermal power plant

A flame-fired thermal power plant is made up of the following parts:

1 - Boiler
2- Turbine
3- Super-heater
4- Condenser
5- Economizer
6- Feedwater pump
7- Alternator
8- Chimney
9- Cooling tower

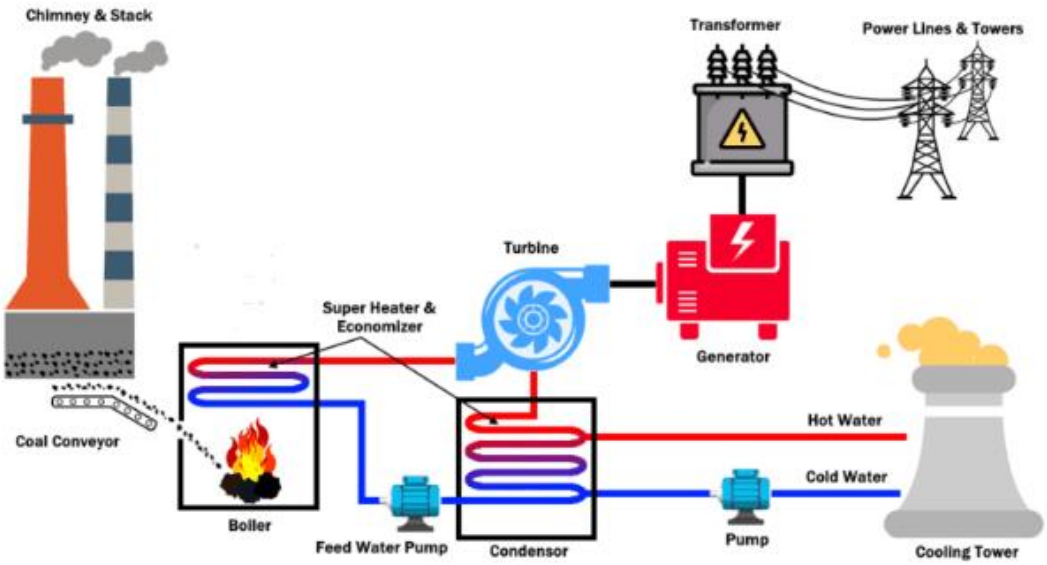

Figure.3. Thermal power planet

to reject waste

Boiler: The boiler in the thermal power plant is used to convert the chemical energy of coal into thermal energy or heat energy. During the combustion of coal, a high temperature is produced inside the boiler. This temperature is high enough to convert water into steam.

Super-heater: The wet and saturated steam is supplied to the super-heater. And it is a device that converts it into dry and superheated steam.

Turbine: This superheated steam is a strike on the turbine blade. And the turbine starts rotating. The turbine is a mechanical device that is used to convert the heat energy of steam into rotational energy or kinetic energy. The turbine is mechanically coupled with an alternator via a shaft.

Condenser: The exhaust steam of the turbine reuse in the cycle. To increase the turbine efficiency, we need to condense this steam to maintain a proper vacuum.

Economizer

The economizer: is a heat exchanger device that is used to reduce energy consumption. In the boiler, flue gases are exhausted into the atmosphere. These gases have a high temperature. So, the economizer uses the heat of flue gases to heat the water.

Feedwater pump: A feedwater pump is used to supply water into the boiler.

Alternator: The alternator and turbine are connected on the same shaft. The rotor of the alternator rotates and generates electrical energy.

Chimney: During the combustion of coal, the flue gases are generated in the boiler. The chimney provides a path to the flue gas and exhaust to the atmosphere. The chimney works based on the natural draft and stack effect.

1.3.1.2 Working principle

1- Combustion: A fuel is burned in the burners of a boiler. Note: before being burned in the boiler, 02 of the 03 fuels undergo special preparation.

- The coal is ground into powder.
- The fuel oil is heated to make it liquid then vaporized into fine droplets.
- While the gas is injected directly without preparatory treatment.

2- Steam production: The boiler is covered with tubes in which water circulates. The fuel, when burning, releases heat which will heat the water and transform it into steam which will be sent at high HT temperature and under HP pressure to the turbines.

3- Electricity production: The water vapor obtained, through expansion, turns a turbine which in turn drives an alternator. The alternator produces alternating electrical current.

4- Recycling: The water vapor leaving the turbines is again "liquefied" by a condenser in which cold water (sea or river water) circulates. The water thus obtained is recovered and recirculated in the boiler to start another cycle. Combustion fumes are removed from dust using filters and are evacuated through chimneys.

1.3.1.3 Positive aspects of Fossil Fuel Power Plants:

Reliable and Versatile:

- Fossil fuel power plants provide a reliable and versatile source of electricity.
- They can respond quickly to changes in demand, making them suitable for meeting peak electricity needs.

Existing Infrastructure:
- Many regions already have well-established infrastructure for extracting, transporting, and utilizing fossil fuels.
- This existing infrastructure contributes to the accessibility and reliability of fossil fuel power generation.

Cost-Effective:
- Fossil fuel power plants can be cost-effective to build and operate, particularly when compared to some other forms of energy generation.
- This can contribute to lower electricity costs for consumers.

On-Demand Power:
- Fossil fuel power plants can provide on-demand power, allowing for quick adjustments to match electricity demand fluctuations which is in contrast to some renewable.

1.3.1.4Negative aspects of Fossil Fuel Power Plants

Greenhouse Gas Emissions:
- The burning of fossil fuels releases greenhouse gases, primarily carbon dioxide, contributing to global warming and climate change.
- This is a major environmental concern associated with fossil fuel power plants.

Air Pollution:
- Fossil fuel combustion releases pollutants such as sulfur dioxide, nitrogen oxides, and particulate matter, leading to air pollution.
- These pollutants can have adverse effects on human health and the environment.

Resource Depletion:
- Fossil fuels are finite resources, and their extraction can lead to environmental degradation.
- Additionally, the extraction process can disrupt ecosystems, harm biodiversity, and contribute to habitat destruction.

Dependency on Imports:
- Many countries depend on imported fossil fuels for their energy needs, which can make them vulnerable to supply disruptions and price fluctuations in the global market.

Land Use and Habitat Disruption:
- The extraction and use of fossil fuels can result in habitat disruption, deforestation, and other land-use changes, negatively impacting ecosystems and biodiversity.

Water Use:
- Fossil fuel power plants often require significant amounts of water for cooling purposes.
- This can strain water resources, especially in regions facing water scarcity.

Non-Renewable:
- Fossil fuels are non-renewable resources, and their depletion raises concerns about the long-term sustainability of relying on them for energy production.

1.3.2 Nuclear energy

Nuclear energy is a source that depends on a fissile fuel, uranium, the ore of which radioactive is contained in the Earth's subsoil. A nuclear power plant is identical to a thermal power plant, except that the boiler is replaced by a reactor containing nuclear fuel.

Nuclear power plants produce electricity from the heat released by a reaction nuclear.

This phenomenon is caused by the division of the nucleus of an atom, a process called nuclear fission.

Figure.4. Nuclear power planet

1.3.2.1 Nuclear power plant

A nuclear power plant is made up of the following parts:

1- Reactor vessel
2- Control rods
3- Steam generator
4- Containment structure
5- Turbine
6- Condenser
7- Pump
8- Alternator
9- Cooling tower

Reactor vessel: Steel vessel that houses the nuclear reactor, the main component of the nuclear power plant where the fission chain reactor is produced. Its nucleus is composed of the fuel elements.

Control rods: These are the reactor's control elements, acting as neutron absorbents. They control at all times the neutron population and the reactor reactivity.

Steam generator: A steam generator is a heat exchanger used to convert water into steam from heat produced in a nuclear reactor core.

Containment structure: A building that houses the reactor's cooling system as well as several auxiliary systems. It functions as shielding in normal operation and prevents the leakage of polluting products to the exterior.

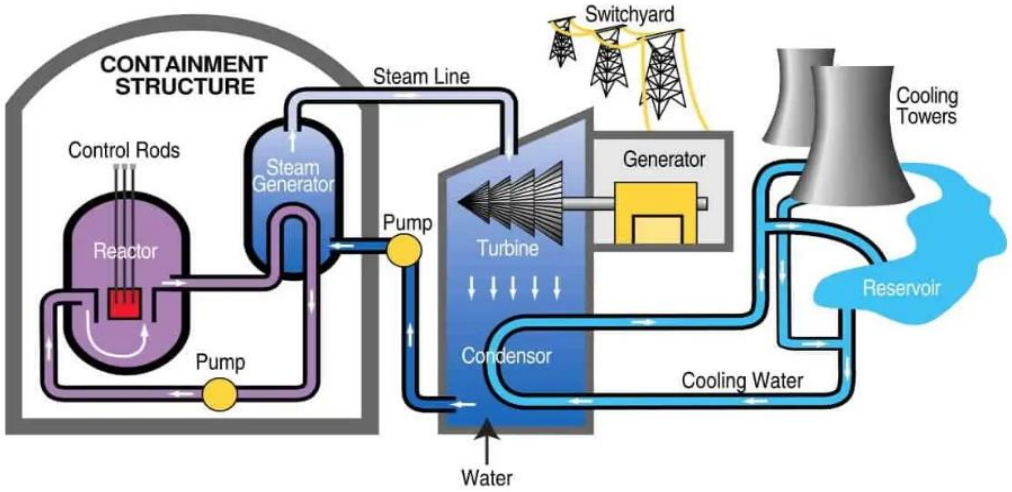

Figure.5. Nuclear power planet

1.3.2.2 Positive aspects of Nuclear Power Plants:

Low Greenhouse Gas Emissions:

- Nuclear power generation produces electricity with low greenhouse gas emissions. Unlike fossil fuel power plants.

Nuclear: 1 kWh = 4 g de CO2
Gas: 1 kWh = 446 g de CO2
Oil: 1 kWh = 818 g de CO2
Coal: 1 kWh = 955 g de CO2

High Energy Density:

- Nuclear power has a very high energy density, meaning that a small amount of nuclear fuel can produce a large amount of electricity.

approx. 8 kWh from 1 kg of coal,
approx. 12 kWh from 1 kg of mineral oil
approx. 24,000,000 kWh from 1 kg of uranium-235.

Reliable Power Generation:

- Nuclear power plants can provide a consistent and reliable source of electricity.
- Unlike some renewable energy sources that depend on weather conditions, nuclear power can operate continuously, providing a stable base-load power supply.

Energy Security:

- Nuclear power can contribute to energy security by providing a stable and diverse energy source.
- Countries with nuclear power capabilities can reduce their dependence on fossil fuel imports, enhancing energy independence.

Long Operating Life:

- Nuclear power plants typically have long operating lifespans, often exceeding 40 years.
- This longevity can contribute to a stable and predictable energy supply over an extended period.

1.3.2.3 Negative aspects of Nuclear Power Plants:

Radioactive Waste:

- Nuclear power generates radioactive waste that remains hazardous for thousands of years.
- Disposal and management of this waste pose significant challenges, and there are concerns about long-term containment.

Nuclear Accidents:

- Accidents, though rare, can have catastrophic consequences. Events like the Chernobyl disaster in 1986 and the Fukushima Daiichi disaster in 2011 underscore the potential risks associated with nuclear power, including the release of radioactive materials and long-lasting environmental impacts.

High Initial Costs:

- Building nuclear power plants involves substantial upfront costs. (it is estimated that nuclear plants cost twice as much as a coal plant to build and five times what a natural gas plant costs)
- The construction of new plants is often expensive and time-consuming, and financing can be a significant barrier.

Nuclear Proliferation:

- The use of nuclear technology raises concerns about nuclear weapons proliferation.
- The same technology that produces nuclear energy can potentially be used to develop nuclear weapons, and there are global efforts to prevent the spread of nuclear weapons.

Limited Fuel Supply:

- While nuclear power is often touted for its low carbon emissions, it relies on uranium as a fuel source.
- The availability of uranium is finite.

Public Perception and Acceptance:

- Nuclear power faces public resistance and due to safety concerns and the potential for accidents.
- This can lead to difficulties in obtaining public support.

Water use:

- Nuclear power plants often require significant amounts of water for cooling purposes.