Chapter

Microgrid Application in Algeria Saharian Remote Areas

Mounir Khiat, Sid Ahmed Khiat, Mohamed Mankour and Leila Ghomri

Abstract

This paper presents a model and simulation for the development of microgrids in remote areas of the Algerian Sahara, including micro power plants, photovoltaic panels, wind farms, diesel energy and storage facilities. The climate of the Algerian Sahara, located on both sides of a tropical region, is hot, sunny and arid. Daytime temperatures are very high and can exceed 50°C, while the thermal amplitude between day and night is often above 350 or 400°C. In addition, there are many microclimates that are characterised by very high wind speeds. This means that wind energy and photovoltaic energy are both widely appropriate in this field, especially if we assume that the distribution of the population is very dispersed. The creation of microgrids for consumption will be an interesting solution to provide energy to the local population. The microgrid is part of the electrical system and is very dynamic. Production and supply forecasts will lead to reshipment, demand and price effects on regional markets. These feedback effects must be modelled and understood to achieve a stable energy system based on renewable energy.

Keywords: remote areas, design microgrid, modelling, real-time simulation

1. Introduction

In the south of Algeria, temperature passes through two extreme values, i.e., from −10 to 34°C (14–93°F), and in some years can reach 49°C (120°F). We see that temperature variation in a day can be more than 44°C (80°F).

On the other hand, winds in the same area are frequent and strong. Rainfall is distributed in irregular manner along the year [1, 2].

The Sahara region is divided into several areas, such as, Bas-Sahara [1], which represents more than half of the population; the western and southern extremities, which are still sparsely populated (less than 0.2 h/km^2), as shown in **Table 1**; followed by Central Western Sahara, where four regions have just over 500,000 inhabitants; and, the northeast Sahara, which represents the most populated region of the Sahara: 1,900,000 inhabitants, or more than two thirds of the Saharan population, live in an area of less than 10% of the desert, with an average density of more than 10 inhabitants/km^2 [3].

These data show that it is impossible to supply energy from conventional power plants. This is why we propose a microgrid model that will be autonomous and self-controlled to ensure continuity of service.

Microgrid power supply networks are emerging to produce, distribute and regulate the flow of electricity at the local level. Microgrids are ideal for university

Power	Realisation			Evolution rate (%)
Maximal power needed from interconnected network	2014	2015	2016	
	10927	12380	28390	3.7
Maximal power from Adrar pole (kw)	261	279	288	8.2
Maximal power from isolated south network (kw)	214	227	242	25.5

Table 1.
Evolution of forecasting power demand.

campuses, military bases, remote sites, office buildings and industrial sites. Improving power quality and reducing transmission losses, robustness and resilience are the main characteristics of microgrid systems [4].

The electricity market in Algeria is very important. Sonelgaz (National Society for Electricity and Gas) is the main supplier of electricity and gas. The country's power plants are open-cycle gas turbines, combined-cycle gas turbines, conventional steam turbines and, more recently, renewable energy sources. Recently, the coverage capacity of the electrical installation's network has reached 98%, with more than 80% in the north [5].

The objective of the real-time simulation is to test the various electrical equipments, under the most natural conditions possible: as if they were connected to the real physical systems associated with them.

The results obtained by this tool will allow us to have a very precise vision of the functioning of microgrids, in terms of power flow or default responses.

The remaining part of the paper is organised as follows: Section 2 describes the evolution of renewable energies in Algeria. In Section 3, we discussed the modelling of a microgrid in Adrar area, located southwest of Algiers, and Section 4 presents a real-time simulation. Finally, Section 5 summarises the results of this work and perspectives of future works.

2. Renewable energy evolution in Algeria

Algeria's national priority is to achieve the multiplication of energy produced by renewable sources. Algeria has great potential in solar energy and may become a leader in the MENA region, and an interesting partner in the world.

Solar and wind energies tend to have become a more serious and efficient solution to enhance supply security and reliability of the whole power system. It contributes too to increasing energy conversion efficiency, transmission and distribution [6].

Since the 1970s, the national programme has strongly supported the use of solar and wind energies; solar is positioned in the first position, but now wind power production is also being strengthened, as shown in **Figure 1**.

Economically, conventional power supply by extending the networks is not suitable for remote centres. This is true for the Sahara regions with its surface area of about 2 million km^2, and only an autonomous mean of supply is to be considered. For this reason, microgrid is the appropriate solution.

Table 1, published by the Algerian National Society for Electricity and Gas (SONELGAZ), shows the evolution of the power forecasts in southern Algeria and in particular in the Adrar area studied.

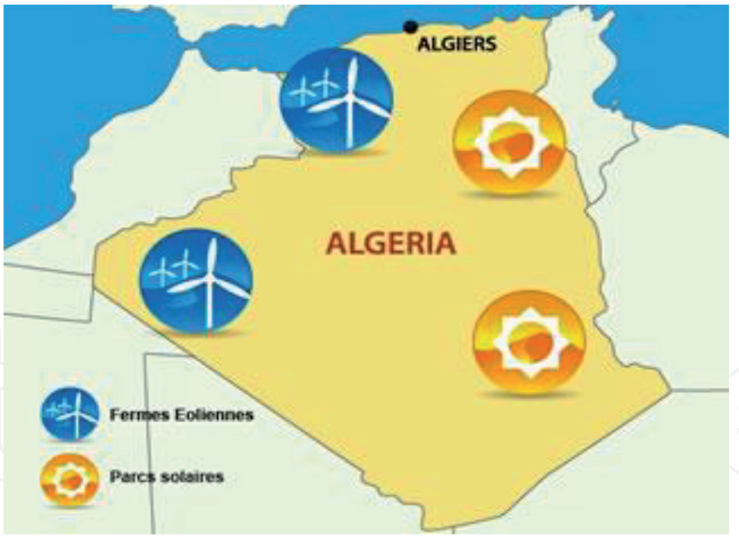

Figure 1.
Algerian renewable energy distribution.

3. Modelling a microgrid in the Adrar study area

Microgrids must adapt existing frameworks. For this reason, the project must be carefully coordinated between the proponent, the utility and the proponent's energy advisor to ensure the best possible result.

For electricity interconnection with the grid and to optimise reliability, resilience and efficiency of the grid, utility tariffs and franchise fees must be adapted.

When designing the microgrid stage, the interconnection specifications of local utilities must be taken into account.

3.1 General architecture

In the first step to designing our microgrid, we will begin by the wind farm of Kabertene (70 km north of Adrar), which produce about 10 megawatts (MW).

This parc is composed of 12 wind turbines, each one have a unit capacity of 0.85 MW. It is interconnected with the 220/30 KV substation located in the locality itself [10].

A simulation model is presented in **Figure 2** (**Table 2**).

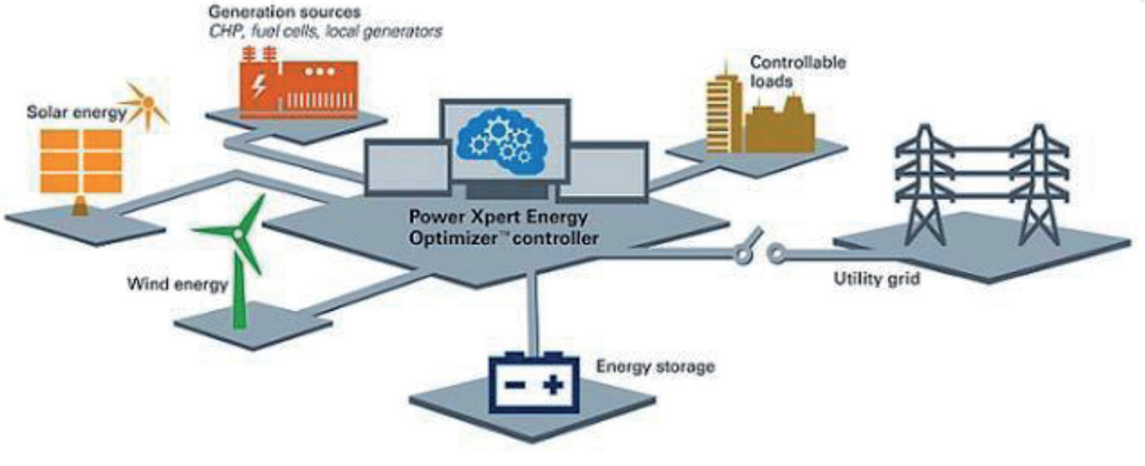

Figure 2.
Microgrids architecture.

Society	GAMESA
Model	G52/850
Wind turbine number	12
Nominal power/unit	850.0 kW
Energy per year	3.42 GWh (Vmoy: 8.5 m/s)
Secondary generator	0.0 kW
Rotor diameter	52.0 m
Column	Tubular shape
Generator type	Variable
Rms in nominal power	26.2 t/mn
Height of the column	55.0; 44.0; 49.0; 65.0 m

Table 2.
Characteristics of wind farm.

The Adrar region seems to be the best location for the installation of wind farms. As shown in **Figure 3**, the value of wind speed is proportional to wind energy production [10].

Several studies have assumed that the average wind speed is about 14 m/s, which is an interesting value [1].

In optimal conditions, power produced by wind turbine is about 10 MW as we see in **Figure 4** below.

The second component of our microgrid is a power plant with eight gas turbines located at "Zaouiet Kounta" (80 km from Adrar). This unity produces 148 MW and allows the Wilaya (department) to ensure its self-sufficiency over 10 years and contribute to supply the city with two power lines, one in the south towards In Salah (Tamanrasset) and the other in the north towards Timimoun (Adrar).

The third energy source is the Kabertène solar power plant which can reach (3 MW) in optimal operation conditions.

The power produced by this photovoltaic source is represented in **Figure 5**.

In comparison with wind energy which is quite stable, solar energy can be used from 7 am to 19 pm (**Figure 6**).

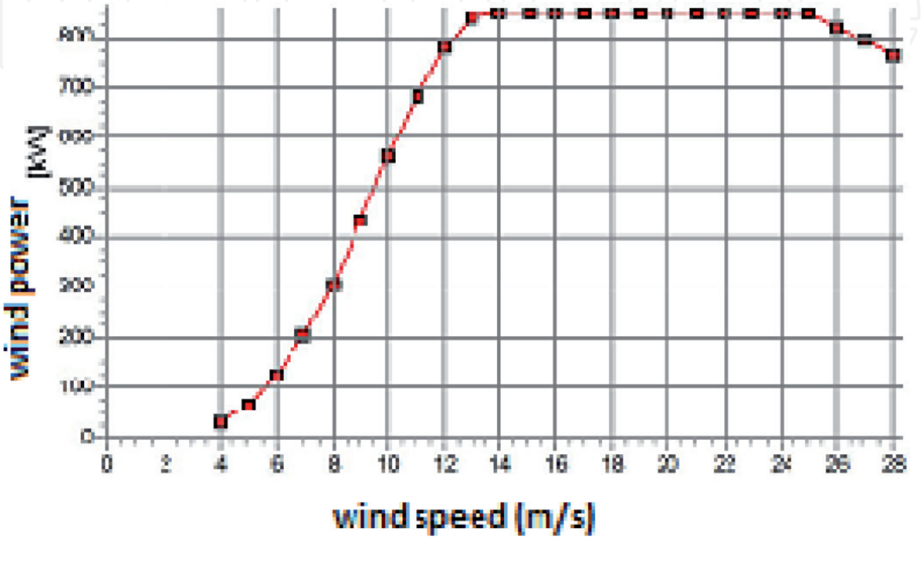

Figure 3.
Wind speed curve.

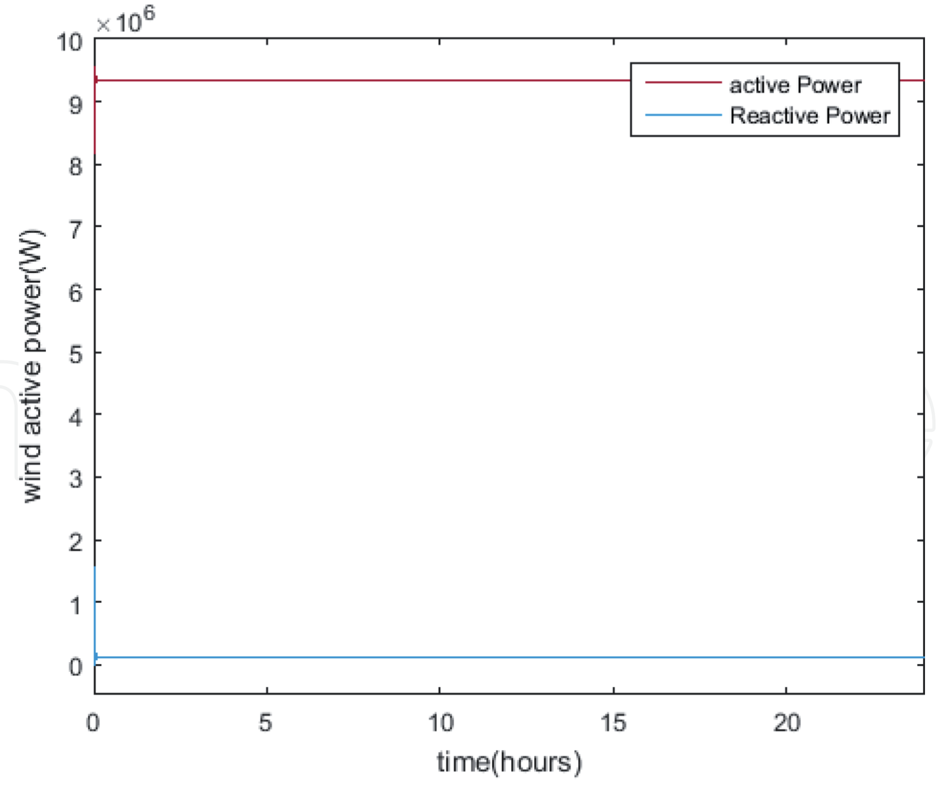

Figure 4.
Wind power curve.

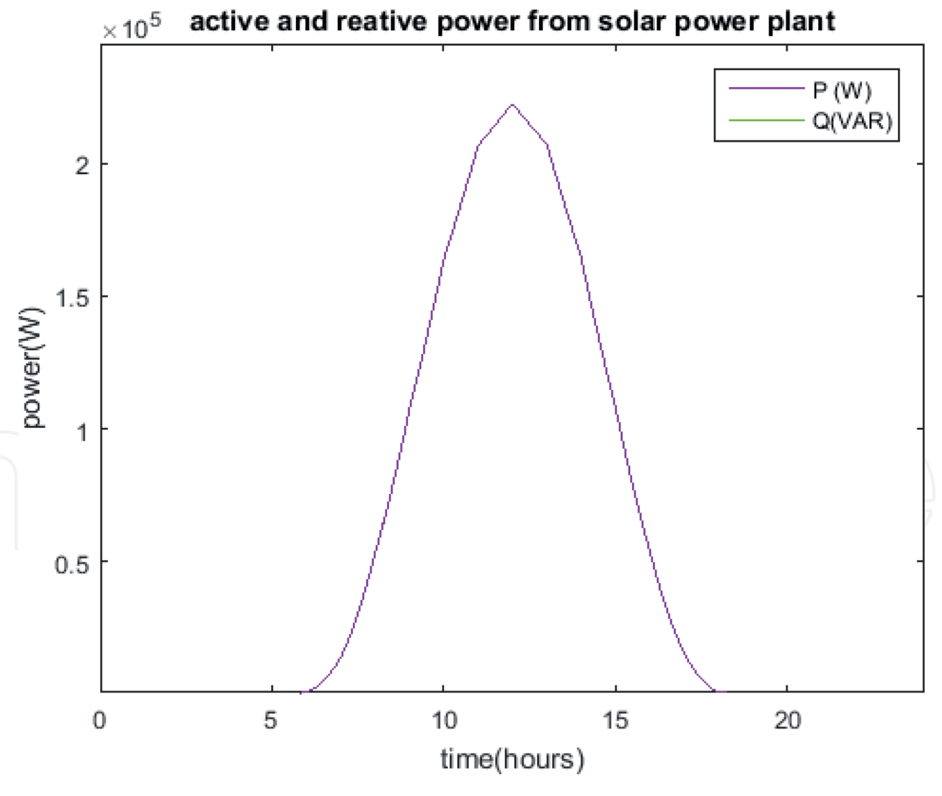

Figure 5.
Power produced by solar power plant.

3.2 Microgrid operation

As indicated hereafter, the Adrar region is mainly supplied by gas turbines. But there are many isolated populations around this locality that are powered by wind and/or photovoltaic energy.

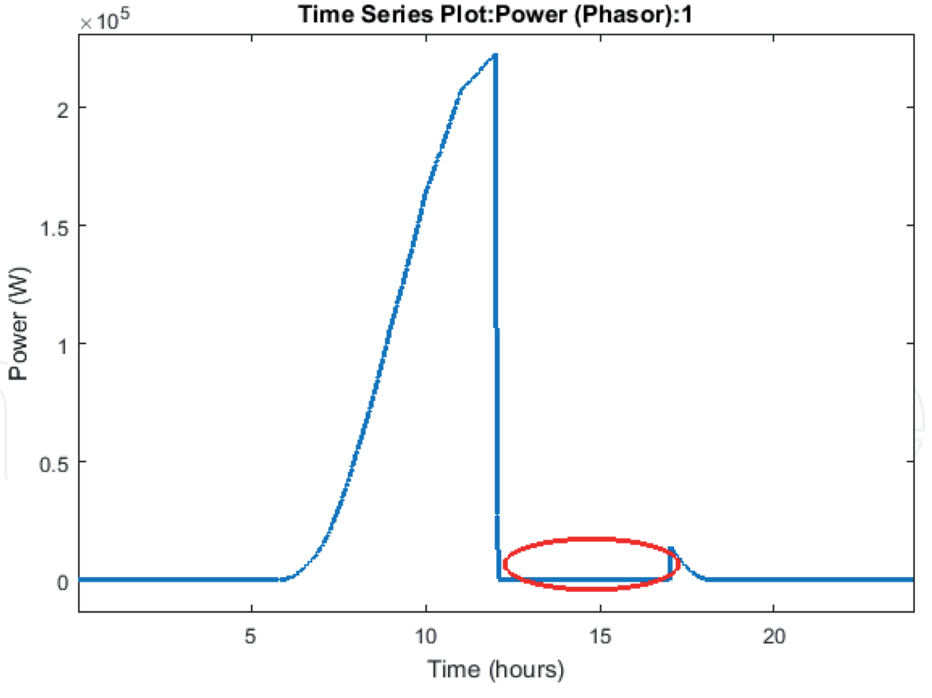

Figure 6.
Simulation of a partial shading in a sunny day from 12 am to 14 pm.

Microgrid, which integrates renewable energy sources, is connected to the main grid by relays. When the load is insufficiently powered by one of the sources, the corresponding switch will open, and other sources available will be the main providers for the load, following the scenarios below:

- Case 1: If the wind energy is sufficient to power load, wind turbine relays will be closed, and the connection to the load will be achieved.

- Case 2: Both wind and solar energies produce enough energy at the same time: the wind turbine is connected to the load, and the photovoltaic panels are used for charging the storage battery.

- Case 3: There is no half energy produced by the wind turbine, but solar radiation allows the photovoltaic panel to power the load.

- Case 4: Renewable source productions are insufficient or non-existent; the load is connected to the grid.

The aim of microgrid design is to study large-scale development, field demonstration and performance evaluation of domain names by:

- The frequency and voltage of control of different methods and technologies, under different microgrid operating modes.

- Switching between grid-connected and island mode.

- High penetration of ADR and its impact on the host network and interaction phenomena between ADRs.

It is important to note that the control strategies and dynamic behaviour of a microgrid in autonomous mode of operation may be different from those of a conventional electrical system [6, 7].

3.3 Communication used in microgrid

For reasons of reliability, large amounts of data must be exchanged as much as possible in real time between zones. This will allow the system to react quickly to any changes in network operating parameters. Microgrid control and monitoring must be ensured:

- High-speed, highly reliable and redundant communication infrastructure
- Optimal real-time communication, infrastructure
- Reliable and coordinated controls by the system before and after disruptions
- Dedicated communication infrastructure, e.g. fibre-optic cables, for monitoring underground cables
- Local flexibility market platform and algorithm

Tools based on real time synchronised network models for preventive and emergency network management systems and simulation of the behaviour of the entire electrical/energy system.

3.4 Modelling and simulation of microgrid

To improve the project's accessibility, it is required to create a microgrid model and simulate it in real time with the Opal-RT software [8].

3.4.1 Adrar main grid

Adrar grid consists of four HV lines (220 KV) and seven transformer stations.

It has six power plants with a global-produced power of 140 MW (**Figure 7**).

First, we tested the grid's operation without micro-sources in order to calculate the load rate. The result of the latter is summarised in **Table 3**.

3.4.2 Simulation of Adrar microgrid

Thanks to various metrological data (wind curve and solar irradiance in the Adrar area), we simulated the operation of the Kebertene wind farm and the Zaouiet Kounta photovoltaic plant with satisfactory accuracy, as shown in **Figure 8**.

We see that in normal climatic condition according to metrological data, we have the load entirely powered by both renewable sources during 24 h.

It is interesting for assuming that this microgrid can work in an islanded mode, during many days in the week. Diesel generator and storage can give the autonomy for the entire system.

3.4.1 Control of supply sources

We propose for supply sources control an electronic power switch (Mosfet or IGBT), controlled by a signal from an algebraic loop.

If the voltage value from decentralised sources is equal to the voltage reference, a positive signal is sent to the switch to be on.

If this is not the case, the main power system will supply the loads, as shown in **Figure 9**.

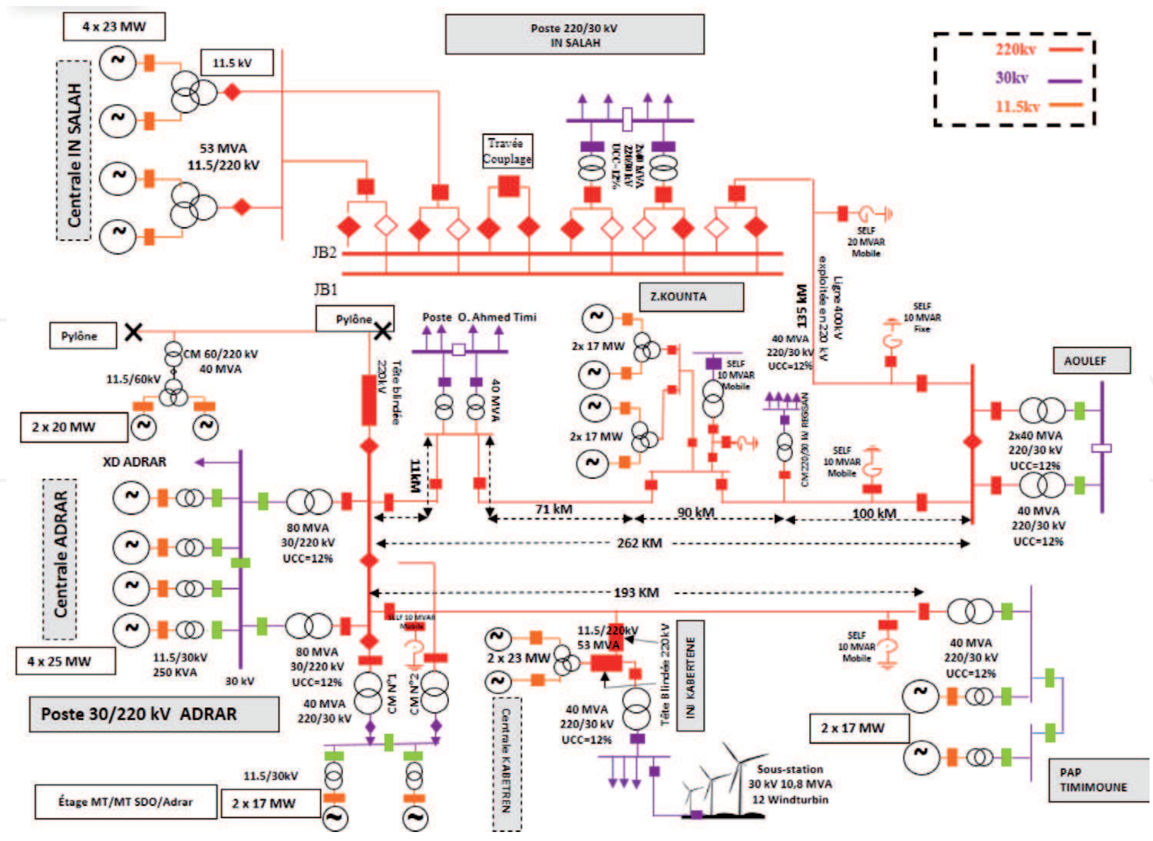

Figure 7.
Adrar grid.

Generation report		
Subnetwork 1	**Adrar network power flow**	
	P (MW)	**Q (Mvar)**
B11.5	6.12330567	167.444605
Bus 30 KV	2.08064306	38.8766705
Total	8.20394873	206.321276

Table 3.
Generation report.

3.4.2 Simulation results

The control of this system is able to verify the following three steps under climatic conditions such as:

- The wind turbine is under optimal operation conditions, so it is connected to the load.
- If both wind and photovoltaic energy installations produce enough energy, wind turbine will be used to power the load, when photovoltaic panels ensure the charge of the storage battery.
- Wind speed is insufficient, and solar radiation produces enough energy, so the photovoltaic panels are connected to the storage battery.
- All sources are deficient, so the network is connected to the load (**Figures 10** and **11**).

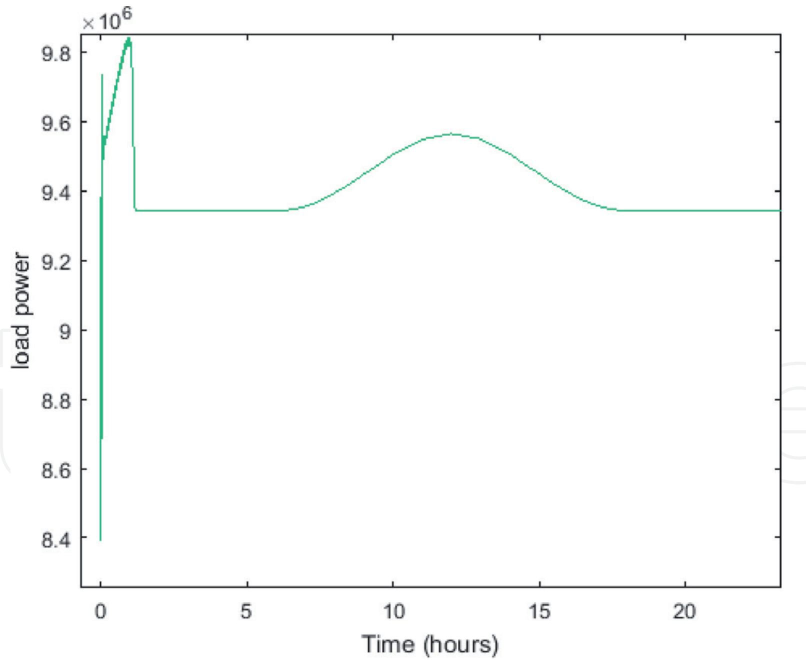

Figure 8.
Load power consumption profile.

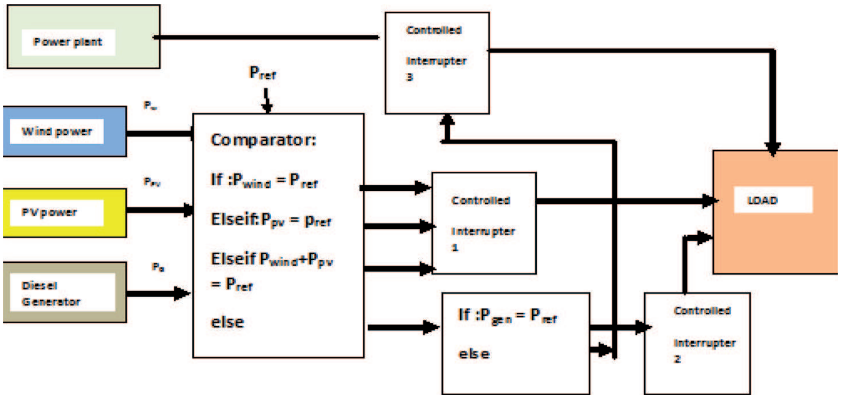

Figure 9.
Schematic microgrid control.

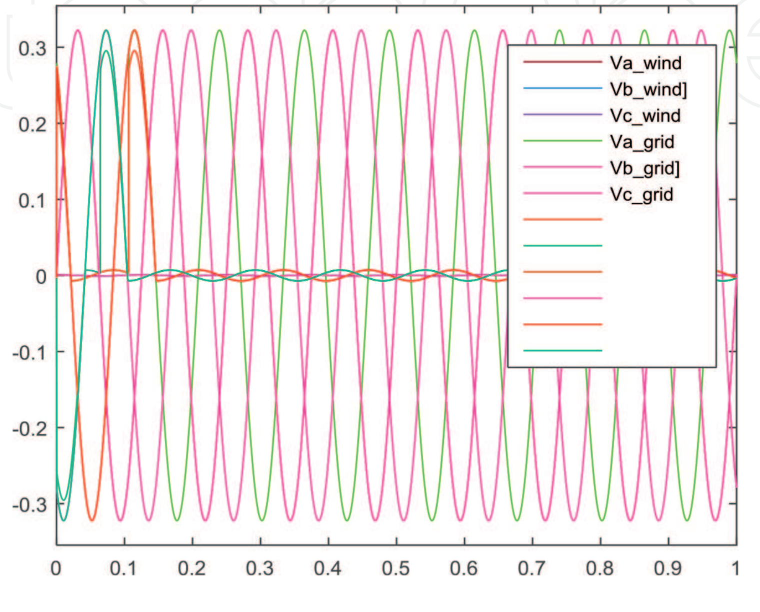

Figure 10.
Simulation of deficiency in micro-sources.

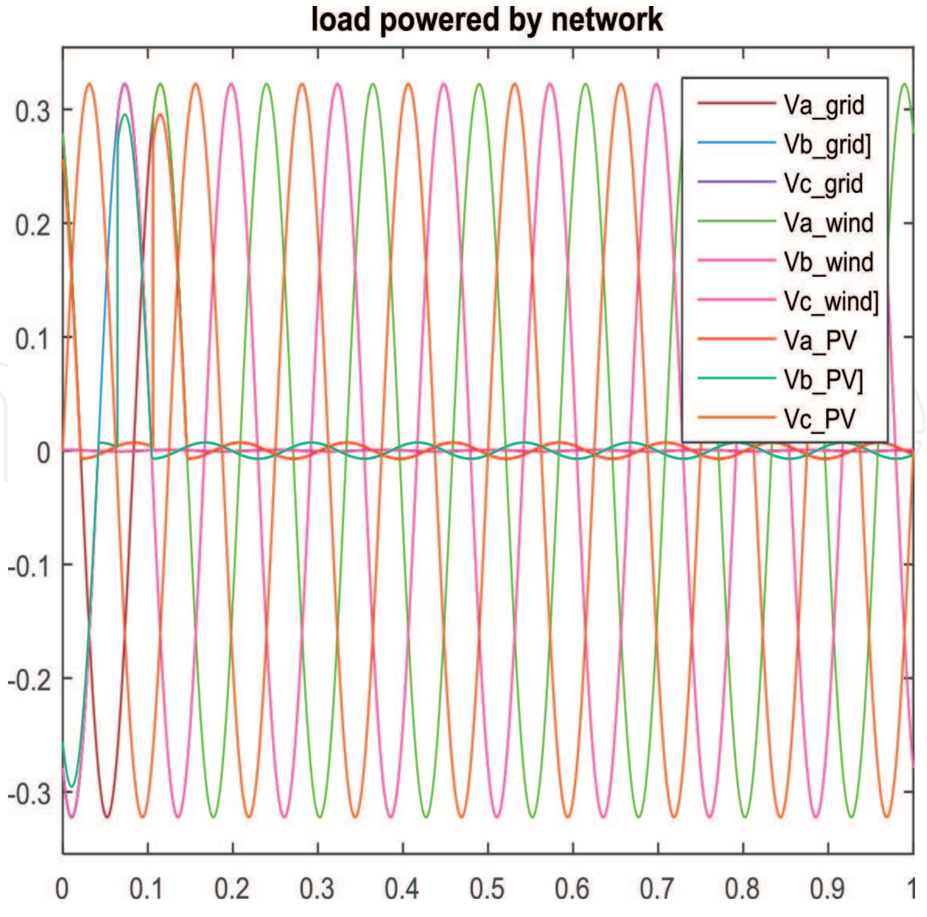

Figure 11.
Simulation of isolated microgrid.

We have simulated operating situations for Adrar microgrids, and the results confirm the expected specifications required for optimal performance.

The control and management system will provide various benefits at all voltage levels of the distribution system. For this reason, different hierarchical control strategies must be implemented at different levels of the network.

4. Real-time simulation

To improve the project's overall effectiveness, it is required to create a microgrid model and simulate it in real time using the Opal-RT software [8].

It is essential to validate this equipment before its installation on the real electricity grid. In order to accelerate the development and validation cycle of this equipment, to reduce costs and risks, the current trend is to test this equipment with a real-time digital simulator.

Therefore, the real-time simulator must reproduce as closely as possible the dynamic behaviour of the controlled electrical system [4]. The real-time simulation of the whole electrical system comes first with a modeling phase that consists of equating the system, then a design phase of an algorithmic specification (choice of the sampling period, discretization and quantification) and, finally, a real-time implementation phase [5].

4.1 Hardware architecture

The hardware system installed in our SCAMRE laboratory consists of two simulators which are connected to each other, the Wanda 4u and the OP 5600. The

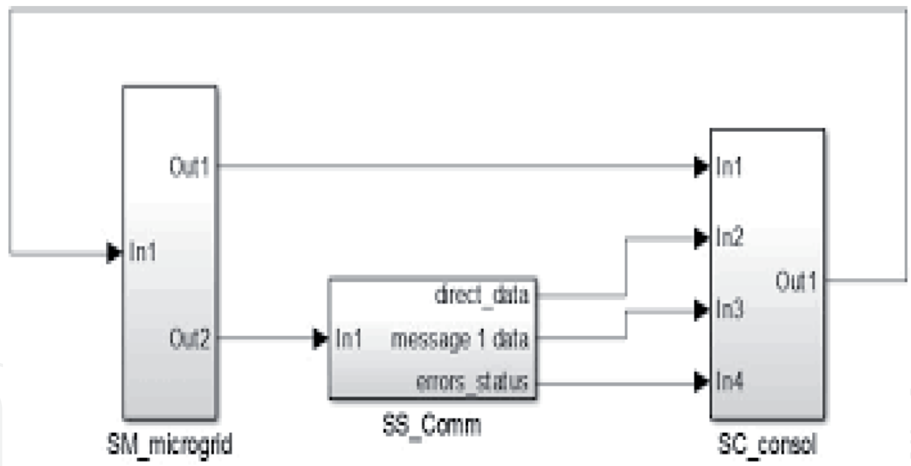

Figure 12.
Example of microgrid model with the real-time software.

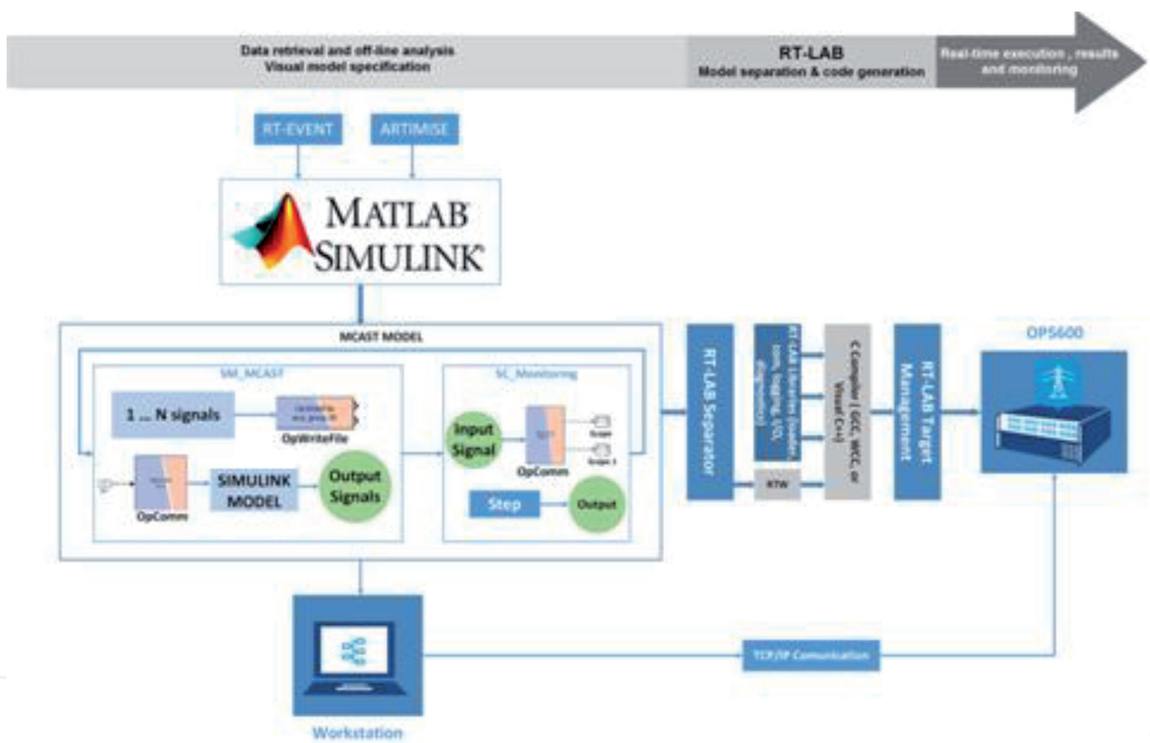

Figure 13.
System architecture in RT-LAB platform with OpComm and OpWriteFile blocks.

target has two CPU processors which have two activated cores and 16 I/O, for the first simulator, and two other CPU processors including two activated cores and 16 I/O, for the second one.

The main task of the target is to achieve a simulation of different models. The host computer will support development, editing, verification and compilation of models. Its second mission is to serve as a console or command post for control and observation during the simulation. Ethernet is used to communicate between hosts and targets. The host computer is a general PC [6, 7].

In the RT-LAB simulation platform, Artemis is a fixed time step solver designed for the electrical systems. It can improve speed simulation. The multiprocessor operating mode allows it to perform real-time simulations on the RT-LAB platform. The idea is to transform a complex system in some simple subsystems in order to perform parallel operations in a multiprocessor.

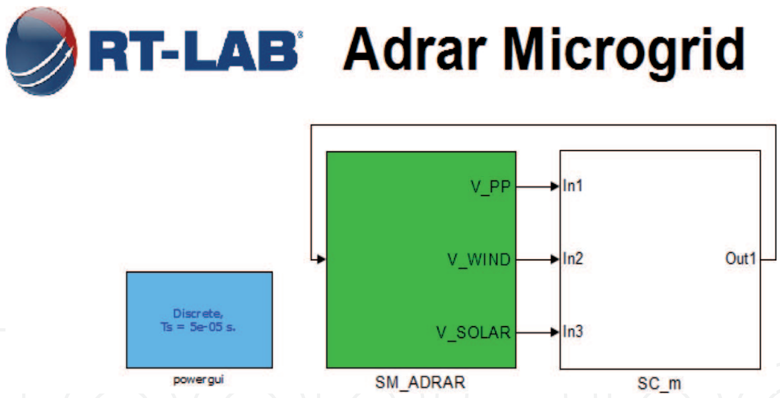

Figure 14.
Real-time compilation model.

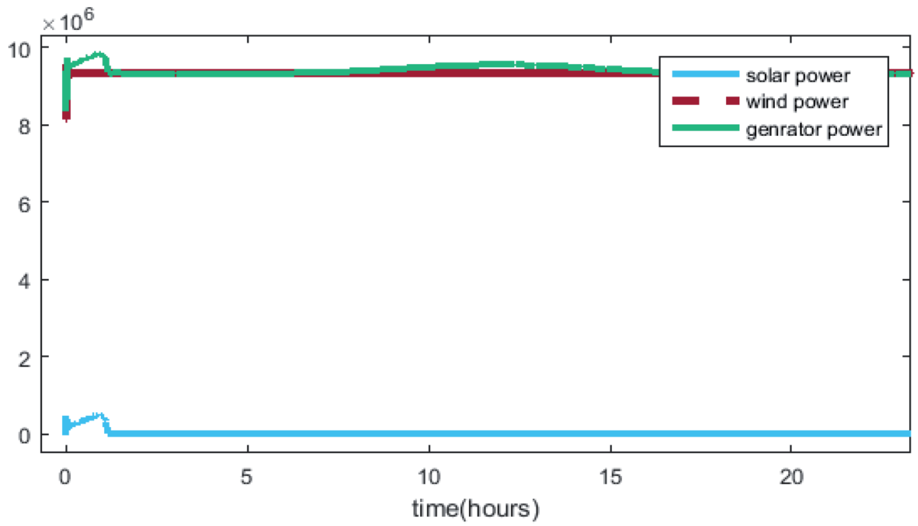

Figure 15.
Irradiance failure.

Another interesting property of RT-LAB software is the possibility to connect physical devices to the simulation system. By this way, the simulation becomes closer to reality, and the results obtained will be more realistic.

For this reason, the entire model must be reorganised mainly into three subsystems, namely, the master, slave and console subsystems, as shown in **Figure 12**.

The microgrid system is modelled first in Matlab/Simulink/SimPowerSystems software, and then it will be compiled with the e-MEGAsim simulation of the RT-LAB platform [2, 6, 7], which improves the simulation of increasingly large systems with real-time performance on multiple CPUs (**Figures 13** and **14**).

One of the main differences that improves with real-time simulation is that we can observe how our system works during 24 h. In addition, it is possible to simulate many real scenarios that affect the normal distribution of microgrids such as the disappearance of the sun for 1 h during the day, point overloads, court circuits.

Figure 15 shows the case of a sudden failure of the irradiance and the ability of the microgrid to switch to wind power to power the load.

5. Conclusion and perspectives

In this work we have designed and simulated a microgrid in real-time situation to propose the best scenario in terms of renewable sources to be installed and ability of the microgrid to operate in island mode or not.

The results obtained confirm that Saharan climate (sunny and windy) open big perspectives to integrate many autonomous microgrids in several remote areas without the need to connect them to the main grid, if there is at least a diesel generator in addition to renewable for particular situations.

The application of micro-sources can obviously regulate the consumption of distribution and transmission installations [9].

The particular landscape of southern Algeria is relevant to implement a diversity of energy sources in microgrids in order to optimise their operation and facilitate their control.

Applications of autonomous microgrids for remote areas are mainly realised for the electrification of electrically nonintegrated areas, such as, islands, or the Algerian Sahara.

A few years ago, some communities in the Sahara were supplied almost exclusively by diesel generators. In addition to reducing fuel costs, the main objective of stand-alone microgrid applications is to study and develop a field experience with the planning and operation of stand-alone distribution networks [10–12].

This work is the first conception of a microgrid in Algerian Sahara area.

It includes diesel generators, wind and solar energy.

The simulation performed in real time for this model provided us real data to improve local reliability. Gas emissions will be reduced, and power quality will be improved by supporting voltage, reducing voltage dips and potentially reducing energy supply costs.

On the basis of the promising findings presented in this paper, the work on the remaining issues is continuing and will be presented in future papers.

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