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Study of the possibilities of connecting to distribution electric networks of the various types of decentralized energy sources

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ABSTRACT: *Decentralization in energy networks is a multifaceted concept with different technological levels. Researching the possibilities of connecting different types of decentralized energy sources to distribution electric networks is an important process for the optimal integration of these sources into the existing energy systems.*
KEYWORDS - *decentralized energy sources, electricity grids, assessment and analysis, capacity*

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I. INTRODUCTION

Decentralized energy systems are diverse and can be based on different types of renewable energy sources and technologies. In addition to offering financial and economic advantages, it alleviates to a certain extent the overly complicated relationships of consumers with energy suppliers and traders.

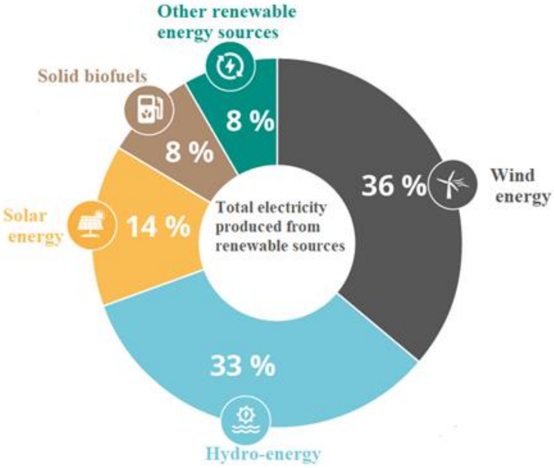

Figure 1. Distribution of renewable energy sources

Here are some of the main types of decentralized energy systems:

1. Solar Energy: Solar energy is a renewable energy source obtained from sunlight and heat reaching the Earth. This type of energy is extremely important for decentralized energy systems because the sun is a universal resource and can be efficiently used to generate electricity at different levels and in diverse contexts. Here are some key aspects of solar energy:

1.1. Solar Photovoltaic Systems (SPVs): These are systems that use photovoltaic panels to convert sunlight into electricity. When photons from sunlight hit the surface of the photovoltaic panel, it causes the release of electrons and generates a direct electric current. These systems can be installed on rooftops, land areas, deserts and even water surfaces.

1.2. Solar thermal systems: These systems use the sun's heat to heat liquids or gases, which are then used to produce steam and generate electricity through steam turbines. They can also be used to heat and cool buildings.

1.3. Solar chargers: Small solar panels can be used to charge batteries and mobile devices. This is especially useful in remote areas where stable power grids are lacking.
1.4. Microgrids with solar systems: Microgrids combine solar photovoltaic systems with batteries for energy storage. This allows communities and individual consumers to generate, store and use electricity even when the sun is not shining.
1.5. Solar Parks: Large areas of land can be equipped with solar panels to generate large amounts of electricity. These solar parks are often integrated into energy networks.
2. Wind Energy: Wind energy is a renewable energy source that uses the kinetic energy of the wind to generate electrical energy. This type of energy is based on the conversion of the movement of air masses into mechanical and, respectively, electrical energy. Wind energy is an important component of decentralized energy systems, as it can be used to produce electricity at different scales and in a variety of conditions. Here are some key aspects of wind energy:
2.1. Wind Turbines: These are large structures with rotating blades that use the wind to turn a generator and produce electricity. Wind turbines can be installed on land or in seawater.
2.2. Onshore wind farms: These are sites with groups of wind turbines installed on land, usually in remote areas with strong winds. These farms can generate significant amounts of electricity.
2.3. Offshore wind farms: These are wind turbines installed in marine waters, often near the coast. Offshore wind farms are characterized by high efficiency, as the air currents over the water surface are significantly stronger than those on land and at a constant speed.
2.4. Hybrid wind farms: Similar to solar hybrid plants, hybrid wind turbine farms combine electricity generation with battery storage. This allows users to have stable access to electricity even when there is an absence of air currents.
2.5. Aerial Wind Turbines: This type of wind turbine is installed at a height and uses consistently strong wind currents at height to generate power. They have the potential to reach higher and more sustained wind speeds.
2.6. Dual-generation energy parks: Some areas combine solar and wind systems in the same park, where weather and wind conditions are usually complementary.
3. Hydropower: Hydropower is based on using the flow of water, such as river or sea currents, to generate electricity. This type of renewable energy is one of the first and most widely used forms of decentralized energy generation.
4. Biomass: Energy is produced by burning or other processes of biomass, such as wood, plant waste, etc. The heat generated can also be used to produce electricity.
5. Geothermal energy: Uses heat from inside the Earth to generate electricity, using steam or water turbines. In the last year or two, there has been a lot of talk about the full use of this type of energy.
6. Ocean and Marine Sources: This involves the use of ocean and marine resources such as currents, tides and tides to generate electricity.
7. Heat pumps: This type of source uses the difference in temperatures to generate electricity through heat pumps.
8. Liquid fuels from renewable sources: Production of biofuels from plant and animal waste or other bioresources.

Researching the possibilities of connecting different types of decentralized energy sources to distribution electric networks is an important process for the optimal integration of these sources into the existing energy systems. Such research usually includes the following steps and aspects:
*Assessing the available climate potential in terms of the energy sources that will be used in the specific location. Among them are: solar radiation, the force of the wind, homogeneity of the water flow, etc.
*Simulations and analysis of production and consumption of electrical energy: Specialized software platforms are used for computer modeling and simulation to check the influence of future built and resp. connected decentralized sources on the production and consumption of electricity.
*Identifying appropriate technologies: Determining the most appropriate energy generation technologies that are appropriate to the resources and conditions of the specific location.

*Choice of configuration: Implementation of a technical project with precise determination of the number, type and type of generating sources, single and total power, availability of storage batteries, management and control systems, as well as the necessary auxiliary and protective components.

Integration to the distribution network:

*Network management and control: Here, technical decisions should be made to select appropriate management and control equipment to enable the system to respond dynamically to changes in energy production, network load and other factors.

*Technical requirements and standards: To ensure quality electricity supply, it is necessary to strictly observe the required technical requirements and standards that regulate the connection of decentralized energy sources to the network.

* Assessment of the need to propose and implement possible solutions for energy storage: it is necessary to make a thorough analysis of the need and the possibilities of storing the surplus of generated energy to be used at a later stage. This includes technical solutions using rechargeable batteries, flywheels, etc.

*Analysis of Investment and Operating Costs: Here a critical analysis of installation, equipment, maintenance and operating costs should be done to determine the return on investment.

It is important to note that the technical analysis should be carried out by a team that includes engineers with specific knowledge and experience in the field of renewable energy sources, electricity and network systems. This analysis would help to accurately assess the available technical opportunities and challenges in integrating decentralized energy sources into the electricity distribution network.

The evaluation of the capacity of distribution electricity networks to take additional loads from decentralized sources is an important stage of the technical analysis for the integration of these sources. This research would help determine whether the network can adapt to additional loads and what measures need to be taken to ensure the stability and reliability of the network.

The main steps and aspects that could be followed here are:

*Data Collection: Provision of network infrastructure database, information about substations, transformers, wires, voltage, load, etc.

*Assessment of current loads: performing network load analysis in different areas and time periods. This includes analysis of peak and average loads. The evaluation indicators should provide quantitative changes in the impact of the DES on the studied perimeter.

For example, if one examines the perimeter N_j that pertains to a j network node, the quantification index $\varepsilon_j$is found after calculating the parameters $N_j\ with\ DES$ and$N_j\ without\ DES$ $,respectively\ for\ network\ with\ and\ without\ DES$:

$$\varepsilon_j = \frac{N_j\ with\ DES - N_j\ without\ DES}{N_j\ without\ DES}$$

*Assessment of potentially possible scenarios to provide additional load: study options for connecting decentralized energy sources to different branches of the network, including different capacities and locations.

* Calculation of the free capacity of the network: To estimate the capacity of the network, the maximum loads that the network can take without disturbing the quality of the voltage and the stability of the network should be taken into account. Various specialized software products can be used here, through which

, different scenarios for the integration of decentralized sources could be played out and their impact on the power grid assessed

*Assessment of production variations: It is necessary to pay critical attention to the fluctuations that occur in the production of energy from decentralized sources, such as photovoltaic systems and wind turbines. These variations can affect network load and network management.

* Determination of the possible additional investments for the reconstruction of the network: if the realized study shows that it is necessary to increase the capacity of the network, in order to take on additional loads and resp. generating sources, steps should be taken to replace nodes and equipment in this direction as well. Usually, this is done by the operators of the respective distribution / supply / networks and fixed in a preliminary connection contract.

*Forecasting future needs: Here an assessment is made for the future development of the network and what measures should be taken in a long-term aspect.

*Control and monitoring: it is necessary to provide a system to control the load and the efficiency of the network after the introduction of decentralized sources.

Creating different scenarios for the integration of decentralized energy sources over time to determine how these systems will interact with the existing grid infrastructure.

*Cooperation with interested parties: ensuring interaction between institutions, including the adoption of legislative changes concerning public institutions, energy suppliers, communities and other interested parties, in order to facilitate the integration of renewable energy sources into energy systems.

II. CONCLUSION

Decentralization in energy networks is a multifaceted concept with different technological levels. It must be considered from many points of view, which requires constant work, to eliminate current and future problems, to correctly assess the expected or already manifested effects of decentralization processes. Particular attention should be paid to the effects of participation – both on specific citizens and specific investors, and on society as a whole. For the past decades, the EU has been giving policies with clear guidelines for the progress of the energy sector and energy technologies in the direction of climate neutrality with a deadline of 2050. In these policies, the development of decentralized energy sources occupies an increasingly large place. There is a growing body of research and publication giving us data, analysis, and types on decentralized energy development as a major part of solving the climate neutrality case. It's no longer a matter of knowledge or technology – it's a matter of action! We'll end with a quote that gives a good summary of what a successful transition from CPE to DPE would look like: "The transition to a climate-neutral energy system in 2050, based primarily on renewable energy sources, can be seen as a technological break with the still existing energy and economic system based on fossil fuels This is a source of challenges and opportunities for economic actors in the EU and globally. Research and innovation will play a crucial role in the transformation, whether through individual technology development or systemic innovation. The key to long-term success is to develop a broad portfolio of cost-effective and efficient carbon-free alternatives, combined with solutions for an integrated energy system built on digitization and sector integration. It is essential to plan and operate such a system "as a whole" with multiple energy providers, infrastructures and consumption sectors, creating stronger links between them in order to provide low-carbon, reliable and energy-efficient energy services, at the least possible cost to society.” [Möst et al. 2021].

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