Chapter 02: Decentralized electricity production

Lecture 02

II.1 Introduction

In the transition from centralized to decentralized and distributed energy systems, there are two well-characterized elements:

• Type of Energy Sources: regarding the nature of the resources, we can distinguish:

a- Non renewable energy sources

b- Renewable energy sources

• System Structure: regarding the configuration of the actors involved in the energy system, we can distinguish the following three main types:

a- Centralized energy systems: large-scale energy generation units (structures) that deliver energy via a vast distribution network, (often) far from the point of use.

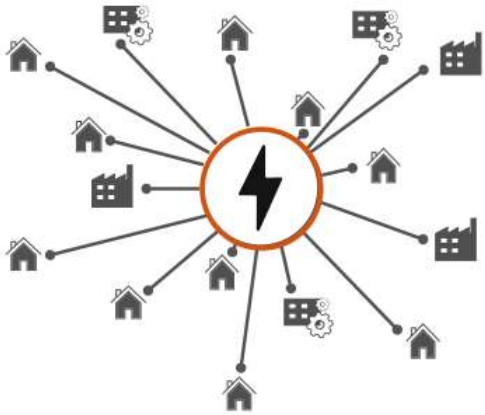

Figure.1. Centralized energy systems

b- Decentralized energy systems: small-scale energy generation units (structures) that deliver energy to local customers. These production units could be stand-alone or could be connected to nearby others through a network to share the energy surplus.

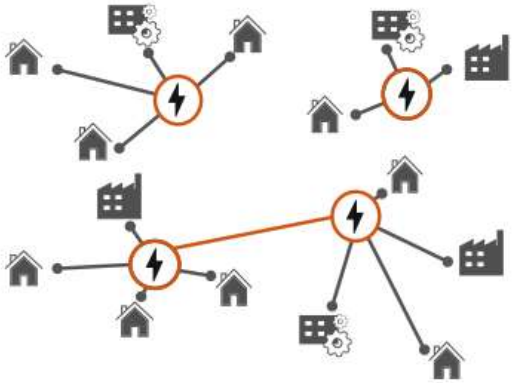

Figure.2. Decentralized energy systems

c- Distributed energy system small-scale energy generation units (structure), at or near the point of use, where the users are the producers whether individuals, small businesses and/or local communities. These production units could be stand-alone or could be connected to nearby others through a network to share the energy surplus.

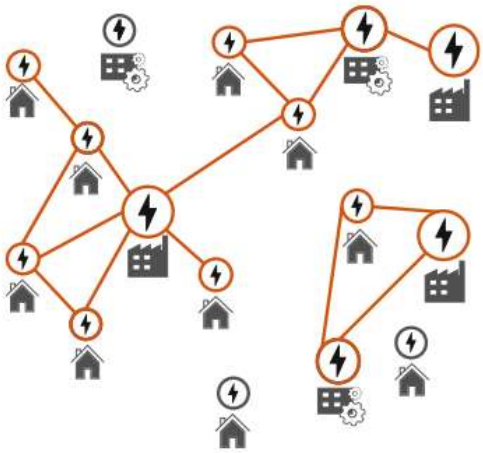

Figure.3. Distributed energy systems

II.2 Importance of Decentralized production

- Enhances energy resilience and reliability.
- Reduces transmission and distribution losses.
- Promotes environmental sustainability by utilizing renewable resources.
- Supports energy democratization by empowering local communities.

II.3 Motivations of adopting Decentralized Electricity Production

a- Environmental Impact:

- Mitigating climate change through reduced carbon emissions.
- Preserving ecosystems and biodiversity.

b- Resilience and Reliability:

- Decreasing vulnerability to centralized failures.
- Improved grid reliability and response to disruptions.

c- Technological Advancements:

- Advances in renewable energy technologies.
- Integration of smart grid solutions and energy storage.

II.4 Key Components of Decentralized Electricity Production

a- Distributed Energy Resources (DERs):

Refer to decentralized, smaller-scale energy sources that generate electricity close to the point of use or within the vicinity of the end-users.

Types of DERs:

- Solar Photovoltaic (PV): converts sunlight into electricity using semiconductor materials. Commonly installed on rooftops, in solar farms, or as solar canopies.

- Thermal Solar: thermal Solar generates electricity by harnessing the sun's heat. It includes technologies such as parabolic trough systems, solar power towers, and parabolic dish systems, concentrating sunlight to produce steam and drive turbines for electricity generation.
- Wind Turbines: convert kinetic energy from the wind into electricity.It can be onshore or offshore, ranging from small-scale turbines to larger utility-scale installations.
- Biomass: utilizes organic materials (biomass). It includes combustion of wood, agricultural residues, or conversion of organic waste into biogas.
- Hydroelectric Power: Generates electricity using the energy of flowing or falling water. It Includes micro-hydro installations, run-of-river systems, and small-scale hydroelectric plants.

b- Energy Storage Systems

Store excess energy for later use, improving grid reliability and flexibility, includes batteries, pumped hydro storage, and other emerging storage technologies.

Figure.4. Energy storage systems

c- Microgrids

A microgrid is a small-scale, localized energy system that integrates various distributed energy resources DERs to generate and manage electricity. It can operate independently or connect to the main grid, providing resilience, flexibility, and optimized energy use for specific communities or facilities. Key components include renewable sources, energy storage, and controllable loads.

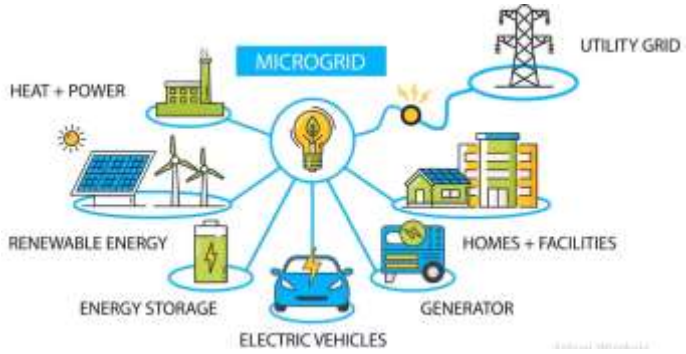

Figure.5. Microgrid

d- Smart grids

They play a crucial role in facilitating decentralized energy production and in the integration of information technology for efficient grid management.

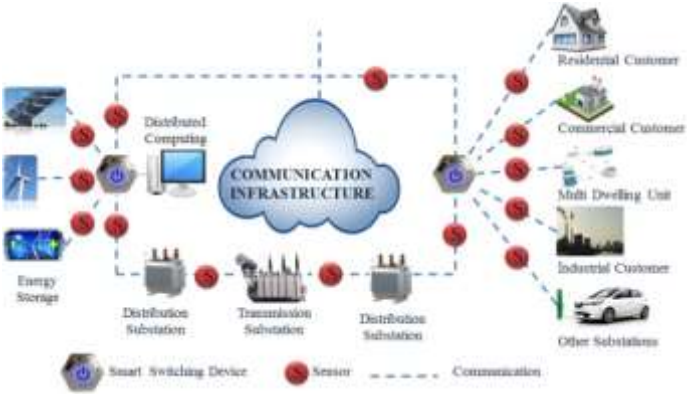

Figure.6. Smart grid.

II.5 Benefits and Challenges of Decentralization

a- Benefits:

- Increased energy efficiency.
- Enhanced grid resilience.
- Local economic development.

b- Challenges:

- Intermittency of renewable sources.
- Integration with existing grid infrastructure.
- Policy and regulatory barriers.

II.6 Future Trends and Opportunities

a- Technological Innovations:

- Advances in energy storage.
- Integration of Artificial Intelligence (AI) for grid optimization.

b- Community Engagement:

- Empowering local communities in energy decision-making.
- Collaborative energy projects and shared ownership models.