Overview of the Management of Micro Grids with Renewable Energy Sources

Peyu Pasev, Nikolina Petkova and Valeri Mladenov

Abstract. **In this paper an overview of Renewable Energy Sources and their application in Micro Grids are made. The method of operation of a Photovoltaic Plant is described, emphasizing the peculiarities of its connection to the energy network. Special attention is paid to Renewable Energy Sources and Energy Storage Methods. The types of Micro Grids and their ways of connecting to the main grid are discussed. Features for managing of multi and micro networks are listed.**

***Keywords*—Distributed power generation, Energy storage, Microgrids, Photovoltaic effects, Photoelectricity**

I. Introduction

Climate change is a fact, and the associated issues primarily revolve around the emissions of greenhouse gases. Fossil fuels, as an energy source, represent a major generator of greenhouse gases [1]. Consequently, in adherence to the requirements of the Paris Agreement for their reduction, there is an increasing shift towards the utilization of energy from Renewable Energy Sources (RES) [2]. Such sources include solar radiation, wind energy (onshore and offshore), energy from seas and oceans, geothermal energy, biofuels, waste biomass, wood, among others. In essence, RES encompass all energy sources that are not fossil fuels.

Microgrids (MGs) can be defined as small-scale energy networks [3]. They consist of voltage sources, Energy Storage Systems (ESS) and consumers. Each renewable energy source occupies a significant position within the structure of a Microgrid, serving as a voltage source. It would be advantageous for a Microgrid to incorporate more than one voltage source to ensure its stable and sustainable operation.

Some of the possible renewable energy sources for voltage generation can be photovoltaics. Their structure and operation are discussed in the following section.

The aim of the paper is to present Renewable Energy Sources and their application in Micro Grids. For this reason, the following problems are considered: network connection of Photovoltaic Power Plants and their operation is shown, Microgrids are represented as a unification of energy sources, storage devices and consumers.

The paper is organized as follows: It start with operation and network connection of Photovoltaic Power Plants. In the next chapter Microgrids are represented. Then in chapter three a different types of Energy Storage Systems are shown. The last chapter the logic of managements of MGs are explain, and we finish with conclusion remarks.

II. Operation and Network Connection of Photovoltaic Power Plants - Photovoltaic Effect, Photocell, PV Panel, PV Power Plant

The phenomenon of generating energy through light absorption is termed as the photovoltaic (PV) effect. Two types of PV effects are distinguished: external and internal. The external PV effect is observed in certain metals, involving the emission of electrons from their surface layers under specific conditions. The internal PV effect is most pronounced in semiconductors, such as silicon and germanium, which belong to the IV group of the periodic table. Their crystal lattice is shown in Fig. 1 and through the sharing of valence electrons it is formed. To generate free charge carriers (electrons and holes), Silicon/Germanium undergo additional processing (doping) with elements from the adjacent V and III groups. Doping with elements from the V group results in a layer with increased electron content (N-type conductivity layer). Conversely, a layer with P-type conductivity (reduced electron content) is formed through doping with_elements from the III group. In Figure 2 are visualized the process of creating an electric potential between the two electrodes of a semiconductor photocell.

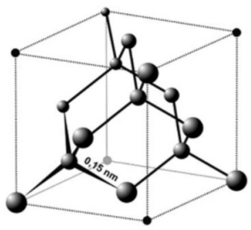

Fig. 1. Crystalline structure of silicon [4]

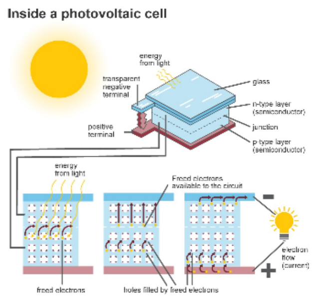

Fig. 2. Performance of Photocell [5]

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Peyu Pasev is with the Technical University of Sofia, 1000 Sofia, Bulgaria (e-mail: ppassev@tu-sofia.bg)

Nikolina Petkova is with the Technical University of Sofia, 1000 Sofia, Bulgaria (e-mail: npetkova@tu-sofia.bg)

Valeri Mladenov is with the Technical University of Sofia, 1000 Sofia, Bulgaria (e-mail: valerim@tu-sofia.bg)

when exposed to sunlight.

PV panels are panels constructed from multiple photovoltaic cells determining the output power. They are shown in Figure 3.

Fig. 3. PV panel [6]

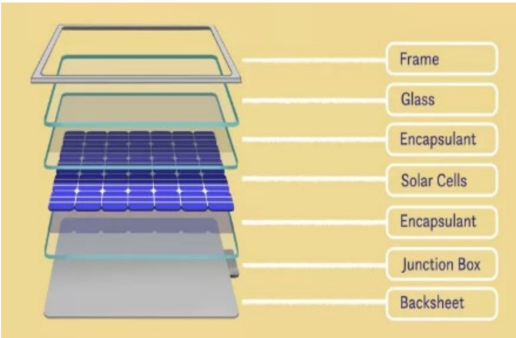

Fig. 4. The parts of a PV Panel [7]

The PV panel is structurally configured as a sandwich Figure 4. of the following layers:

- Glass
- Two layers protecting from atmospheric influences
- Semiconductor layer (active) composed of interconnected PV cells connected in series
- Back sheet to provide structural strength to the panel
- Junction box
- Adhesives and seals between individual elements.

Several panels properly connected constitute the generating part of the PV power plant where solar radiation is converted into electrical energy.

Figure 5 illustrates an exemplary PV power plant with an installed capacity of 100 kWp.

Fig. 5. 3D, Grid-connected PV System with Electrical Appliances

III. MICROGRID REPRESENTATION

The Microgrid (MG) defined as decentralized energy networks. Energy sources, storage devices and consumers are included in Microgrids. They can also be standalone entities connected or not to the Main Electricity Distribution Network (MEDN) with the capability of bidirectional energy exchange at the Point of Common Coupling (PCC) [3].

Microgrids can be classified based on the type of voltage as: [8]

• Alternating Current for Low Voltage (ACLV MG);
• Direct Current for Low Voltage (DCLV MG).

Or based on the connection to MEDN:

• Local, MG provides energy to clients within its boundaries;
• Islanded, MG can operate independently in case of MEDN failure;
• Smart, MG with the ability for intelligent energy flow management [9], [10].

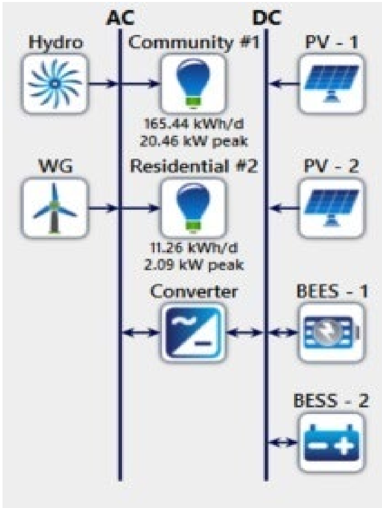

Fig. 6. Microgrid

Figure 6 illustrates a schematic example of a Microgrid. It depicts two types of loads (municipal and residential) connected to the AC grid, various types of RES utilizing generators, as well as two Battery Energy Storage systems (BES), with the connection between DC/AC branches facilitated by the inverter.

The classification of MGs according to various criteria are well done in Figure 7 [11] .

MGs can be classified depending on:

- Way of control;
- Size;
- Power supply;
- Source;
- Scenario;
- Location;
- Application.

The stochastic nature of energy production from RES and the non-inertial nature of MGs present a problem when we connect and manage Microgrids with the Medium Voltage Distribution Network (MEDN). The inclusion of numerous non-inertial electronic devices in MEDN (as part of the MG connection to MEDN) reduces its inertia and increases its susceptibility to power supply failures. As compensation for these drawbacks, an article [12] proposes methods for connecting and merging several MGs into one MMG, as well as methods for control and management.

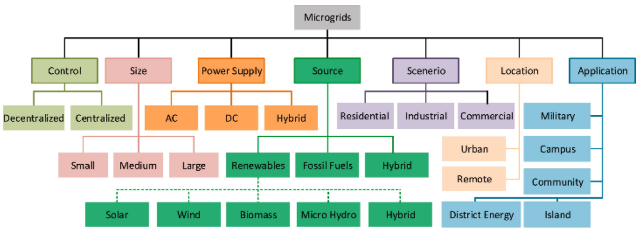

Fig. 7. Classification of MGs

When several MGs into one MMG are combined, various connection methods to MEDN can be exist per example [12]:

- ➢ Star configuration without interconnection between individual MGs, with each MG connected to MEDN at a separate PCC.
- ➢ Star configuration with a chain topology interconnecting the MGs, with each MG connected to MEDN at a separate PCC.
- ➢ Chain-connected MGs, all connected to MEDN at a single PCC.
- ➢ Chain-connected MGs, connected to MEDN at both ends of the chain (two PCCs).
- ➢ Star configuration with all MGs interconnected and each connected to MEDN at a separate PCC.

There are numerous other combinations depending on the needs and capabilities of the MG. Considerations for different types of connection to or separation from MEDN can include: Financial factors; Terrain topography; Distance between individual MGs; Independence for operation in island mode, etc.

The stable operation of an MG is related to its management and control methods. The control and management can be divided into several levels:

Primary: Also known as hardware control, it is conducted in close proximity to the generation part of the MG.

Secondary: Aims to monitor the quality of the supplied power. Through a feedback software loop, information is provided to the primary control devices to optimally adjust the quality parameters of the voltage.

Tertiary: Aims to control and manage the amplitude-frequency characteristics of the voltage when connected to MEDN. [12]

IV. Energy Storage Systems

Microgrids could not achieve stability and their efficiency would be significantly lower without Energy Storage Systems (ESS). Several types of ESS are described in articles [13], [14], [15], [16]. ESS can be categorized into five groups based on the method of energy storage, which can be seen in Figure 8 [17], [18], [19], [20].

- ✓ Mechanical ESS: This type utilizes stored mechanical energy, which is transformed into electrical energy when needed.
- ✓ Electrical ESS: Energy stored in capacitors and super capacitors.
- ✓ Electrochemical ESS: Methods involving various types of batteries, where energy is stored chemically and released as electrical energy during the reverse reaction.
- ✓ Chemical ES Biofuels, Green Hydrogen Hydrated Salts.
- ✓ Thermal ESS: Cryogenic ES systems are based on storing energy in liquefied gases (using the expansion coefficient of low-temperature liquids), such as air, nitrogen, etc. The concept varies depending on the type of liquefied gas. In some cases, (like liquid air), air is used in conventional generators that operate on natural gas, with the heat released during liquefaction used for heating. In others, cryogenic engines are used to generate electricity [21], [22], [23], [24], [25].

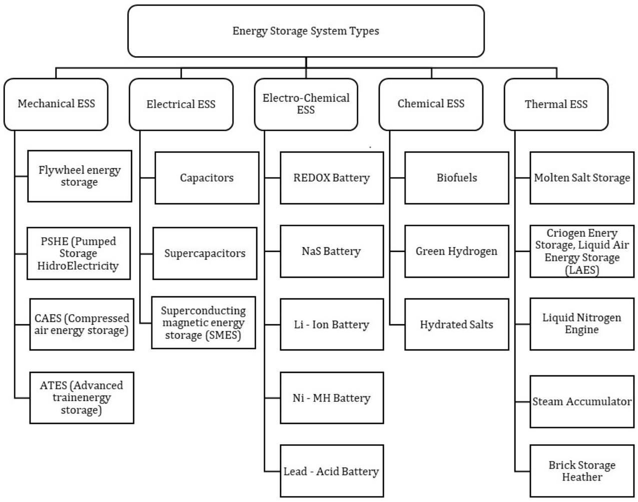

Fig. 8. Types of ESS

V. Management of MGs

Currently, a characteristic feature of MGs is the non-inertial nature of the control of output parameters. The energy production from RES stochastic is given in nature, the non-inertial character of MGs presents a problem when connecting and managing MGs with MEDN (Medium Voltage Distribution Networks). Due to the connection of numerous non-inertial electronic devices to MEDN which is a part of the connection between MGs and MEDN, a reduction in their inertia and an increase in their susceptibility to power supply failures are observed. To minimize this effect a hierarchical structure for the management and control of MGs is proposed at four levels [26], [27], [28].

In Figure 9 are shown a management structure of MGs, as follows:

- Zero level - The innermost level of control is applied in close proximity to the generating elements PV, WG, etc. Its task is to ensure the stability and operational reliability of the generated electricity.

- Primary control level - Its task is to restore and maintain system parameters to their nominal values after disturbances.

- Secondary control level - The goal of this level is to optimize the operation of the MGs to increase the economic efficiency of energy production and distribution.

- Tertiary control level - There, the human factor in the management of MGs can play a role with analyses of operations and long-term planning of energy production and distribution.

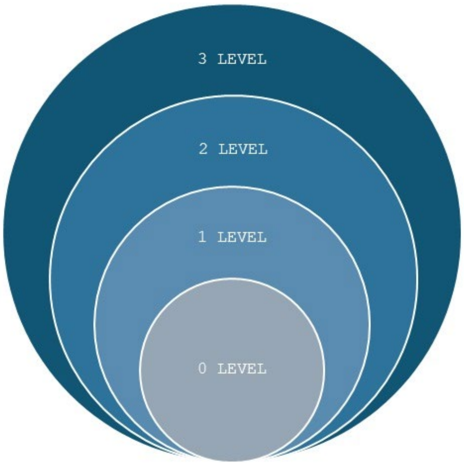

Fig. 9. The hierarchical management and control structure of MGs

VI. Conclusion

The paper represents Renewable Energy Sources as a part of Micro Grids. Different types of Micro Grids and their application to the Main Grid are described. A classification of Micro Grids and different types of Energy Storage Systems are shown and the logic of managements of MGs are explain.

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