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An Overview Study of Micro-Grids for Self-Production in Renewable Energies

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Abstract

Micro-grids (μ -grids) are small-scale power grids, specially designed to provide low voltage (LV) power supply to a small number of consumers. These networks include: different production units (energy resources), storage devices and local controllable loads, which have the possibility of being controlled. In this chapter, we will study in detail the constitution of an electrical micro-grid, their two operating modes (connected mode and islanded mode), and their controls. On the other hand, we will also discuss on hybrid micro-grids and their advantages. We will also discuss for the monitoring and data logging products used in micro-grids and hybrid micro-grids. Finally, at the end of this chapter we will ended with the importance of micro-grids systems.

Keywords: Self-production, Renewable energy, Micro-grid, Monitoring, islanded mode

1. Introduction

Since the advent of electricity and the establishment of its generating stations, its distribution has been mainly focused on urban and populated areas, as many rural and desert communities are still isolated from the larger traditional networks due to geographic and economic constraints. Providing electricity to rural and desert populations outside the global grid remains a major task for many developing and developed countries alike, and according to the International Energy Agency, micro-grids represent the most cost-effective solution to providing universal electricity access to these small (or micro) communities [1].

A micro-grid or μ -grid is defined as a group of distributed resource (DR) units which is designed to provide low voltage (LV) power supply to a small number of loads, and can operate in grid-connected mode, islanded (autonomous) mode (in the event of a fault in the main network), or ride-through between the two modes [2, 3]. This network includes [4, 5]:

1. Different local production units (energy resources) (micro-turbines, fuel cells, small diesel generators, photovoltaic panels, mini-wind turbines, small hydro).
2. Storage devices (flywheels energy storage (FES), energy capacitors and batteries).

3. Local controllable loads, which have possibilities of being controlled vis-a-vis the operation of the network.

In many areas, micro-grid provides an attractive alternative with improved stability when compared to centralized systems which are not feasible due to the relatively small loads scattered in remote areas. In addition, transmission is a problem for geographically isolated areas, and this makes off-grid alternatives very necessary in some situations. The large distances between rural and remote desert areas on the one hand and central generation centers on the other hand, make it possible to lose approximately 30% of the transmitted energy, which greatly reduces the efficiency of the overall electrical system. Therefore, local micro-grids with on-site generation provide a very reasonable alternative [6].

In what follows we will first explain the micro-grids operating system and their control, then we will present the hybrid micro-grids with distributed generation and accumulation, after we will discuss the monitoring and data logging products such as Consospy and Webdynsun technologies, and finally we highlight the importance of micro-grids systems.

2. Micro-grids operating and control system

Micro-grids can be connected directly to the LV distribution network or operate in islanded mode. In the field of renewable energies, an islanded system is an autonomous electricity production system operated to supply consumers in isolated regions (without access to the public electricity grid). The Chernobyl accident of April 25, 1986 occurred during an islanding test [7].

In order to achieve long-term island operation, a micro-grid must meet high requirements in terms of storage size and nominal capacity of micro-generators for a continuous supply of all loads on which it must rely with great flexibility on demand.

Generally, the maximum capacity of a μ -grid in terms of peak load demand is limited to a few MW, but other regions may have different upper limits [7].

A μ -grid has 3 essential characteristics: local load, local μ -sources and intelligent control. The following are misconceptions regarding μ -networks:

- μ -grids are exclusively isolated systems.
- Customers who own μ -sources build a μ -grid.
- μ -grids are composed of intermittent renewable energy sources (RES), so they must be unreliable and easily prone to blackouts.

Clarification: A μ -grid can compensate for fluctuation in renewable energy sources through its own storage units (when in islanded mode) or external production reserves (when connected to the grid). In addition, the ability of the μ -grid to switch from connected mode to islanded mode actually improves security of supply.

- As μ -grids are expensive to build, the concept will be limited to field tests or only to remote sites.

The final schemas of configuration and exploitation of a micro-grid depend on potentially conflicting interests between the different stakeholders involved in the supply of electricity, such as system/grid operators, distributed generation (DG) owners, distributed generation operators, energy suppliers, customers and

regulatory agencies. Therefore, optimal planning of operations in micro-grids can have economic, technical and environmental objectives [7].

In the economic option, the objective is to minimize the total costs regardless of the impact/performance of the network. This option can be considered by owners or decentralized generation operators. Decentralized productions are exploited without worrying about network or emission obligations. The main limitations come from the physical constraints of distributed generation (DG).

The technical option optimizes the operation of the network (minimization of power losses, voltage variations and device load), without taking into account the costs and production revenues of distributed generation. This option may be preferred by system operators.

The environmental option performs DG units with lower emission levels, without taking into account economic or technical aspects. This is preferable to achieve environmental goals.

The combined objective option solves an optimal distribution problem of multi objective DG, taking into account all economic, technical and environmental factors.

The control of intermittent RES units (e.g. use of solar energy source in sunny weather and wind source in time away from the sun) is limited by the physical nature of the primary energy source. It is generally not advisable to reduce intermittent SER units unless they are causing line overloads or overvoltage issues.

The main control functionalities in a micro-grid can be distinguished into three groups [5]:

2.1 Upstream network interface

The main interaction with the upstream grid is linked to market participation, more specifically to micro-grid actions to import or export energy following decisions of the energy service company. Due to the relatively small size of a micro-grid, the energy service company can manage a larger number of micro-grids, in order to maximize its profits and provide ancillary services to the upstream grid [5].

2.2 Micro-grid internal control

This level includes all the functions of the micro-grid which require the collaboration of more than two actors. The functions at this level are as follows [5]:

- Forecast of load and renewable energy sources,
- Load shedding/management,
- Secondary voltage/frequency control,
- Secondary control of active/reactive power,
- Security monitoring.

2.3 Local control

This level includes all the local functions [5]:

- Protection functions,
- Primary voltage/frequency control,

- Active/reactive primary power control,
- Battery management.

On the other hand, and due to the intermittent nature of Renewable Energy Sources (RES) that greatly affect the operation of micro-grids systems, as well as the continuous fluctuations in demand of the loads, and in order to ensure and support its reliability, the achievement of equilibrium lies in the use of hybrid micro-grids that combine two or more technologies for the production of decentralized electrical energy. This is what makes it one of the best options available due to its many technical and economic advantages [8].

3. Hybrid micro-grids with distributed generation and accumulation

Today, modern technology allows the use of hybrid μ -grids which provide the generation and distributed storage (accumulation) of electricity. These hybrid μ -grids combine at least two technologies for power generation, and typically use renewable energy as primary energy source and diesel fuel as an auxiliary. This results in reliable, sustainable and profitable energy [9]. A hybrid micro-grid structure is depicted in **Figure 1** below.

As shown in figure above, we can see that this hybrid micro-grid combines two renewable energy technologies for power generation (solar and wind generation) as well as a number of diesel generators.

As an example, the “Princess Elisabeth” polar station depicted in **Figure 2** below is a scientific research station not connected to an electricity network because it is located in Antarctica in extreme climatic conditions (Air temperatures: -5°C to -50°C , maximum wind speed per month: 125 km/h) [10].

Thanks to the installation of a hybrid micro-grid, the station is energy self-sufficient. To produce electricity for the polar station, this hybrid μ -grid combines: solar

Figure 1.
Hybrid μ -grids.

Figure 2.
“Princess Elisabeth” polar station powered by a hybrid μ -grid.

panels (379.5 m^2) and wind turbines (9 wind turbines of 6 kWh each), then stored in lead-acid batteries with a capacity of 6 000 Ah. The heating is produced by thermal solar panels (22 m^2). Two diesel generators (44 kWh) are available as backup [10].

On the other hand, for proper functioning and better operation of micro-grids and hybrid micro-grids, it is highly necessary to integrate monitoring and data logging installations.

4. Monitoring and data logging

Network monitoring provides the information that network administrators need to determine whether the network is operating optimally in real time. Using tools like network monitoring software, administrators can proactively identify shortcomings, improve efficiency, and more [11].

There are different solutions to monitor the production and proper functioning of inverters, photovoltaic panels, etc. What we call them “monitoring”, “data logger”, and their function is to help us acquire and analyze the production data of solar panels, inverters, etc.

The role of monitoring and data logger devices can be summarized in the following points [9]:

- Real-time display of parameters
- Control and data logging.
- Creation of databases
- Logging and consultation of historical data, stored on computer, in the form of graphs or tables.
- Export to text files and spreadsheets

- Access to information through a simple internet browser
- Management and control of events or facts programmed by the user.
- Design of reports or simulation of electric bills for the allocation of partial costs.

Among the examples of monitoring and data logging products:

4.1 Consospy

The CONSOSPY Electricity module (see **Figure 3**) is a box that connects to the electronic electricity meter. Thanks to its storage capacity, it records the power of the counter at regular intervals (every minute, 10 minutes or every hour). With this module we can, thus, follow either our consumption, or our production of electricity. Communication is wireless (radio waves). The energy evolution of the different periods can be consulted with the monitoring software “SuiviConsoSpy” [12].

The operating principle of this module is schematized in **Figure 4**. All communication with the Internet module is carried out by radio. So there are no wires to install or holes to achieve. Operating on mains but also by batteries, the module is immune to power cuts! [12].

The energy evolution of the different periods can be viewed on the ConsoSpy Monitoring website from a smartphone, a tablet or computer without geographic limitation [12].

4.2 Webdynsun

The WebdynSun gateway makes it possible to monitor and collect data from a photovoltaic installation. On a single box, the gateway pools all the indicators coming from inverters, electricity meters and environmental sensors (sunshine, temperature, etc.).

Figure 3.
Consospy electricity module.

Figure 4.
Schema of the operating principle of the Consospy electricity module.

Figure 5.
Photo of a WebdynSun module (gateway).

Figure 6.
Schema of the operating principle of the WebdynSun electricity module.

The objectives are preventive and curative remote maintenance of the plant as well as real-time monitoring of electricity production [13].

Figure 5 below represents a photo of the Webdynsun electricity module.

On the other hand, the schema of the operating principle of this module is shown in **Figure 6**. The WebdynSun gateway operates in an advanced data logging mode. From a configuration file and (or) from the local HTML interface, which describes all of the plant's equipment (inverters, meters, sensors, etc.), the WebdynSun gateway scans and collects the data associated with each equipment. These data are formatted and sent periodically, through the GPRS, Ethernet or telephone network to a federating server [13].

5. Importance of micro-grids systems

Micro-grids advantages can be summarized into technical, environmental, social and financial benefits as follows [14]:

5.1 Financial advantages

- Low fuel cost
- Micro-grid can spread electrical storage across multiple users which reduces cost when compared to home off-grid systems where electrical storage is concentrated in one area.
- Due to improved electrical services and reduced breakdowns such as power outages, customers are generally more satisfied, and thus they are willing to pay for services provided by small networks, resulting in increased revenues [14].

5.2 Technical advantages

- Micro-grids are more efficient because they can provide a low load at night when less electricity is required.
- Unlike conventional power generation, micro-grids reduce energy lost at night when society needs less energy as larger electrical systems such as diesel generators cannot provide this because they are ineffective at lower loads and often continue to operate at higher loads regardless of the amount of electricity required.
- The use of micro-grids reduces the amount of time the generators are run at low loads and thus increases the efficiency of the entire system.
- Micro-grids require less maintenance than large electrical networks. Since it reduces the hours of use of diesel generators at lower loads, the generators last longer and do not need to be replaced as often [14].

5.3 Social advantages

- In order for many companies and institutions to operate, they must have working and efficient electricity, so the micro-grids provide the necessary services for these companies and institutions to achieve success in developing regions and this leads to the creation of more job opportunities and increased income for society.
- Electricity micro-grids provide more opportunities for social gatherings and events that enhance the community and also create the opportunity to build more buildings and expand the community [14].

5.4 Environmental advantages

- Micro-grids are much more environmentally friendly than other types of grids because they reduce the need for diesel generators.
- Micro-grids reduce greenhouse gas emissions dramatically, and this reduces air pollution.
- Micro-grids reduce noise in areas where they are used [14].

6. Conclusion

In this chapter, we provided an overview of strategy of self-production in renewable energies or also called in another term “Micro-grids”. Micro-grids are considered as systems that include LV distribution systems with distributed energy sources, storage systems and controllable loads. Through this chapter we have explained many concepts and principles such as: micro-grids operating systems, control of micro-grids, hybrid micro-grids with distributed generation and accumulation. We have also discussed for monitoring and data logging products such as Consospy and Webdynsun electricity modules and we ended with the importance of micro-grids systems.

Many excellent research works on various aspects related to micro-grids is done in Europe, United States, Japan and Canada where several activities were carried out such as: analysis of communication constraints and control architecture, development and improvement of micro source controllers intended for frequency and voltage control by droop curves, study of new market concepts for the sale of energy and micro-grid system services, the development of a centralized controller, ... etc.

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