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Présenté par

BENHAMOU Aziza
MESKINE Cherif Nasr Eddine

Intitulé du sujet

Management of a smart Microgrid in Adrar region

Soutenu le 14 / 07 / 2021 devant le jury composé de :

Président :	Mustapha REBHI	MAA	Université de Mostaganem
Examinateur :	Hamza OMARI	MAA	Université de Mostaganem
Rapporteur :	Leila GHOMRI	MCA	Université de Mostaganem

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ABSTARCT

Microgrid is a part of the electrical system; and it is highly dynamic: Forecasts of generation and supply will lead to re-dispatching, demand-side and price effects on regional markets. These feedback effects must be modeled and understood to reach a stable energy system based on renewable sources.

In this work, we will achieve a new method for management and control of a Microgrid. For this purpose, we have established the state of the art and review of the literature on the techniques of microgrids management which will be devoted to bibliographical research on different techniques of energy management by micro-grids.

A real model with Adrar data has been simulated, and an application of a management program thanks to Python software has been done.

After the definition of the objective function, a judicious choice on the data management with a simulation that will be done in this work.

The results obtained by the simulation with MATLAB/Simulink and Python, were very satisficing regarding other similar works.

Le micro-réseau fait partie du système électrique ; et il est très dynamique : les prévisions de production et d'offre conduiront à des effets de réacheminement, de demande et de prix sur les marchés régionaux. Ces effets de rétroaction doivent être modélisés et compris pour atteindre un système énergétique stable basé sur des sources renouvelables.

Dans ce travail, nous allons réaliser une nouvelle méthode de gestion et de contrôle d'un Micro réseaux.

Pour cette raison, nous avons établi un état de l'art et une revue de la littérature sur les techniques de gestion des micro-réseaux qui seront consacrés à une recherche bibliographique sur les différentes techniques de gestion de l'énergie par les micro-réseaux.

Un modèle réel avec des données Adrar a été simulé, et une application d'un programme de gestion grâce au logiciel Python a été réalisée.

Après la définition de la fonction objective, un choix judicieux sur la gestion des données avec une simulation qui sera fait dans ce travail.

Les résultats obtenus par la simulation avec MATLAB/Simulink et Python, étaient très satisfaisants par rapport à d'autres travaux similaires.

List of Abbreviations

PV – Photovoltaic

LV – Low voltage

DER – Distributed Energy Resources

MG – Microgrid

MC – Micro source Controller

LC – Load controller

MGCC – Microgrid system central controller

DMS – Distribution management system

PCC – Point of common coupling

BESS – Battery energy storage system

SOC – State of charge

SOH – State of health

CB – Circuit breaker

DC – Direct current

DOE – Department of energy

CRS – Congressional research service

EU – European Union

RES – Renewable energy sources

HVAC – Heating ventilating and air conditioning

SHS – Solar Home System

CHP – Combined heat and power

EMS – Energy management system

PMS – Power management system

DG – Distributed generation

DS – Distributed storage

LC – Local control

MCC – MG Control Center

DSP – Digital signal processes

MAS – Multi Agent System

CAES – Compressed Air Energy Storage

LAES – Liquid Air Energy Storage

SNG – Synthetic Natural Gas.

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General introduction

The energy needs of the growing world population increase more and more, caused by the consumption of new uses of factories, means of transport such as electric vehicles or other equipment that requires high consumption. According to the statistics of the International Energy Agency (IEA), The global production of electricity could be doubled by 2050, from 20,440 TWh to 45,970 TWh ". As a result, researchers are doubling their efforts to improve the quality and efficiency of the electricity network.

The use of power plants meets the energy needs of consumers on the one hand, but the cost, pollution, depletion and scarcity of fossil fuel resources on the other hand, worry the world for the future of the planet, these concerns are pushing scientific researchers and energy companies to move towards the study and development of other energy resources such as photovoltaics, wind turbines etc. Despite their intermittence, these energies have always existed from the beginning discovery of electricity but had no major impact on the operation networks. Today, these so-called decentralized energies are gaining momentum day and respond as much as possible to the concerns and aspirations of energy achieve the power required by socio-economic consumption which is constantly increase.

The integration of these green energies in the electrical networks requires a very precise management of the various energy flows, and in order to ensure the resilience of the electrical networks, while respecting the constraints of the various elements that make up its new architecture, because a single imbalance can cause a grid blackout and will deprive several consumers of electricity for times that can extend up to several days.

The problem consists, in energy management, in finding the most suitable power and distributing it adequately between the different elements that build the hybrid architecture electrical network. This distribution is based on several evaluation criteria such as: emission of polluting greenhouse gases, variable and limited power of sources, battery life, and states of charge of storage elements, etc. These problems are mostly solved by algorithms called either "energy management law" or "control strategy" or "energy strategy law".

In this work, we will define a smart network, called "Microgrid", efficient in order to optimize production, distribution and consumption by using information technology, in order to improve the efficiency of networks. The new technique of the most suitable distribution of power is based on a particular architecture: two-way information and energy flows, intermittent renewable energies, as well as new electrical uses that must be integrated. For an entire power system management, generation and consumption must be flexible.

Objective of the Work

The aim of this work is to present an optimal configuration and control strategies to ensure secure, reliable and efficient operation of a microgrid including photovoltaic and wind turbine productions, battery energy storage system (BESS) and diesels.

The objectives of this work are described as follows:

- Data Management in a microgrid
- Control of communication protocols

Micro grids can provide a very interesting response to the objectives of using renewable energies. The proximity of the energy production makes it possible to optimize the distribution of the current and to reduce the energy losses. Our aim is to give an answer to these questions

How to develop an efficient microgrid management?

1. How can we manage the Data in a microgrid?
2. How can we control the communication protocols?
3. How can we optimize consumption?

Work contributions

The main contributions of this work can be listed as follows:

- Proposition of a method to enhance the energy management in operation of a microgrid with its configuration achieved from the above part.
- a real application of a microgrid in ADRAR, proposition of communication protocol mode to manage the system.

Work organization

This work comprises four chapters. Contents of each chapter are briefly described as follows:

- Chapter I: General introduction of Microgrids,

- Chapter II: presents the constituent elements of the microgrid, the microgrid operation, the microgrid control and the microgrid protection.

- Chapter III: brings out the modeling of microgrid components: Photovoltaic productions (PV), Wind turbine, battery, energy storage systems, diesels and loads.

- Chapter IV: discusses the microgrid management system using Python and MATLAB Simulink, conclusion and future works.

Table of Contents

CHAPTER I: Introduction to Microgrids..11

List of Figures

List of Tables

CHAPTER I

Introduction to Microgrids

SUMMARY

I. Introduction

There have been global initiatives for the promotion of self-sufficient renewable energy systems. This initiative hasled to the development of renewable power generating systems which are capable of providing self-sufficient powergeneration with the use of more than one renewable source of energy.

The most commonly used hybrid renewable energy sources are solar and wind energies. Both of those energy sources ~~of~~ are intermittent in nature; therefore, the use ofan energy storage system (ESS) is standard in stand-alone applications. In hybrid renewable energy systems, there are multiple control techniques to provide an efficient power transfer.

Most interesting application in the last decades are microgrids which combine renewable sources and storage system with a limited power. These systems are controlled smartly which allowed an optimal operation.

In this chapter we will present a global survey of microgrids.

II. Definition of Microgrid

There have been countless numbers of microgrid definitions presented in published studies by research groups around the globe. A few microgrid descriptions can be seen as continues to follow:

The U.S. Department of Energy (DOE) posted a detailed definition of Microgrids:

“A Microgrid, a local energy network, offers integration of distributed energy resources (DER) with local elastic loads, which can operate in parallel with the grid or in an intentional island mode to provide a customized level of high reliability and resilience to grid disturbances”.

This advanced, integrated distribution system addresses the need for application in locations with electric supply and/or delivery constraints, in remote sites, and for protection of critical loads and economically sensitive development [1].

The Congressional Research Service (CRS) perceives Microgrid; It seems to have a subtle decrease with the description mentioned earlier in this section:

A Microgrid is any small or local electric power system that is independent of the bulk electric power network. For example, it can be a combined heat and power system based on a natural gas combustion engine (which cogenerates electricity and hot water or steam from water used to cool the natural gas turbine), or diesel generators, renewable energy, or fuel cells. A Microgrid can be used to serve the electricity needs of data centers, colleges, hospitals, factories, military bases, or entire communities [2].

The definition of EU research projects would be as continues to follow:

Microgrids comprise LV distribution systems with distributed energy resources (DER) (microturbines, fuel cells, PV, etc.) together with storage devices (flywheels, energy capacitors and batteries) and loads. Such systems can be operated in a non-autonomous way, if interconnected to the grid, or in an autonomous way, if disconnected from the main grid. The operation of micro sources in the network can provide distinct benefits to the overall system performance, if managed and coordinated efficiently.

From these definitions, the features of the microgrid entail:

- Microgrid is an integration of micro sources, storage units and controllable loads located in a local distribution grid.
- A microgrid can operate in grid-connected or disconnected modes.
- The energy management and coordination control between available microsurgeries demonstrated in a microgrid.

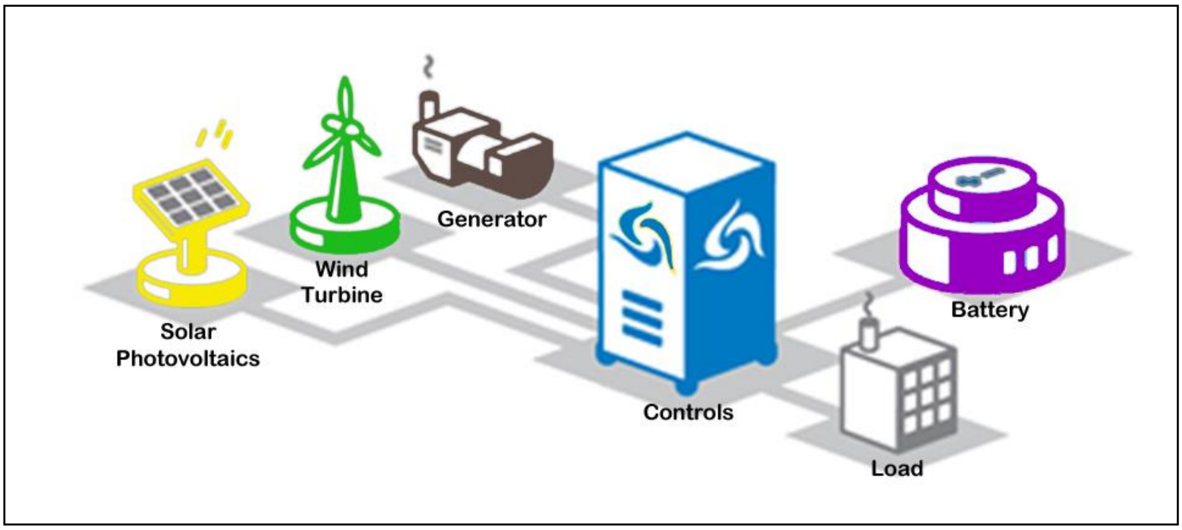


Figure I.1 Schema of a MG

III. Microgrid and Energy trends

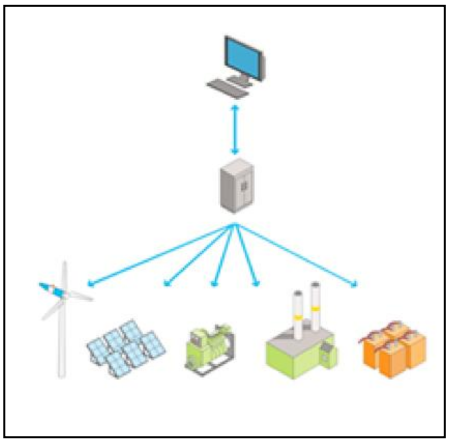


Figure I.2. Multiple energy sources

The energy outlook envisions an increase in the demand for electricity, an improvement in access to energy and a reduction in CO2 emissions and therefore fossil fuels. These trends, associated with the need for resilience, lead to new energy ecosystems: microgrids. They are independent local energy resource systems that typically rely on multiple energy sources (Figure I.2).

Thus, microgrids could be one of the keys of the energy transition.

IV. Microgrids contribution to the energy transition

Microgrids are energy ecosystems which are capable of providing concrete answers to the challenges of the energy transition. What are the issues of this energy transition and how can microgrids solve it?

Microgrids allow optimized access to reliable, green and resilient energy. They integrate loads, decentralized energy sources, storage and a control system.

V. The context of the energy transition

The energy transition involves a number of challenges, the first of which is a global increase in demand for electricity.

V.1. An expected increase in global demand for electrical energy

According to the International Energy Agency (IEA), we can expecta worldwide increase in electrical energy of approximately 40% by 2030.

- Satisfying demand and securing the supply of energy (electricity and gas),

- Population growth of 18% expected by 2030, mainly in developing countries. A world population of 7.5 billion by that time,
- The need for access to energy in developing countries,
- The continued growth of new electrical uses,
- The expected transfer of certain uses of energy to electric energy,
- Increasing urbanization requiring new sources of energy and an extension of the electricity grid infrastructure,
- Preservation of fossil resources,
- Development of alternative energy sources and adoption of an energy mix for the medium-long term,
- Availability of significant potential, particularly solar; wind,
- Reduction of fuel consumption;
- Development of an energy mix;
- Promotion of energy saving and energy efficiency
- Diversification of the national economy and creation of a new socio-economic dynamic around renewable energies.

Such growth should go hand in hand with the reduction of CO2 emissions.

V.2. A necessary reduction in CO2 emissions and fossil fuels

CO2 emissions from the generation of electricity are responsible for 45% of total global CO2 emissions. These carbon emissions depend on both the amount of electricity produced and the energy mix, or the type of energy sources used.

The amount of electricity produced is directly linked to demand, which is expected to increase overall. As a result, reducing the amount of CO2 emitted will necessarily require a change in the energy mix in favour of cleaner energy sources.

In addition, in isolated areas, residents, who rely mainly on electricity produced by diesel generators, spend considerable sums on obtaining petroleum products, making the generation of renewable electricity a competitive solution.

V.3. A need for resilience

In some industrialized countries, the aging power grid lacks resilience in the face of interruptions or instabilities, especially when subjected to severe weather conditions. The number of power outages lasting more than an hour has increased steadily over the past decades. The need for resilience is therefore a key expectation, inseparable from a right to access to energy.

V.4. A need for access to energy for 1.6 billion people

In 2019, it was estimated about 1.6 billion human beings, the number of people without access to electricity, for lack of appropriate infrastructure.

In addition, other people have unreliable or poor-quality access to energy. Most of those who live without electricity live in rural areas of sub-Saharan Africa and developing countries in Asia, where they represent 95% of the population. Access to modern energy is a major stake in achieving the United Nations Millennium Development Goals, which should enable the poorest developing countries to engage in productive use of energy, and thus improve their living conditions [3].

VI. Microgrid concept

The microgrid concept is introduced to have a self-sustained system consisting of distributed energy resources that can operate in an islanded mode during grid failures. In microgrid, an energy management system is essential for optimal use of these distributed energy resources in intelligent, secure, reliable, and coordinated ways.

The use of renewable energy source (RES) in meet the needs of electrical energy is getting into attention as solution of the problem a deficit of electrical energy, particularly for areas that are difficult to reach existing power grids. A variety of development related to the use of RES continues. Start from optimizing the use of energy sources, the development of the power conversion system up to the electrical power system architecture.

Production of electric power from RES such as solar power generation varies greatly depending on the source of the sun received at the time. This raise concerns on quality of generated power, especially if it is connected to the grid system, where solar power would be seen as a negative expense by net system because it has characteristics associated with uncontrolled fluctuation from energy sources [4].

This problem can be addressed by adding another generation system more controlled, such as, the addition of energy storage systems (batteries) or forming a hybrid system by adding diesel generators or micro turbines [5]

Implementation of microgrid systems provide many advantages both from the user and from the electric utility provider. From the user's application of the microgrid is connected to the grid, it can improve network quality, reduce emissions and can reduce the cost to be incurred by the user.

From the electric utility provider implementation of distributed generation systems with the ability microgrid can reduce the power flow on transmission and distribution lines, so as to reduce losses and reduce costs for additional power. Moreover, microgrid can also reduce the load on the network by eliminating the impasse in meeting electricity needs and help repair network in case of errors [6]. Implementation of microgrid system will also help improve the reduction of emissions and the threat of climate change.

Microgrid development done by many countries since microgrid offers many advantages such as better power quality and more environmentally friendly. Moreover, the economic potential that may still be used from this system is the opportunity to utilize the waste heat from the engine generator using a combined heat and power (CHP). Application of this system with RES as an alternative generation system in the future. Surely this system requires the operating mechanism and a sophisticated control system to make the finger with a reliable and efficient, and it can all be met by the microgrid [7].

VII. General structure of a Microgrid

A microgrid is defined as a system consisting of generation sources, focuses on the use of renewable energies in the majority, storage equipment, and electrically connected loads, to meet a determined energy demand. It can operate connected to the main grid in medium voltage or low voltage, or isolated from the same [8].

Energy sources in a microgrid can be renewable (photovoltaic, wind, thermal and geothermal generation, biomass, tidal and cogeneration, etc.), conventional (diesel thermal plants) or the electric grid [9]. Figure I.3 shows the general structure of a microgrid, formed by different energy generation systems (conventional and unconventional), energy storage system, and power management units (converter, grid-tied inverter, pure inverter, regulator [10]) for the system operation and the possible connection to the grid.

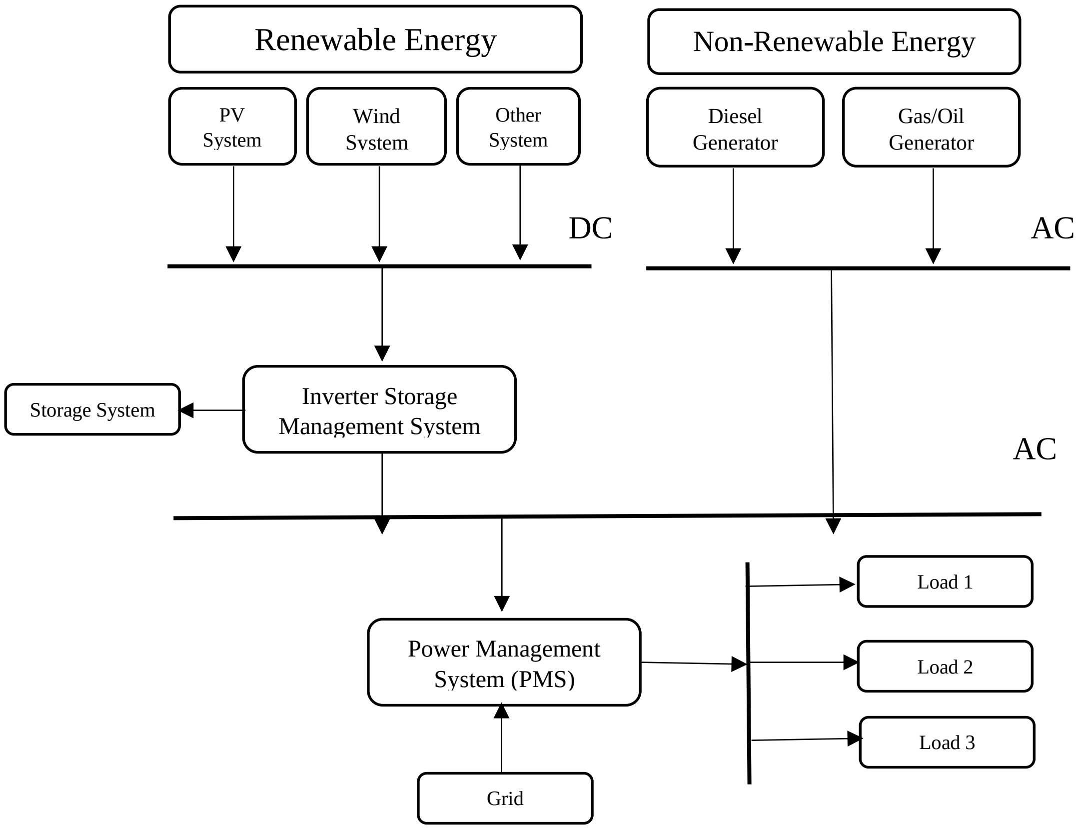


Figure I.3. General structure of a micro-grid

The most advanced microgrids have a power management strategy (PMS) and an energy management strategy (EMS) [11], which are described in the information flow diagram of Figure I.4.

These management functions require a communication infrastructure consisting of smart metering equipment [12], to determine in real time the load, prioritize the renewable generation, calculate the power flow, do connections to the grid, operate conventional generators; in addition, to store energy and use it according to the criteria of operation.

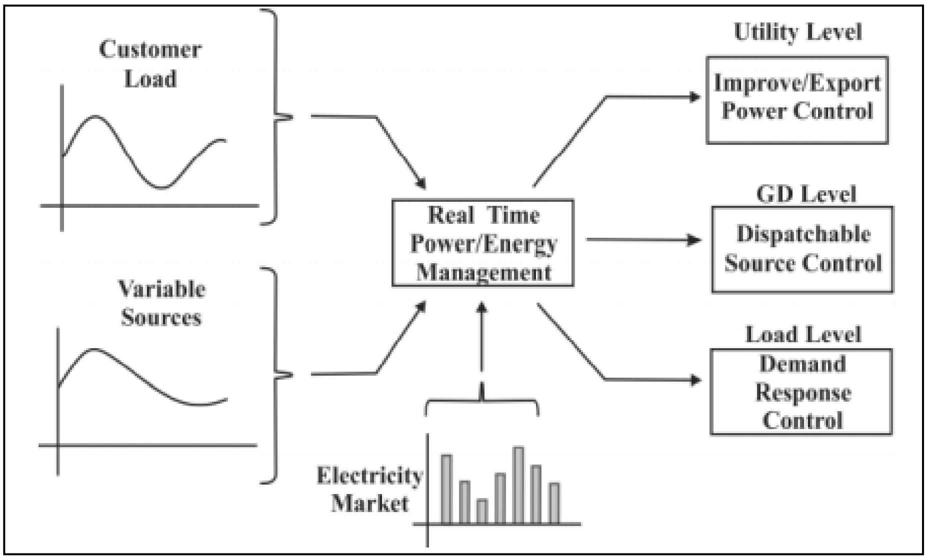


Figure I.4. Information flow and functions of a real time PMS/EMS for a microgrid

VIII. Micro-grids operating modes

VIII.A. Island mode :

Island-mode microgrids are microgrids isolated from other power generation networks capable of supplying a single installation or multiple users. They are self-sufficient for the production of electricity but cannot supply excess energy and, if there is a deficit, cannot take electricity from the grid. These systems can be located in remote areas, in areas where the local electricity grid is very unstable, or in places where self-sufficiency in electricity is essential.

VIII.B. Grid connected mode:

The connected micro-grids are directly linked to the country's local electricity distribution grid. They have the advantage of being able to generate electricity on the grid but also of being able to receive electricity from the local electricity grid.

One of the potential challenges of micro-grids connected to the local grid is that if the local power grid fails, the micro-grid can also fail. To avoid this risk, Clarke Energy which is a multinational company specializing in decentralized energy production solutions brings additional considerations to the device to facilitate automatic switching from one operation to another and to ensure load shedding so that the connected loads do not exceed the production capacities of the micro-grid.

VIII.C. Grid connected in island mode:

Some microgrids, while operating normally in parallel with the local network, can disconnect incoming power from the network and provide the necessary electrical infrastructure, independent of the network. To do this, you need power generation sources that can operate independent of the grid and independent of climatic profiles.

IX. Microgrid topologies

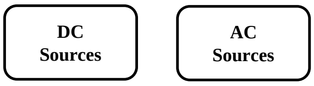
Microgrids can be designed according to criteria such as connection with the grid, support, relations with types and number of energy sources, and according to load; all this determinate by the needs to be satisfied. The most common configurations are shown in Table 1.

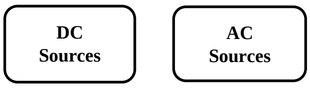
Table I.1. Microgrid configuration

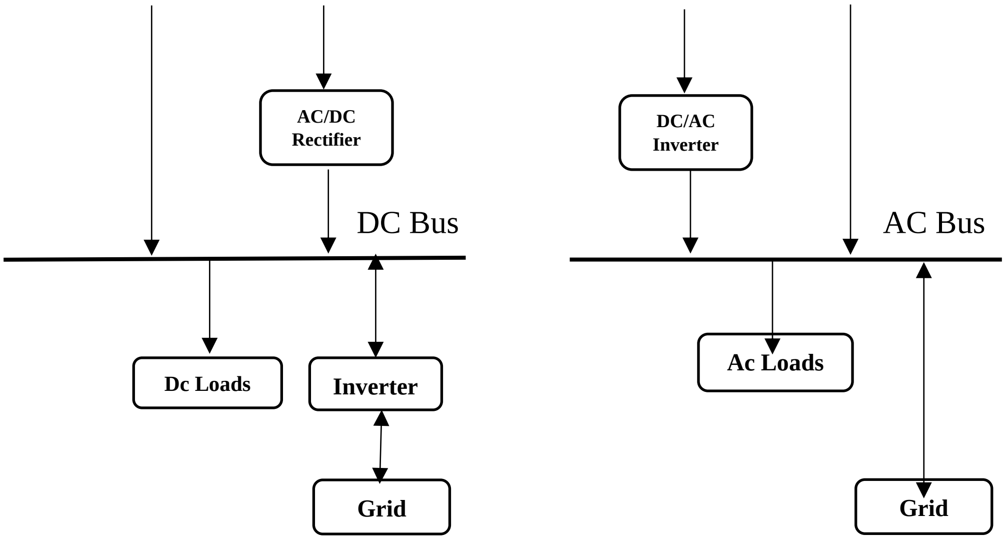
CRETERIA	CONFIGURATION
Bus	CC bus CA bus Mixed bus
Interaction with the grid	Remote Complement Support
Back-up energy system	Grid Emergency Plant Batteries
Types of energy sources	Renewables Conventional Hybrid
Numbers of energy sources	Individual HybridGeneration
Types of loads	DC Loads AC Loads

a- According to the type of bus

The microgrids can be classified according to the type of bus through which the energy exchange happens: direct current (DC), alternating current (AC) or mixed, which depends on the load. Figure I.5a) shows the basic structure of a micro-grid with AC source and that requires a rectifier to supply power. Similarly, Figure I.5b) shows a micro-grid with DC load that requires and inverter to charge the AC loads. Both types of microgrids can be connected to the grid, taking into account the signal conversion required to charge loads.







a) Basic structure of a DC bus b) Basic structure of an AC bus

Figure I.5. Microgrid topology by bus kind.

b- According to the level of interaction with the grid

The interaction of a microgrid with the main grid and the loads allows classifying micro-grids into three types:

- Remote microgrids, that are those that are located in distant areas where it is too expensive to make the interconnection to the main grid;
- Complementary microgrids, that are those that are used to meet a given load;
- Support micro-grids, that are also connected, although they generate a considerable percentage of energy. Its installation is ideal in areas with limited availability of fossil fuels.

X. Architecture of Microgrid

Microgrid system operate at a low voltage distribution, and has several distributed energy resources. Microgrid system also has the ability to operate connected to the grid (on grid) or disconnected to the grid (off grid/islanded) [13]. The microgrid structure consists of several types of distributed energy sources (DER) such as solar panels, wind turbines, microturbine, thermal power plant each in the form of distributed generation (DG), including energy reserves from battery (Distributed Storage/DS).

Microgrid electrical connection points that connected to the low voltage network in the PCC (point of common coupling) that connected to the DG, DS and loads, which consist of several types of loads such as residential, commercial buildings, campuses and industrial complexes. As shown in Figure I.6, architecture of microgrid organized as AC microgrid (AC bus) or DC microgrid (DC bus) or combine of both [14].

Figure I.6.Architecture of Microgrid (a) AC microgrid (b) DC microgrid

XI. Classification of Microgrids

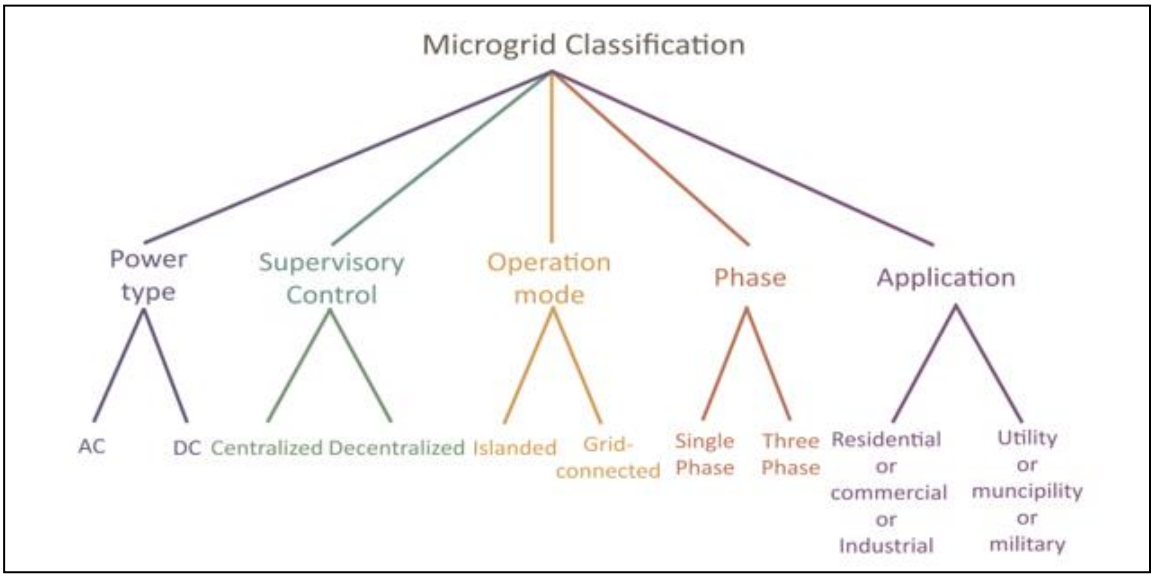


Figure I.7. MG classification

XII. Technology of Microgrid

Operation of microgrid system cannot be separated from technologies that support from each part that make up the microgrid system, as the source of energy (distributed generation), energy storage, interconnect switches and microgrid control system.

Technologies in energy sources distributed generation include the utilization of renewable energy sources such as photovoltaic, wind turbines, and fuel cells. Several power systems improve efficiency by implementing the use of flue gas using CHP technology (combined heat and power) as microturbine, Figure I.8.

Figure I.8. Microturbine

Technologies in energy storage microgrid systems which include battery, super capacitor and flywheels. Energy storage in microgrid system is used among others to:

- Stabilization of the microgrid system in the face of fluctuating energy sources and load changes.
- Enables load sharing operation in microgrid system.
- Reduce the loads spikes and electrical interference
- Backup energy source

Switch interconnection technology in microgrid system utilizing digital technology using Digital Signal Processor (DSP) and equipped with communication devices, while meeting the IEEE 1574 standard network interconnection. To improve the response speed semiconductor switch used technologies such as thyristors, Figure I.9.

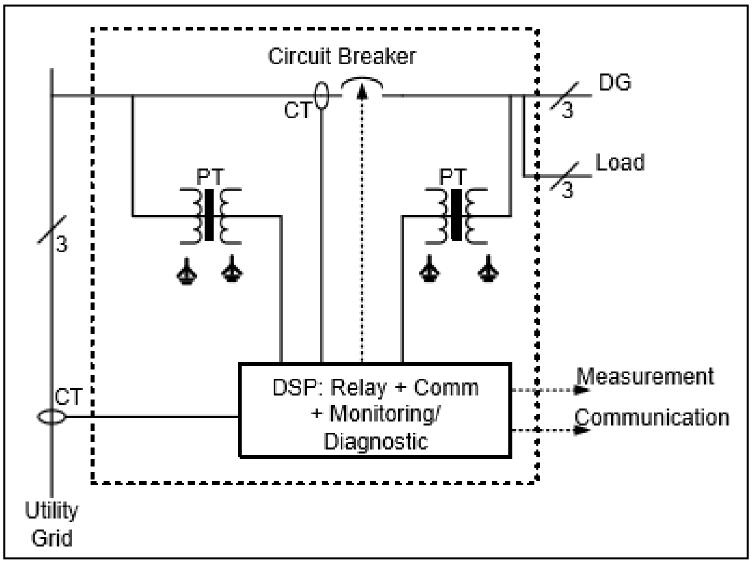


Figure I.9. A schematic diagram of circuit breaker on connection to the grid

Control system technologies in microgrid can be grouped in two modes of operation are connected to the network mode and isolated mode (islanding). The control system is intended to regulate the stability of microgrid operation particularly in frequency and voltage to maintain stability in face of changes in load and interconnection with other networks. The control system is applied to power converter technology in regulating active and reactive power supply, applying droop control and frequency control [15].

XIII. Control and management of Microgrid

Control system in microgrid contrast to conventional power systems, this is due to several reasons, among others:

- Steady state and dynamic characteristics of microgrid different from conventional plants.
- Microgrid possesses inherent unbalanced load due to one phase loads.
- The supply of power from microgrid can come from uncontrolled sources such as wind.
- The role of energy storage is very large in the control mechanisms used.
- Microgrid accommodate disconnection and connection mechanisms to maintain expenses during its operating.
- Microgrid requires initial requirements of power quality or service preferences for certain types of loads

Table I.2. Several types of mechanisms control used in der

	Main energy sources	**Interface/inversion**	**Power flow control**
DG conventional	Reciprocating engine small hydro Wind Turbine fixed speed	Synchronous generator Induction generator	AVR Control and Governor (+P, ±Q) Stall or pitch control of turbine (+P,-Q)
DG non-conventional	Wind Turbine variable speed Microturbine Solar panel Fuel cell	Power electronics converters (conversion AC-DC-AC) Power electronics converters (conversion DC-DC-AC)	Turbine speed control and DC link voltage control (+P, ±Q) MPPT Control and DC link voltage control (+P, ±Q)
Long time storage (DS)	Battery storage	Power electronics converters (conversion DC-DC-AC)	State of charge and / or control output voltage / frequency (±P/±Q)
Short time storage (DS)	Flywheel Super capacitor	Power electronics converters (conversion AC-DC-AC) Power electronicsconverters	State of charge (±P, ±Q) Speed control (±P, ±Q)

As described previously microgrid consists of DER configuration, loads with classified characteristics and management control systems and microgrid. DER may include distributed generation (Distributed Generation/DG) or distributed storage systems (Distributed Storage/DS).

Diagram of DG on the microgrid system consists of primary energy sources, media interface and interconnect switches. A DS can be a major energy source for the DG. Moreover, main energy source can be generated using a rotary machine /spinning and generating device that consists of power electronics converters. Both provide concepts, strategies and characteristics of different controls.

Moreover, control strategy and operation of interconnect system, as well as energy/power management used largely determined the type of DER technologies in use, the type of load demand and the expected operating scenarios. Several types of control mechanisms used in DER described in Table 2.

In context of power flow control DER units can be grouped into unit dispatchable energy (power output can be regulated) and non-dispatchable (power output cannot be adjusted).

In dispatchable energy unit output power setting is set externally using supervisory control such as AVR, while for non-dispatchable energy unit output power settings based on the maximum power that can be generated using MPPT concept.

A non-dispatchable energy units can be converted into dispatchable energy units using additional energy storage systems and power electronic circuit converter dc-dc-ac. In addition to provide faster response electronic converters also able to limit short circuit contribution not less than 200% from current capability and to prevent damage due to currents, Figure I.10.

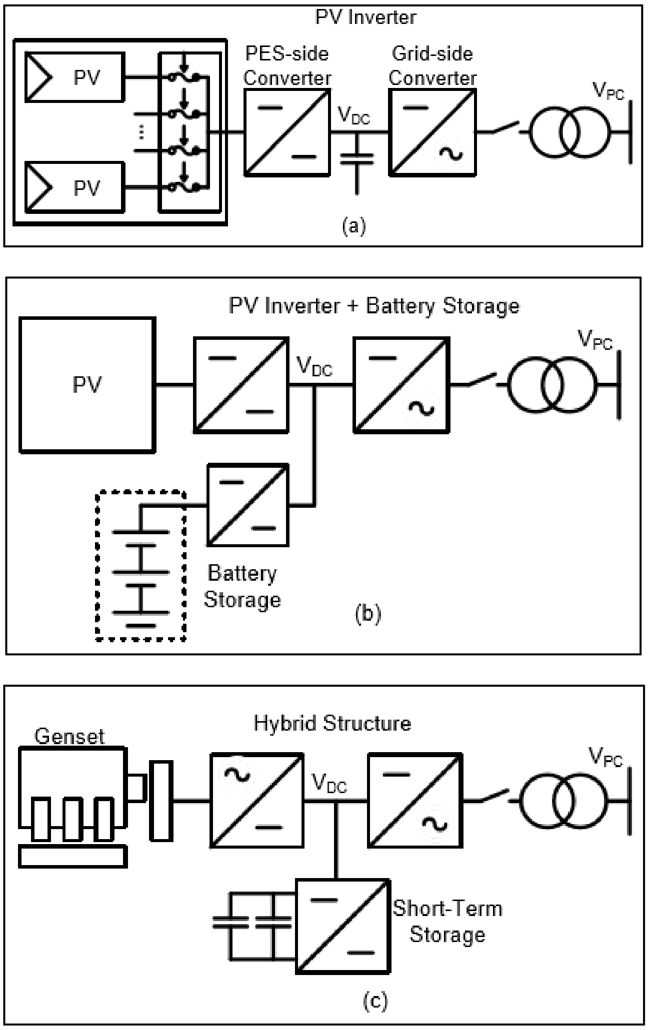


Figure I.10. Configuration of non-dispatchable (a) and dispatchable (b) and (c)

Stability of microgrid operation was also obtained by setting the loads connected to the network, especially on non-critical loads. Critical loads more attention than the other loads that are not critical. Settings done in several ways including termination control loads in order to maintain the stability of the voltage and frequency. The distinction between loads service, improved power quality and reliability for certain expenses.

XIV. Control Method of Microgrid

The aim control mechanisms of microgrid are to regulate voltage and frequency, as well as reactive and active power output, to fit the setting. Microgrid control strategies can be grouped into several alternative control as shown in Table 3.

Table I.3. Classification of DER unit control method

Control method	Grid following control	Grid forming control
Non-interactive control method	Power Export (With/Without MPPT)	Voltage and frequency control
Interactive control method	Power dispatch real and reactive power support	Load sharing (Droop control)

In non-interactive control strategies, output power settings carried out independently while at interactive control strategies output power setting performed as command from control unit. Each control strategy is divided into grid following and grid-forming control.

In grid-following control, settings power output including voltage and frequency are determined by the microgrid. In grid-forming control power settings, including output voltage and frequency, by DER units and will be followed by another DER units. DER units that implement grid-forming should have a greater energy potential.

XV. The microgrid central controller

The microgrid central controller (MGCC) plays an important role in microgrid control. In fact, it provides the main interface between microgrid and other actors. In addition, the MGCC will response depending on the different roles for entire microgrid or local MCs from difficult to simple.

For example, it can provide set-points for the MCs or simply monitor or supervise their operation. A microgrid can be operated in a centralized or decentralized way.

a- Centralized control

On centralized supervisory control strategy, amount of power output from each LC (Local Control) is determined by MCC (Microgrid Control Center) based on input (biding) production capacity owned by each LC. MCC based on inputs of LC and operating policy that covers current energy market prices, estimates need and production as well as consideration of infrastructure conditions other microgrid, determine LC operations include setting LC production capacity. The number of loads to be served and amount of market price for energy optimization of LC in determining biding further production capacity to MCC. (Luu, 2014).

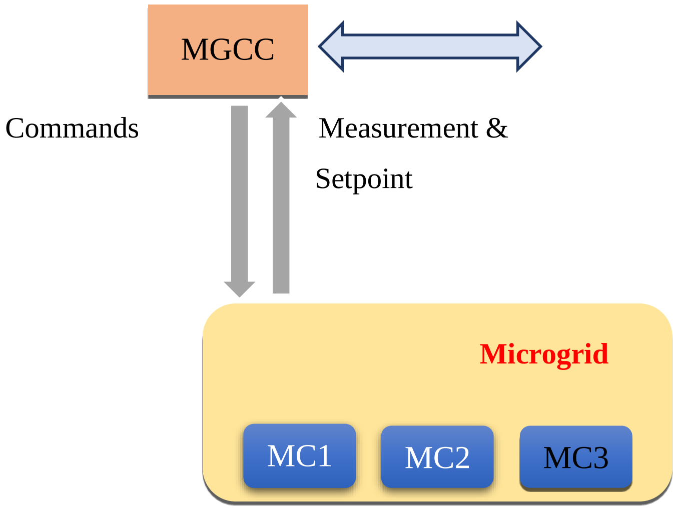


Figure I.11. The principle of centralized control

b- Decentralized control

In decentralized supervisory control strategies, each LC has ability to determine operating autonomy of energy production that will be generated by LC. The main purpose of control strategy in each LC is not aimed at increasing financial income but rather to overall performance of microgrid. So, at each LC already has economic parameters, environmental conditions/ potential energy (weather) and the estimated load. The principle of decentralized control is shown in Figure I.12. One method of control that can be applied to this system is using Multi Agent System (MAS).

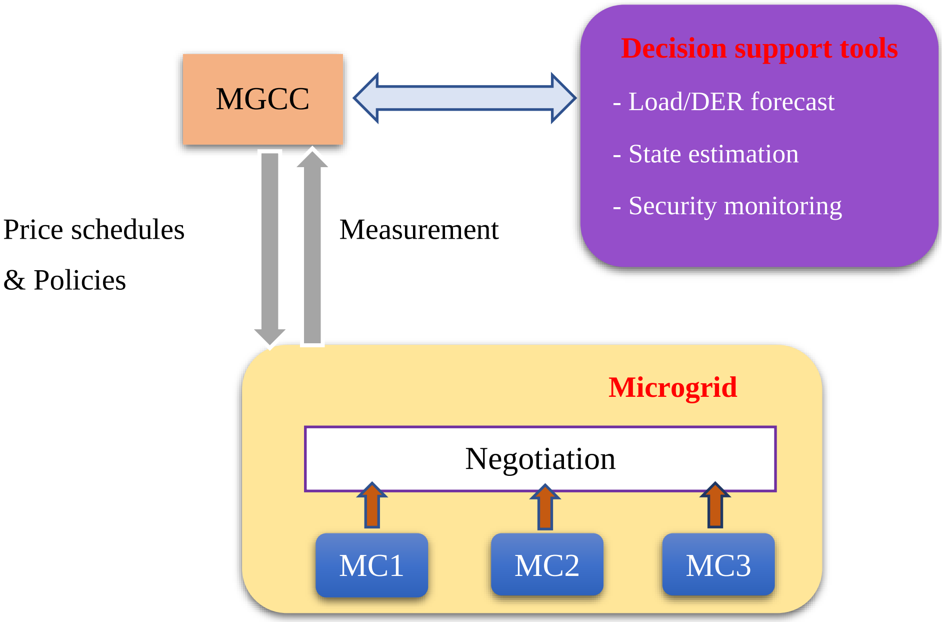


Figure I.12. The principle of decentralized control

MAS is an evolution form of classical control of distributed control systems with the ability to control large and complex entity. The main feature of MAS is the ability to incorporate elements of intelligence in each local control (LC). Configuration of MAS system on a microgrid as shown in Figure I.13.

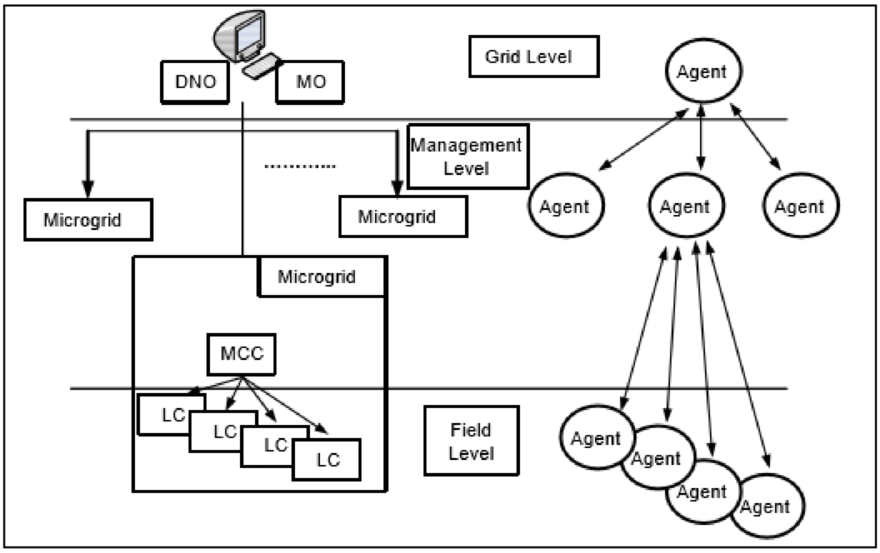


Figure I.13. Multi Agent System configuration on microgrid

In the centralized and decentralized systems both require reliable data communications facilities. Data communication network can be radio, telephone or power line carrier. Through this communication networks microgrid operation mechanism arranged between each DER unit or the main control system in form of energy management system applications. Table 4 show us the difference between the two control methods of microgrid.

Table I.4. Comparison of Centralized and Decentralized Control method

TYPE	PROS	CONS
Centralized control	• Easy to implement • Easy to maintenance in the case of single point failure	• Computational burden • Not easy to expand (so it is not suitable for smart grids) • Single point of failure (highly unstable) • Requires a high level of connectivity
Decentralized control	• Local information only • No need for a comprehensive two-way high-speed communication • Without leaders, system still includes some control island-area • Parallel computation	• Absence of communication links between agents restricts performance • Moderate scalability

XVI. Technical challenges on microgrid

As a new paradigm of power systems, implementation of microgrid still face many obstacles. Less understanding about microgrid and unfavorable government policies become an obstacle in applying microgrid technology.

In general, in addition can be applied as a solution to electricity in remote areas, microgrid technology can also be used as electrical solutions such as urban residential complexes, offices, schools and others. In which implementation of microgrid technology will provide advantage compared if have to build a new transmission and distribution network.

Table I.5. Advantages and disadvantages in applying microgrid technology among others:

Microgrid Advantages	Microgrid disadvantages
✓ Microgrid, have ability, during a utility grid disturbance, to separate and isolate itself from the utility seamlessly with little or no disruption to the loads within the Microgrid. ✓ In peak load periods microgrid can prevents utility grid failure by reducing the load on the grid. ✓ Microgrid have environmental benefits made possible by use low or zero emission generators. ✓ In microgrid to increasing energy efficiency, the use of both electricity and heat is permitted to get closer the generator to user. ✓ Microgrid can act to mitigate the electricity costs to its users by generating some or all of its electricity needs.	* In microgrid, that must be considered and controlled voltage, frequency and power quality parameters to acceptable standards whilst the power and energy balance is maintained. * Electrical energy needs to be stored in battery banks thus requiring more space and maintenance. * The difficulty of resynchronization with the utility grid. * Microgrid protection is one of the most important challenges facing the implementation of Microgrids. * Issues such as standby charges and net metering may pose obstacles for Microgrid. * Interconnection standards needs to be developed to ensure consistency.

XVII. Conclusion

In this chapter, we have made a survey on mainly definitions of a Microgrid, then we have presented different operation mode following type of current (DC or AC), and finally we have explained general management and control way of the system.

In the following chapter, we will detail each component for modeling and simulation purpose.

CHAPTER II

Microgrid Architecture

SUMMARY

CHAPTER II: Microgrid architecture ……………………... 32

I. Introduction

The use of new electricity production ways, especially so-called renewable energy has continued to increase in recent years, which implies the improvement of new architectures to face the new challenges and issues of microgrids.

Given that the energy yield of these systems is highly dependent onmeteorological conditions, the combination ofmany sources in a hybrid framework seems tobe a reasonable solution to ensure stable energy production.

In order to achieve a balance betweenthe production and the consumption, energystorage elements are required. Moreover, complementary energysources such as dieselgenerators are necessary in case of outages.

A multi-source power supply must obey someconnection architecture. Also, a convenient production monitoringof the sources with respectto loads allows accomplishment of electrical need aswell as an optimalutilization of the producedenergy.

In this chapter, it conducts a survey on the optimalarchitecture of a grid connectedhybrid system, and the well-suited monitoringandsupervision strategy.

II. Microgrid structure and components:

A microgrid encompasses distributed source of energy (DER) (photovoltaics, small wind turbines, fuel cells, internal combustion engines, micro-turbines, etc.), distributed energy storage devices (flywheels, superconductor inductors, batteries, etc.). The DERscould be classified into two major groups:

(i) DER directed-coupled conventional rotating machines (e.g., an induction generator powered by a fixed-speed wind turbine)

(ii) DER grid-Coupled to the inverter (e.g., Photovoltaic, fuel cells, etc.). Transmitted energy storage devices can be charged with surplus power and discharge to support the power deficit.

They therefore, help to improve the dependability of microgrid as well as make it effective and economical. In addition, energy storage is considered as fast response systems. They also help stop transitory instabilityand take part in the control of voltage and voltage Frequency of the microgrid by delivering a short-term balance reserve.

Figure II.1 shows a schematic diagram of the microgrid, which incorporates numerous systems: PV, variable-speed wind generator, diesel generator, and battery-powered storage system.

Every other distributed energy asset is attached to its correlating bus by means of a power-electronic converter. The microgrid is tied to the upstream network at the common coupling point (PCC). Power is supplied from a low-voltage (LV) transmission grid via a transformer substation.

The microgrid is continuing to work with two mechanisms: grid-connected mode and insulated mode. In the connected grid mode, the PCC is closed and the microgrid is connected to the primary grid. It translates to the microgrid being willing to trade energy with the main grid. When the upstream network is disturbed or the microgrid is optimally operated, the switch at the PCC could be opened to disassociate the microgrid. The microgrid can therefore continue to function in the commonly called island mode.

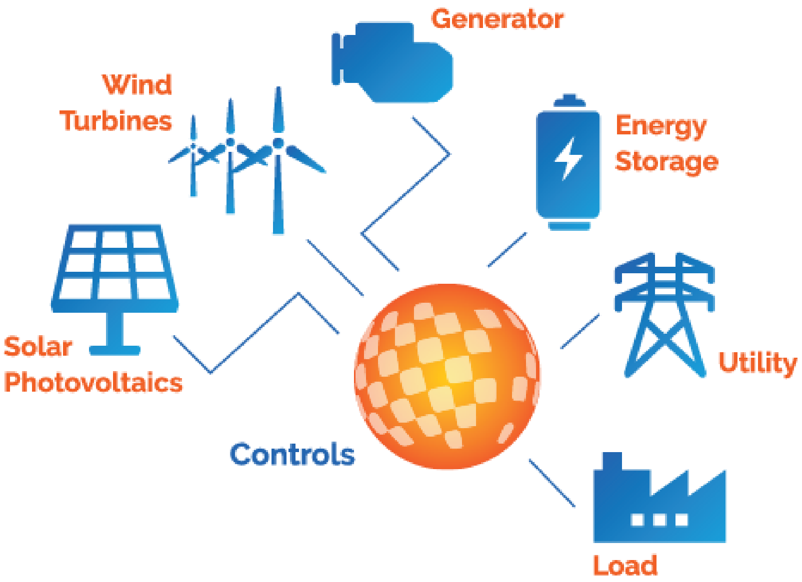


Figure II.14.A studied Microgrid structure

Many hybrid systems are stand-alone systems, which operate "off-grid" - not connected to an electricity distribution system. For the times when neither the wind nor the solar system is producing, most hybrid systems provide power through batteries and/or an engine generator powered by conventional fuels, such as diesel. If the batteries run low, the engine generator can provide power and recharge the batteries.

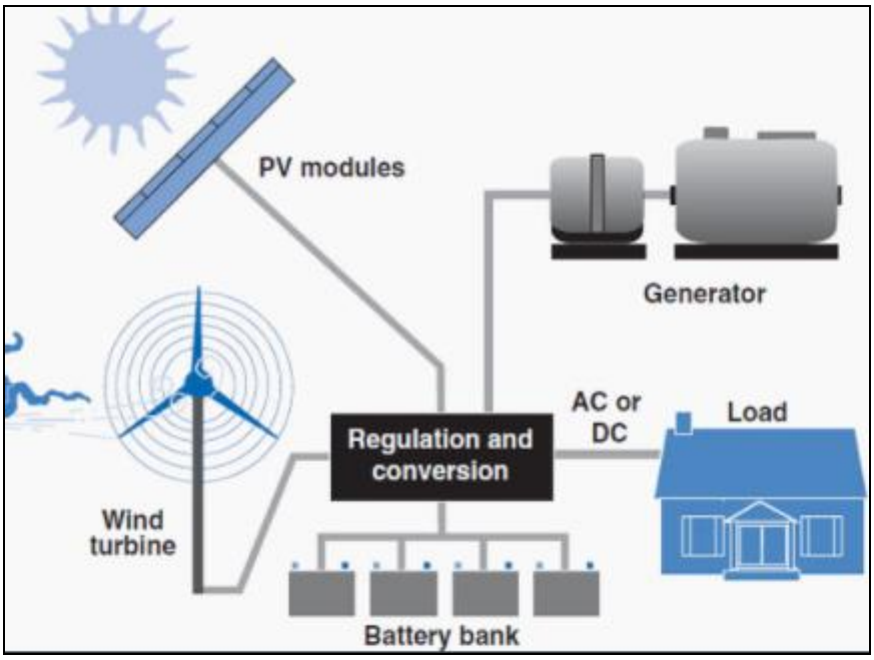


Figure II.15. Hybrid power system

Microgrids are power generation systems that are built around the electricity needs and / or resilience needs of one or more electricity consumers.

Microgrids, although not limited in size, are typically designed and implemented to meet local electricity needs and therefore tend to be distributed, stand-alone power systems that may or may not be connected to the national grid.

Depending on the specific objectives and the availability of local resources, micro-grids can be powered by various types of power generation. Renewable energy sources such as wind power and solar photovoltaic energy are combined with high efficiency gas engines and cogeneration systems powered by natural gas or renewable gases.

Energy storage systems are often integrated to maximize the efficiency of renewable energy, to improve resilience or simply to add "synthetic inertia" and stability to a micro-grid. Microgrids are designed and built to be self-sufficient or more broadly, to support the power grid system.

III. Hybrid system configuration

A typical hybrid energy generation system is shown in Figure II.3

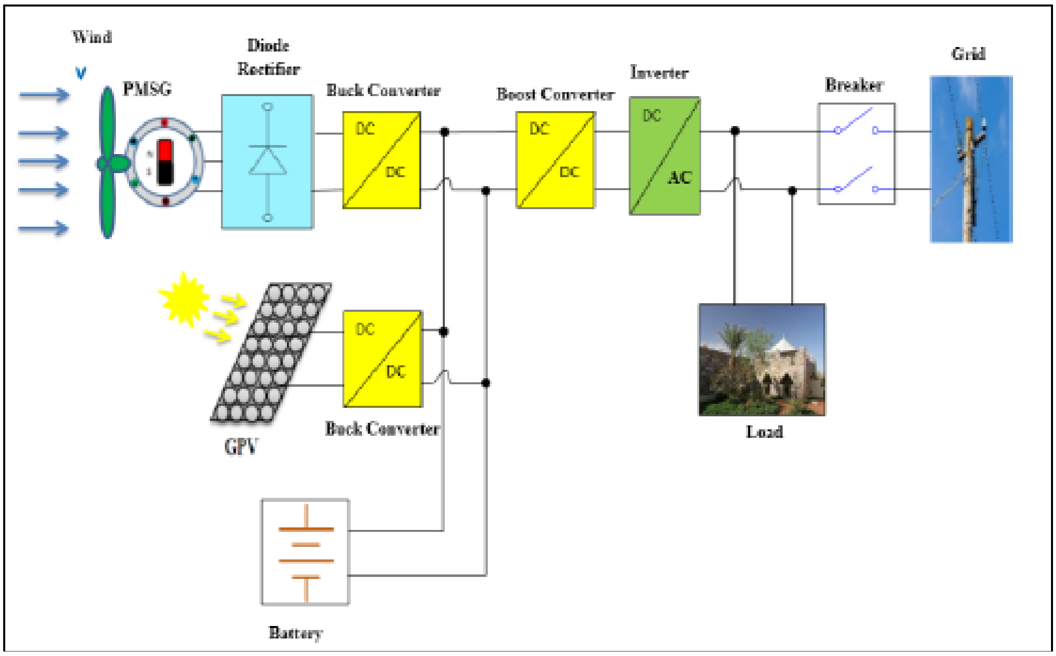


Figure II.16. The studied hybrid system configuration

IV. Energy storage

Energy storage has contributed to the operation of the electricity system already over decades, based on the technical and economic grounds of arbitrage, storing electricity[17] during low electricity demand and releasing it back into the grid during high demand, typically over a daily cycle. Given that in the past the electricity generation mix relied almost exclusively on fossil fuels, nuclear and hydro, and variability of generation was not a major challenge, the necessity for energy storage was more limited and less economically attractive.

The global installed capacity in electricity storage was estimated in 2014 in the range of 171 GW[18] , approximately 2% of total generation capacities. Further, 16 GW of new storage capacity is announced or under construction globally. The main energy storage technology is pumped hydro storage (PHS), which counts for over 97% of the existing electricity storage capacity.

V. Relevant energy system developments

The main driver towards larger structural changes in the electricity system is the increasing variable renewable electricity generation. Renewable energy has been supported through policy, and its recent cost reduction brings it towards cost-competitiveness on the energy markets. The cost of renewable technologies has reduced significantly over the last few years, with an 80% reduction for solar panels (PV) between 2009-2015, and a 30-40% reduction for wind turbines in the same period.

We can highlight some main benefits Microgrids can brings:

Supporting the electricity generation profile of variable RES:

A good mix of RES electricity (in particular of wind and solar) can in itself already contribute to a balanced operation over certain timeframe. This is becoming important with the growing share of variable RES.

The typical generation profileof PV has a well-established daily cycle, with a peak around noon and low generation over the darker part of a day. In addition, varying cloud coverage can cause significant changes in electricity generation even over the course of minutes, which presents a specific challenge to the grid. However, the annual variation in PV generation is typically not in line with the annual consumption profile.

The annual profile of wind generation roughly matches the annual consumption profile in some geographical locations, with year-round and higher generation during the winter period. Wind generation fluctuates significantly over longer periods, typically over days or weeks, and needs to be balanced. Energy storage can ensure

(i) Effective operation of the grid,

(ii) Fast reaction times in case of rapid power drops or surges,

(iii) Linking of various grid elements for a cost-effective balancing of variable RES over various timeframes.

Enabling energy efficiency

Energy storage brings benefits to the electricity system in a similar way as demand response, flexible generation and grid extension (including interconnections): it helps shave the peaks and provides flexibility solutions to market participants. Furthermore, storage can help reduce emissions from the conventional electricity generation: on the one hand by facilitating a more efficient use of the existing assets, on the other hand by reducing the carbon content of the fuels.

Using renewable electricity and synthetic fuels in sectors like transport, agriculture or industry, is a viable pathway to decarbonize the energy system in a broader sense. For this **sectorial integration** to happen there is a need to link these different markets. This will bring benefits to the electricity sector. Thanks to sectorial integration, some flexibility and storage solutions could come from thermal systems, gas infrastructures, industrial feedstock and agriculture (see Figure 1), while at the same time decarbonizing those sectors where alternative carbon-reduction measures could be missing, limited or costly.

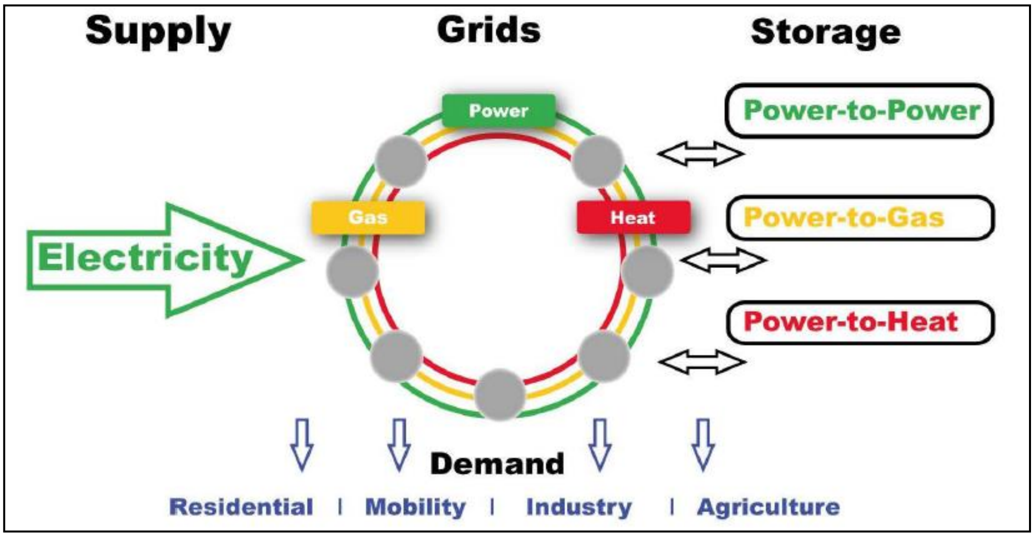


Figure II.17. Illustration of flexibility components in the electricity system.

VI. Energy storage technologies

Energy can be stored using several different technologies: mechanical, thermal, chemical, electro-chemical and electrical. The most important functional characteristic of a storage technology is the combination of power and capacity. Together these establish the potential set of suitable applications for a specific storage technology. In addition, the speed of reaction (response time) of a storage technology is an increasingly important factor for the electricity system. These three characteristics, together with efficiency and cost have a direct impact on the business cases through the revenue that the storage can generate on the markets through services and benefits.[19]

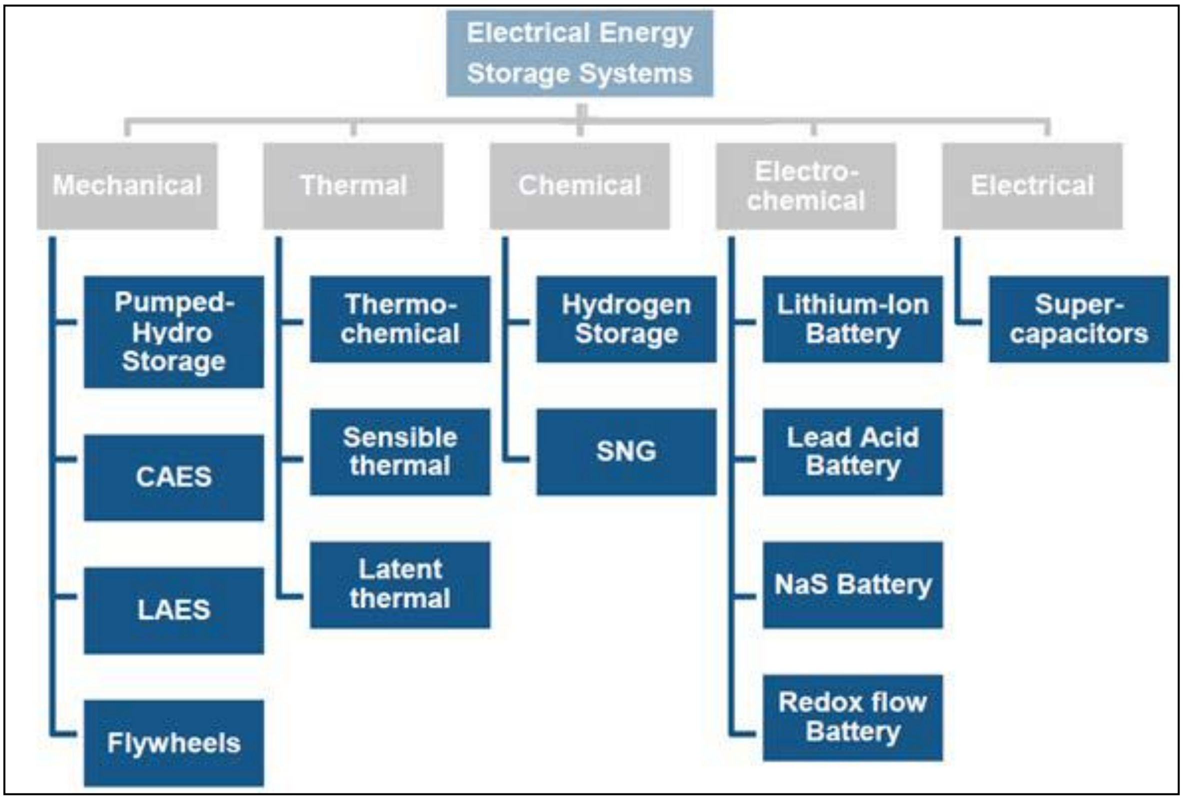


Figure II.18.Example of energy storage types (source: World Energy Council)

9 CAES = Compressed Air Energy Storage; LAES = Liquid Air Energy Storage; SNG = Synthetic Natural Gas.

Many methods to store energy exist. A selection of the main energy storage technologiesis presented below:

VI.1 Mechanical storage

Mechanical storagetechnologies store energy in various forms of kinetic and/or potential energy:

a) Pumped hydro storage (PHS) is the most mature technology, and accounts for a major share of storage capacity globally (around 97%). The response time for pumped hydro systems varies, with the older facilities having slower response times and the most modern facilities being able to respond within seconds.

b) Compressed air energy storage (CAES) uses electricity to compress air which is then stored either in underground caverns or above-ground vessels. The stored air is then expanded through turbines to generate electricity again. In adiabatic CAES systems the heat generated during compression is stored to be used at the expansion. The characteristics of CAES are similar to PHS, although CAES is a recent application and only two facilities are currently in operation.

c) A variant of air-based storage is liquid air energy storage (LAES), which uses electricity to drive an air liquefier to produce liquid air which is then stored in insulated vessels. The stored air is then vaporized and expanded through turbines to generate electricity again.

This technology is currently at the level of pre-commercial demonstration. Viable efficiencies may require coupling with heat or cold applications;

d) Flywheels store electrical energy as kinetic energy by increasing the rotational speed of a disc rotor on its axis. Flywheels have a very short response time, usually in the order of milliseconds to seconds making them suitable for frequency control.

VI.2 Thermal storage

Thermal storages convert electricity to heat, which is then stored in various types ofmaterials. Thermal storages can use resistive heating or heat pumps/engines to convert electrical energy to heat. This heat is then converted back to electricity through steam turbines. Heat could also come from cogeneration plants. Thermal storage can have large capacity and fast response time, while the retrieval response time is similar to the conventional steam turbines:

a) Thermo-chemical storage uses a chemical which can store heat through changes in its chemical bonds. The initial chemical is heated, which alters the chemical bonds and absorbs the energy in the heat. The chemical can then be "discharged" through a reversed chemical reaction which results in heat. This heat is then used to generate steam for re-electrification. The chemical is typically some kind of salt that can be hydrated.

b) Sensible thermal storage relies on changing the temperature of a storage medium. This can be water, rock, earth, or anything else that can be heated and which returns a large share of the initial energy when cooled while it generates steam for re-electrification purposes.

c) Latent thermal storage relies on melting or crystallization of a material (e.g. paraffin) to store heat. The materials in this application have a higher storage capacity within a small temperature range compared to sensible thermal storage materials.

VI.3 Chemical storage

Chemical storage can provide storage services over various timeframes, depending on the specific application. Chemical storage allows cost-effective separation of the power and the energy components in an energy storage application. The characteristics of chemical storage technologies can also support the linking of economic sectors, and the integration of heat, gas and electricity infrastructure. Chemical storage is mostly based on hydrogen production.

Modern electrolysis used for hydrogen production have fast response time and are currently installed in multi-megawatt sizes. The produced hydrogen can be stored in a variety of ways, from small cylinders or tanks to large underground storage facilities. The hydrogen and derived chemicals produced could fuel gas turbines, fuel cells or combustion engines to generate electricity, or used as feedstock in industrial chemical processes.

VI.4 Electro-chemical storage

Batteries are a group of electro-chemical storage solutions. Their characteristics depend on the specific battery technology that is applied. Batteries are generally suitable for relatively short duration of storage, and they have in most cases very fast response times. Batteries are therefore especially suitable for medium or low-voltage distribution networks

Below the main characteristics of a few different battery types are presented:

a) Lithium-ion (Li-ion) batteries are emerging as one of the fastest growing battery technologies for grid applications. They are presently deployed globally in a variety of applications, from small scale distributed systems (1-10 kilowatt) to large fast-responding systems for frequency services and energy time shifting (1-50 megawatt).

b) Lead-acid batteries are a simple solution, where lead plates are suspended in sulfuric acid electrolyte, which can be charged and discharged. This is one of the cheapest and oldest battery technologies. The competitiveness of lead acid batteries for electricity system purposes is limited by their lower energy density and shorter lifetime compared to other batteries.

c) Sodium sulfur (NaS) batteries are deemed to be a commercial technology with several grid applications. This battery is attractive due to its long discharge times, quick response capability and high cycle life.

d) Newchemistries and structures are being researched and developed to reach performance and cost reduction beyond those possible with the above technologies. New chemistries are investigated for electrodes and electrolytes, and further developments include nanostructures and electronics for grid interfaces.

e) A flow battery is a type of rechargeable battery where rechargeability is provided by two chemical components dissolved in liquids contained within the system and most commonly separated by a membrane. Different classes of flow cells (batteries) have been developed, including redox, hybrid and membrane less.

The fundamental difference between conventional batteries and flow cells is that energy is stored as the electrode material in conventional batteries but as the electrolyte in flow cells.

VI.5 Electrical storage

Super capacitors are advanced capacitors that have higher energy storage capacity thanconventional capacitors, and are able to discharge over longer time periods. They are able to respond very quickly through both charge and discharge cycles, and provide a high-power output over a very short response time. This is the only pure electrical storage technology.

Superconducting electromagnetic storage systems store energy in the magnetic field created by the flow of direct current in a superconducting coil. They are used to enhance power quality, but do not currently see widespread use due to cost.

VII. The different types of power generation in MG

VII.1 Wind turbines

The first possible source is the energy of the wind. Clean and renewable, it is available in abundant quantities all over the planet. Its operation has becomein recent years the main source of electricity from renewable sources, excludinghydropower, with more than 200 TWh produced worldwide

The transformation of this energy into electricity is done through wind turbines, which cancover a wide range of power according to needs and the type of generation chosen. Several wind turbine structures exist, which are chosen according to the power to be generated, the range of wind speeds considered, and the desired dimensions. Two types of architecture are distinguished:

- The horizontal axis wind turbines Named HAWT for Horizontal Axis Wind Turbine, these wind turbines fail to absorb air flow in only one direction, which reduces production.

Figure II.19. Horizontal axis wind turbines: (a) three-bladed, (b) multi-bladed

- Vertical axis wind turbines named VAWT for Vertical Axis Wind Turbine.

The different shapes of turbines, shown in figure II.7, are defined as follows. The Savonius turbine is characterized bysolid blades, which can be straight or helical. The Darrieus have perforated blades, leaf-shaped, or say H-type in the form of vertical or helical bars.

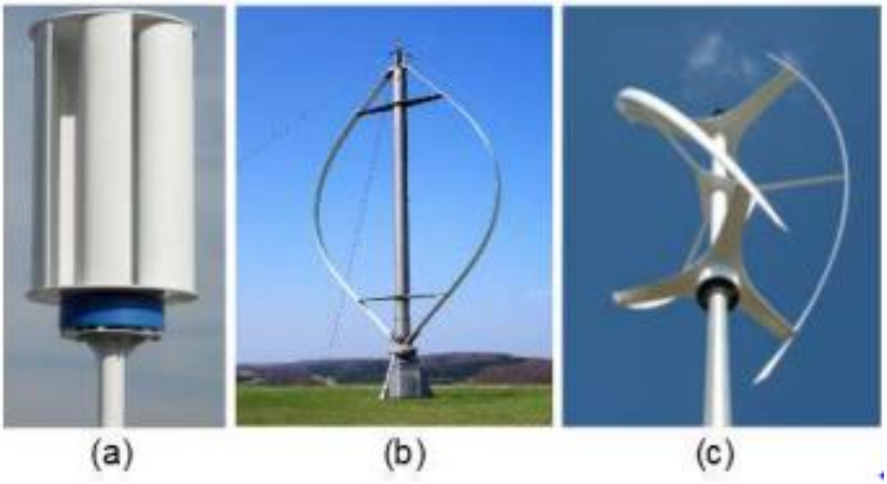


Figure II.20. Vertical axis wind turbines: (a) with Savonius turbine, (b) with Darrieus, (c) with helical Darrieus turbine

Figure II.21. Wind turbine model

VII.2 Photovoltaic panels

The second energy available in large quantities on the earth's surface is energysolar, characterized by the sunshine which gives the energy supplied by the sun per unitsurface area over a given period, in J / m2, and by solar irradiation which corresponds to thepower at a given time, in W / m2. The latter is given for a given thickness of atmosphere, crossedby the solar rays with the absorption of power which infollows:

Photovoltaic panels are semiconductor components that use their property of photoelectricity to generate electrical power. Each panel consists of photovoltaic cells designed from PN junctions, connected together inseries. When a voltage is applied to them, the solar radiation that reaches them bringsenergy to the electrons they contain, allowing them to get excited beyond the gap ofthe junction, thus generating a tunnel effect, and a current.

Figure II.22. Example of installation of photovoltaic panels

Characterization of photovoltaic panels

In order to estimate the characteristics ofphotovoltaic panels, and to be able to compare them with each other, standard conditions oftest, or STC for standard test conditions, havebeen established. Thus, in the manufacturers' data, the characteristic electrical quantities of apanel are given at AM 1.5, thereforefor irradiation of 1000 W / m2, and a temperature of 25◦C.

VIII. Photovoltaic generator model

Generally, the PV panel can be modeled using the equivalent circuit shown in Figure II.9.

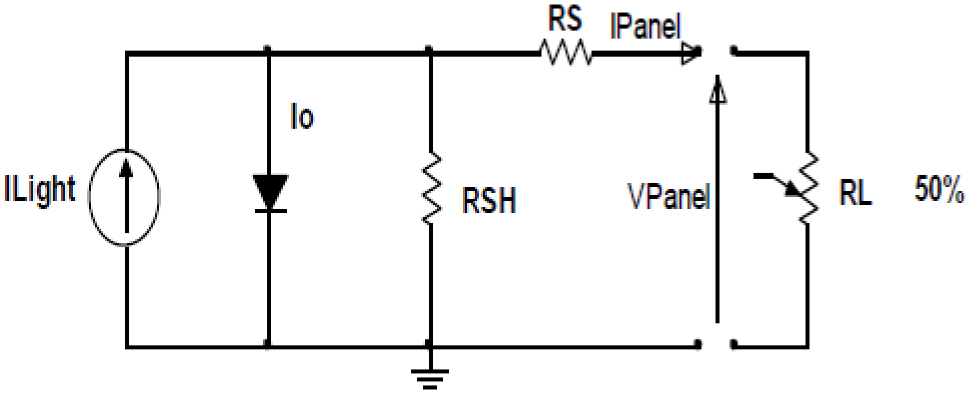


Figure II.23. Equivalent circuit of the PV cell

This lumped circuit includes a current generator providing the short-circuit current (*ILight*), which is a function of the solar irradiation, a diode to account for the typical knee of the current–voltage curve through the reverse saturation current (*I0*), a series resistor (*RS*), and a shunt resistor (*RSH*), emulating intrinsic losses depending on PV cell series and parallel connections. The PV module current at a given cell temperature and solar irradiance is given by:

$$I_{Panel} = I_{Light} - I_0 \left(e^{\frac{Vpanel + Ipanel\ Rs}{a}} - 1 \right) - \frac{Vpanel + Ipanel\ Rs}{R_{SH}} \qquad (II.1)$$

a: is the modified panel ideal factor defined by a is the modified panel ideal factor defined by:

$$a = \frac{N_S \cdot \gamma \cdot k \cdot T_c}{q} \qquad (II.2)$$

q: is the electron charge, *K* is Boltzmann’s constant, γ is the usual PV single-cell ideal factor (typically ranging between 1 and 2),

NS is the number of cells in series,

TC is the PV panel temperature.

$$\mathrm{I_{sc}} = \mathrm{I_0}\left(\mathrm{e}^{\frac{\mathrm{q\,.Voc}}{\mathrm{k\cdot T_c}}} - 1\right) + \frac{\mathrm{Voc}}{\mathrm{R_{SH}}} \qquad \text{(II.3)}$$

Since the ratio between *VOC* and *RSH* is typically negligible, *VOC* can be derived from the diode saturation current as

$$v_{OC} = \left(\frac{k\cdot T_c}{q}\right) ln\left(\frac{I_{SC}}{I_0} + 1\right) \qquad \text{(II.4)}$$

I0 and *ILight* depend on irradiance and temperature.

$$\mathrm{I_0} = \mathrm{I_{0.STC}}\left(\frac{\mathrm{T_c}}{\mathrm{T_R}}\right)^3 \mathrm{e}^{\left(\frac{\mathrm{q\cdot E_G}}{\mathrm{k\cdot T_c}}\right)\left(\frac{1}{\mathrm{T_{ref}}} - \frac{1}{\mathrm{Tc}}\right)} \qquad \text{(II.5)}$$

$$\mathrm{I_{Light}} = \mathrm{I_{Light,STC}}\mathrm{S} + \alpha_{\mathrm{I_{SC}}} \left(\frac{1}{\mathrm{T_{r_ef}}} - \frac{1}{\mathrm{T_c}}\right) \qquad \text{(II.6)}$$

X.a. Maximum Power Point Tracking

Incremental conductance method has been implemented in this study. If the array is operating at voltage V and current I, the power generation is *P=VI*, at the maximum power point, *dP/dV* should be zero and the sign of *dP/dV* may be identified by the next equation. Increase or decrease in the PV array voltage is determined by judging the sign of this equation.

$$\frac{\mathrm{I}}{\mathrm{V}}\frac{\mathrm{dP}}{\mathrm{dV}} = \frac{\mathrm{d(VI)}}{\mathrm{VdV}} = \frac{\mathrm{I}}{\mathrm{V}} + \frac{\mathrm{dI}}{\mathrm{dV}} \qquad \text{(II.6)}$$

The MPPT flow returns the desired PV array voltage for the dc/dc converter.

IX. Conclusion

Solar power is well known to be an expensive solution to remote electrification. This cost can be reduced by adding wind turbine generators to reduce the reliance on PV.

In this chapter, we have focused on the study of photovoltaic wind production of electrical energy optimization as well as its transfer to the mono-phase electrical network supply through an inverter with minimum possible losses. The adopted approach was to improve the chain various parts point by point.

The type of connection of the different components to the system is just as important. The AC coupling with inverter allows us to connect nearly any type of electricity generator and any type of consumer to our system. This makes our system easily extendable on the consumer side as well as on the generator side.

Finally, we see that the energy produced by the system remains constant, according to the load with a voltage of (220V/50Hz). This is due to the power stored in the batteries, which will be used to compensate energy lacks and the efficiency of the control strategy we have used.

CHAPTER III

Modeling of the Microgrid components

SUMMARY

I. Introduction

Advances in wind turbine and photovoltaic generation technologies have brought opportunities for utilizing wind and solar resources for electric power generation. They have unpredictable random behaviors. However, some of them, like solar radiation and wind speed, have complementary profiles.

The Wind/solar complementary power supply system is a reasonable power supply which makes good use of wind and solar energy. This system can not only provide a bargain of low cost and high dependability for some region where power transmission is not convenient such as frontier defenses and sentry, relay stations of communication, but also inaugurate a new area which resolve the crisis of energy sources and environment pollution.

It is very difficult to make use of the solar and wind energy all weather just through solar system or wind system individually, for the restriction of time and region. So, a system that is based on renewable resources but at the same time reliable is necessary and wind/solar hybrid system with battery storage can meet this requirement.

II. Photovoltaic system Modeling

II.1. Photovoltaic module

Photovoltaic cells produce DC electricity from the sunlight. Cells are connected together and placed in the supportive material covered by the glass layer known as module. The PV module is connected to the grid or the isolated grid through inverters. Currently, there are three main groups of PV modules and inverters as shown in Figure III.1:

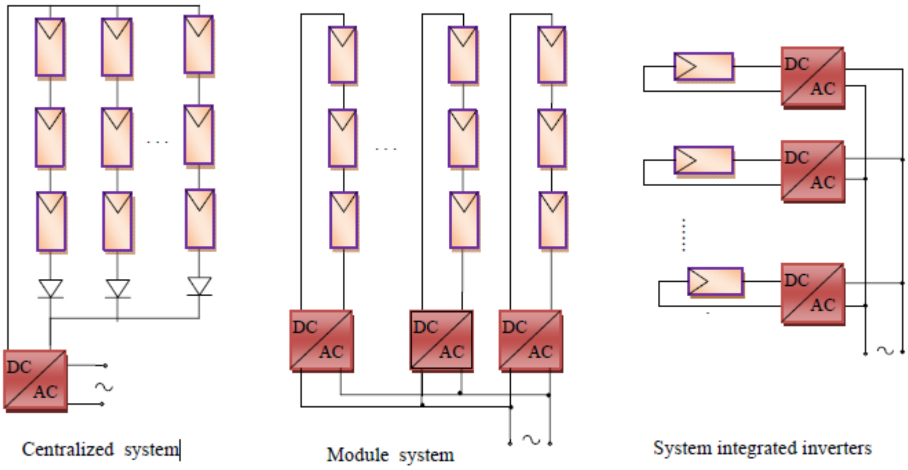


Figure III.24. PV module and inverter

- Centralized system uses a single inverter to transfer the total power. It is useful for small installations

- For modular system, several inverters are connected to a series of PV modules.

- System integrated inverters are useful for PV modules with high power installations.

II.2. PV system sizing

The PV sizing variables are given as the PV Panel number and the amount of string in a PV array. The required number of PV panels in series is estimated by the number of panels needed to match the bus operation voltage. Thus, the PV panel number in series is calculated as follows:

$$\boldsymbol{n_{Pv,serins}} = \frac{\boldsymbol{U_{bus}}}{\boldsymbol{Upanel}} \qquad (III.1)$$

where
U_{bus}: the bus operation voltage
$U_{panel:}$ the PV panel voltage
$n_{pv,series}$: the number of PV panel in series

Each PV string includes $n_{pv,series}$ connected in series. In order to match the current requirement of the system, this PV string is needed to be installed in parallel with other strings. The parallel string number is the sizing variable that needs to be optimized.
Because the parallel PV string number $x_{pv,parellel}$ relates with the amount of the available output current from the overall PV array.

Thus, when one changes the value of $x_{pv\ parallel}$, the value of the output current is also changed. Therefore, in the optimal sizing system, the parallel PV string number is handled as a variable value to be found through the optimization algorithm. The current output of PV array at time t is calculated as follows

$$IPv_{array(t)} \quad = IPv_{,}panel\ (t, Xsize, type, PV).Xpv.parallel.fmm \qquad (III.2)$$

where

xsize,type,PV: PV panel size of a certain PV panel type

Ipv,panel(t, xsize,type,PV) : the PV panel output current at time t depending on panel type

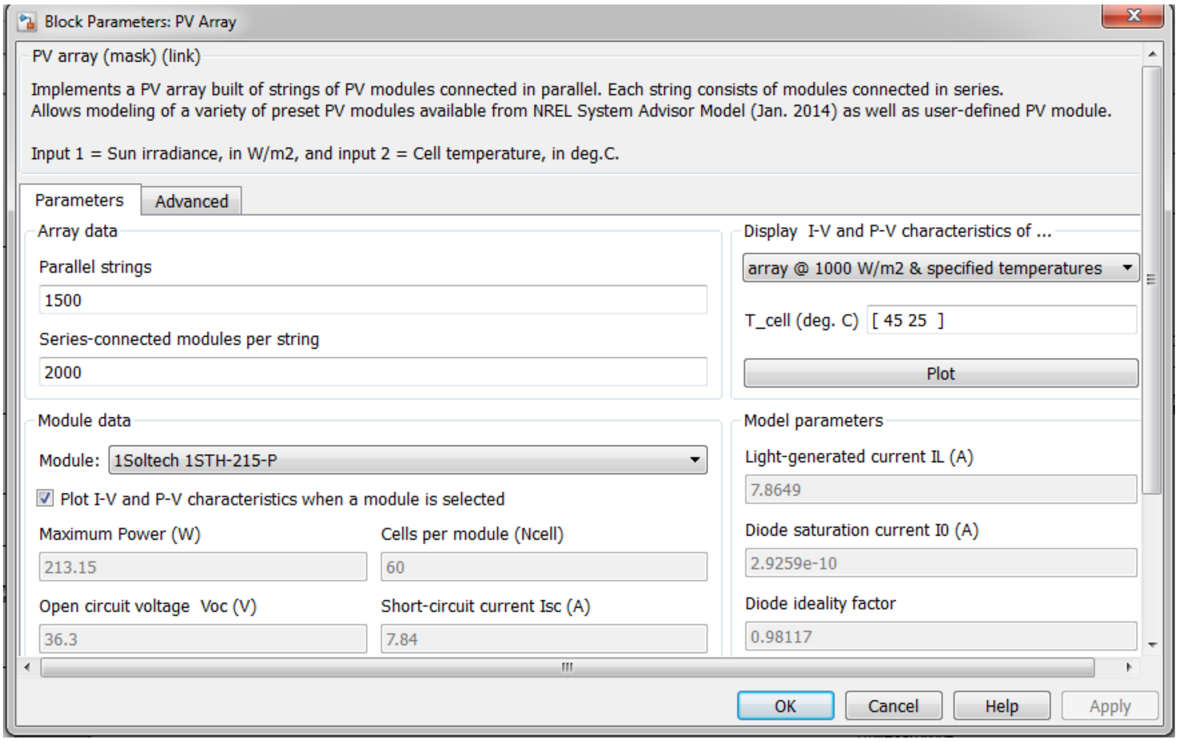
fmm: mismatch factor

II.3. PV system simulation

This figure represents our system simulation using MATLAB Simulink

Data:

Temperature curve: from Adrar area



Block Parameters: PV Array

PV array (mask) (link)

Implements a PV array built of strings of PV modules connected in parallel. Each string consists of modules connected in series.
Allows modeling of a variety of preset PV modules available from NREL System Advisor Model (Jan. 2014) as well as user-defined PV module.

Input 1 = Sun irradiance, in W/m2, and input 2 = Cell temperature, in deg.C.

Array data

Parallel strings: 1500

Series-connected modules per string: 2000

Display I-V and P-V characteristics of ...: array @ 1000 W/m2 & specified temperatures

T_cell (deg. C): [45 25]

Module data

Module: 1Soltech 1STH-215-P

☑ Plot I-V and P-V characteristics when a module is selected

Maximum Power (W): 213.15

Cells per module (Ncell): 60

Open circuit voltage Voc (V): 36.3

Short-circuit current Isc (A): 7.84

Model parameters

Light-generated current IL (A): 7.8649

Diode saturation current I0 (A): 2.9259e-10

Diode ideality factor: 0.98117

Figure III.25. PV characteristics

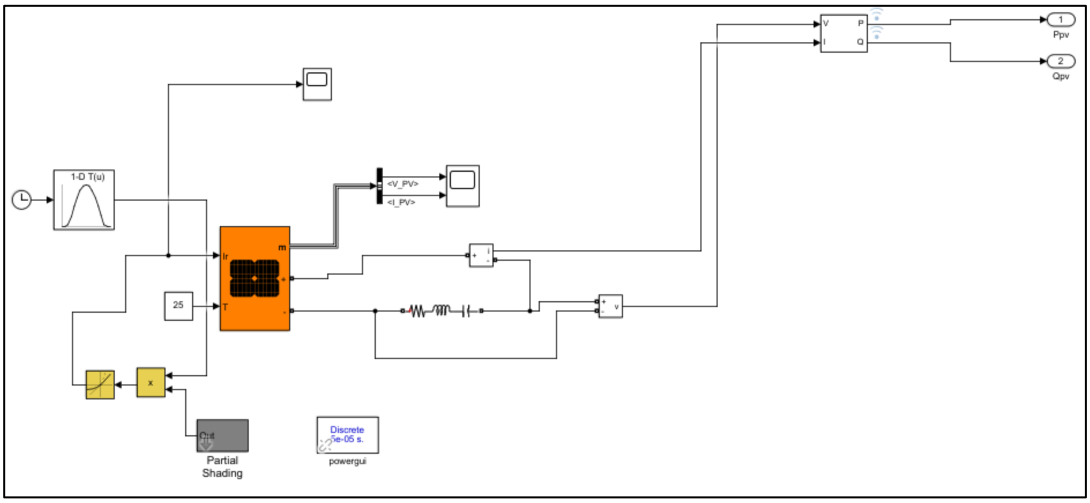


Figure.III.26. PV Simulink model

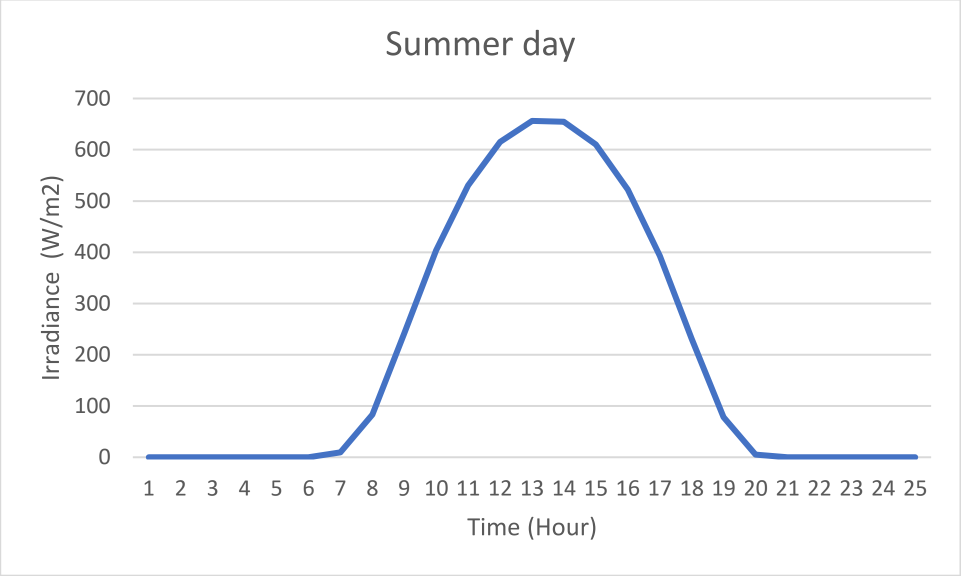


Figure III.27. Summer day irradiance

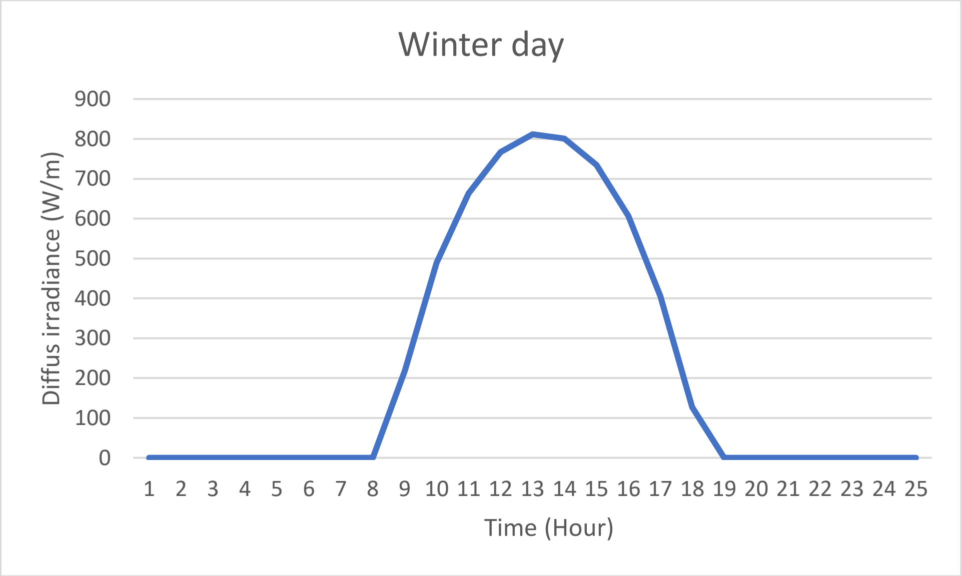


Figure III.28. Winter day irradiance

We can clearly see that the two curves have the same allure, but in summer day there is about two supplementary hours of sunshine.

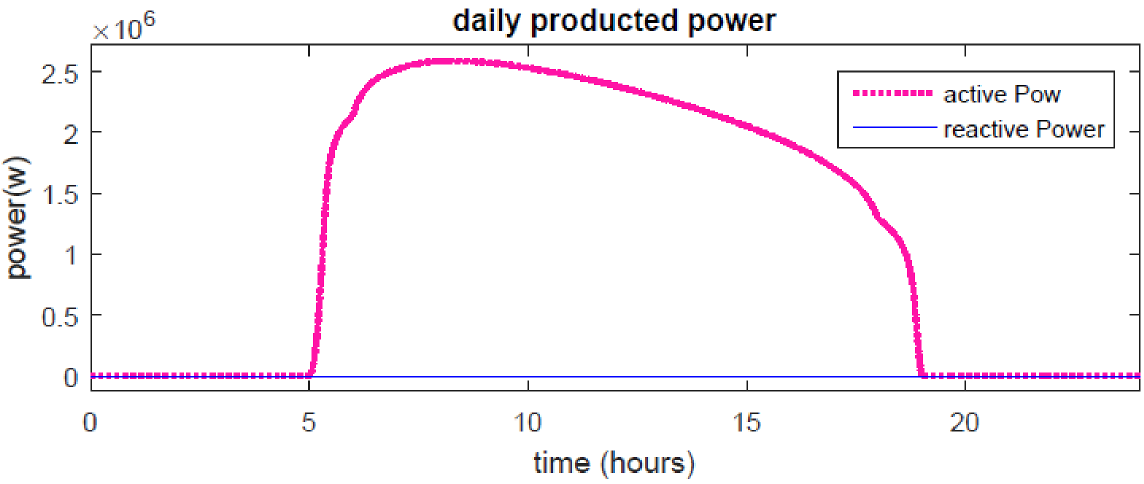


Figure III.29. Diagram of daily produced power

This curve shows us the daily power produced and it follows exactly the precedent allure of daily.

II.4. P and Q calculation

The values of active and reactive power use the information of instantaneous values of line to line voltages and line currents. The equations are shown as follow:

$$p_{m_u} = V_{bc^{ic}} - V_{ab}ia \tag{III.2}$$

$$Qmes = \frac{V_{bc}(2ia+ib)+V_{ca}(2ib+ia)}{\sqrt{3}} \tag{III.3}$$

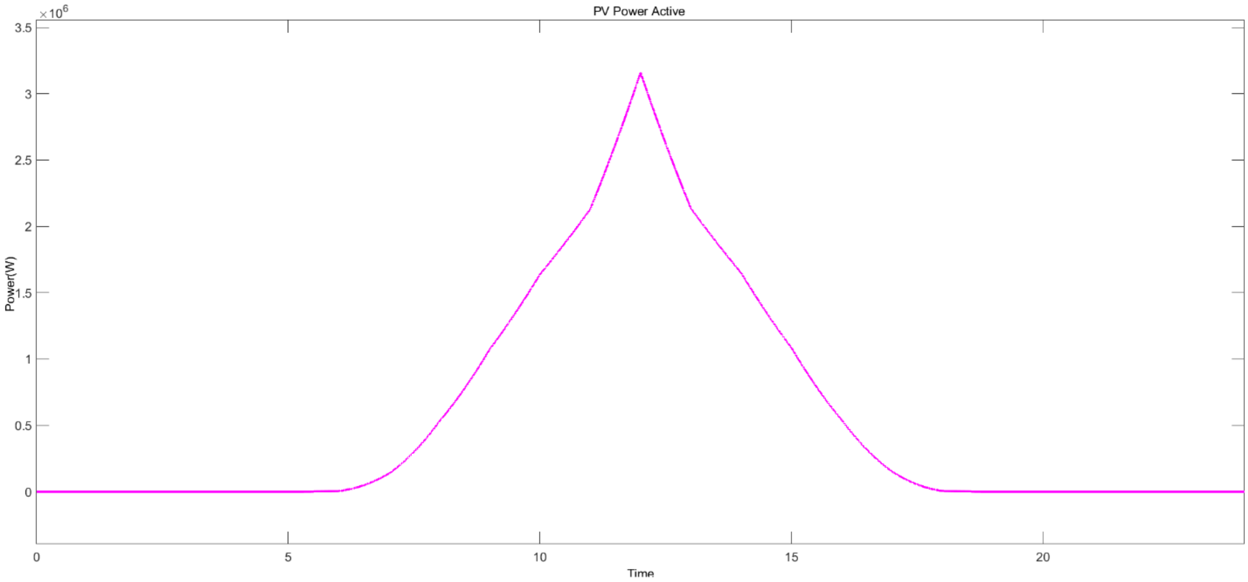


Figure III.30. PV active power

This curve shows the PV active power which has the maximum point at 13h and starts to decrease after that hour.

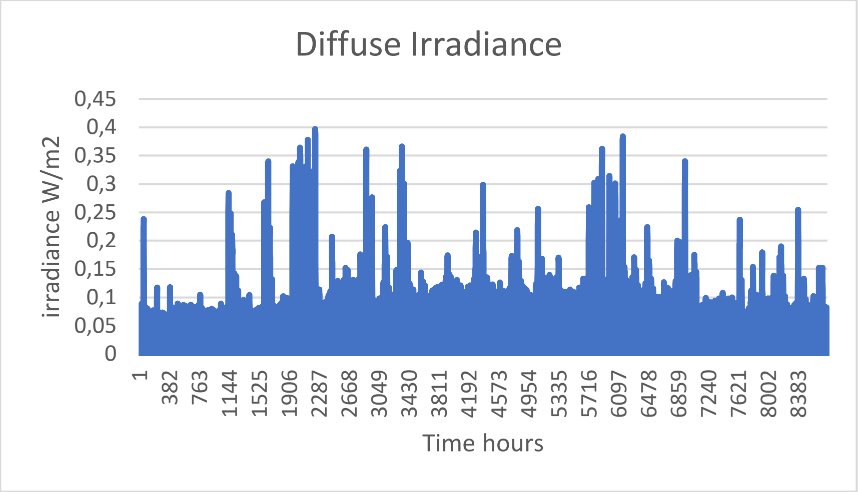


Figure III.31. Solar Irradiance Diagram

We notice that there are lot of maximums in irradiance values according to the data: 0.4w/m which is a very interesting value for PV operation.

III. Wind turbine modeling

III.1. Wind Speed

We have obtained the curve bellow: (Figure Figure III.32.) from Adrar meteorological data, the Wind turbine model used there is GAMESA.

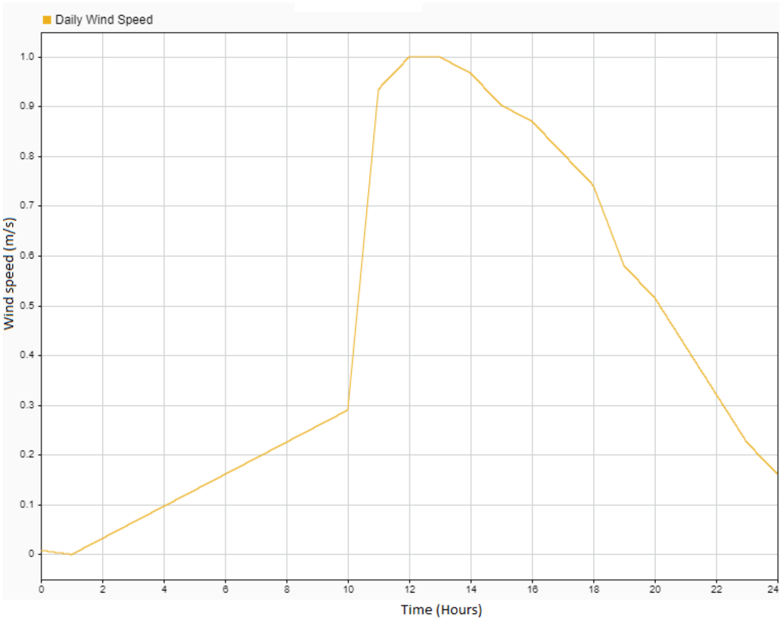


Figure III.33. Daily Wind speed

III.2. Wind Turbine simulation

The mechanical power of the wind turbine is given by:

$$P_{wind} = \frac{1}{2}.\,\rho.\,S_t.C_P(\lambda,\,\beta).V^3 \qquad \text{(III.4)}$$

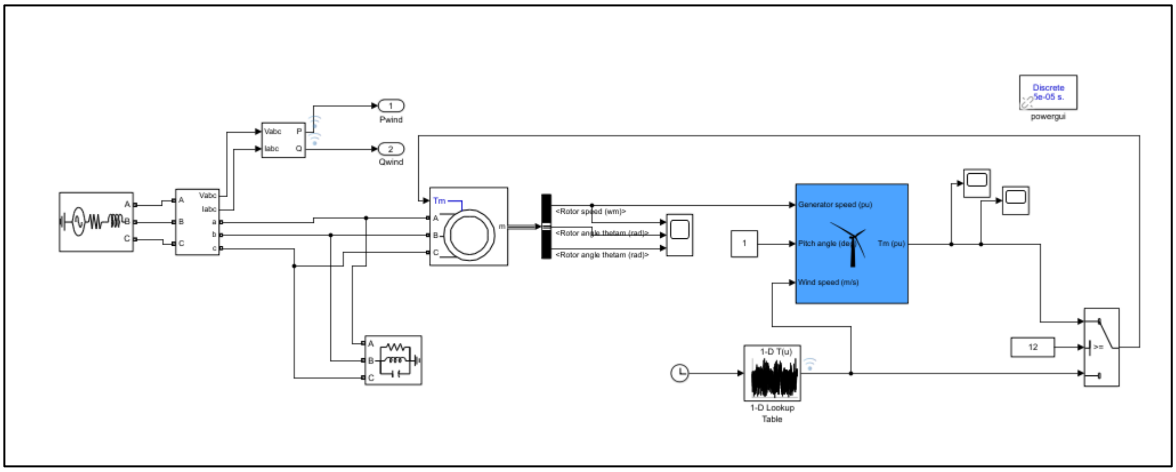


Figure III.34. Wind turbine model

III.3. Permanent Magnet Synchronous Generator

Permanent magnet synchronous generators (PMSG's) are typically used in small wind turbines for several reasons including high efficiency, gearless, simple control...

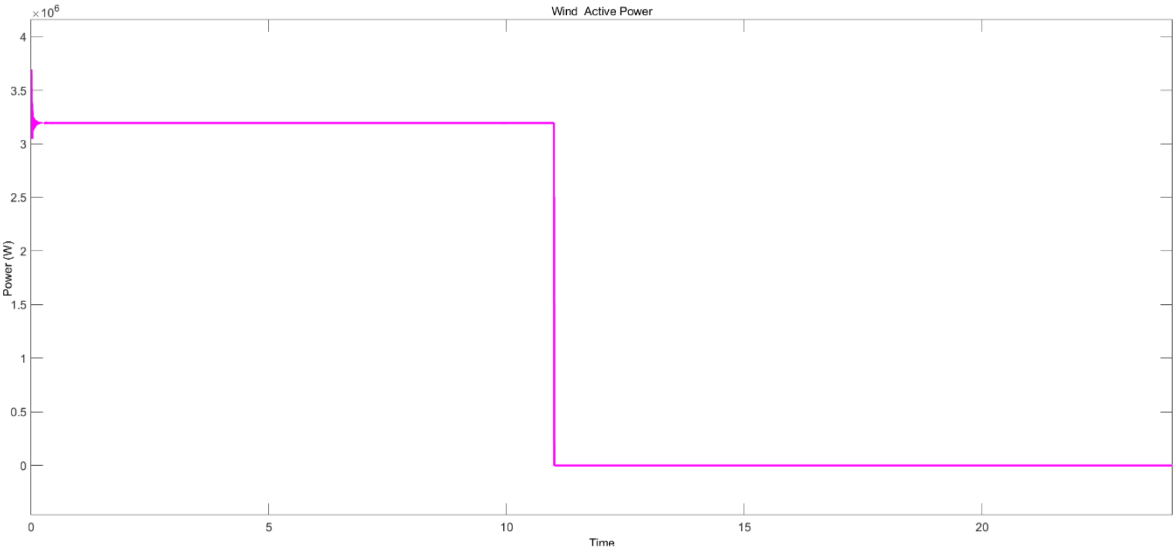
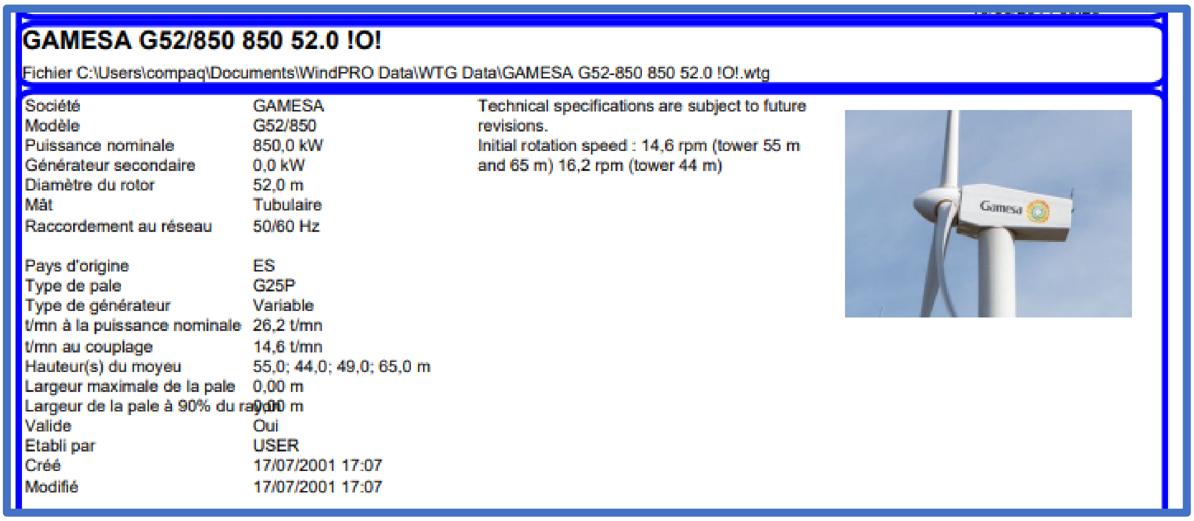


Figure III.35. Wind power



GAMESA G52/850 850 52.0 !O!

Fichier C:\Users\compaq\Documents\WindPRO Data\WTG Data\GAMESA G52-850 850 52.0 !O!.wtg

Société	GAMESA
Modèle	G52/850
Puissance nominale	850,0 kW
Générateur secondaire	0,0 kW
Diamètre du rotor	52,0 m
Mât	Tubulaire
Raccordement au réseau	50/60 Hz
Pays d'origine	ES
Type de pale	G25P
Type de générateur	Variable
t/mn à la puissance nominale	26,2 t/mn
t/mn au couplage	14,6 t/mn
Hauteur(s) du moyeu	55,0; 44,0; 49,0; 65,0 m
Largeur maximale de la pale	0,00 m
Largeur de la pale à 90% du rayon	0,00 m
Valide	Oui
Etabli par	USER
Créé	17/07/2001 17:07
Modifié	17/07/2001 17:07

Technical specifications are subject to future revisions.
Initial rotation speed : 14,6 rpm (tower 55 m and 65 m) 16,2 rpm (tower 44 m)

Figure III.36. Wind turbine characteristics

IV. Electrochemical storage Modeling

In this work, electrochemical storage is used. Therefore, in this part the modeling of these storage units will be presented the model is presented corresponding to this type of battery.

IV.3.1 Battery

IV.3.1.A. Battery Parameters

- *Voltage*

The batteries voltage is expressed as a function of the SOC; thus, it has been considered as linear function. For the battery bank modelling, Thevenin's equivalent circuit of the battery has been used.

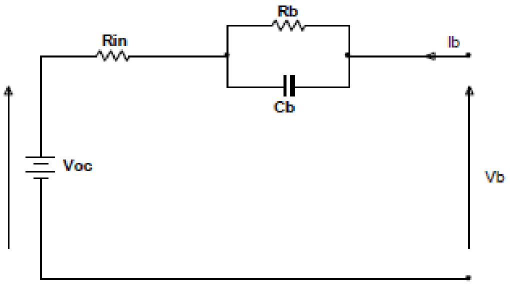


Figure III.37. Thevenin's equivalent circuit of the battery

The BESS are charged /discharged depending on the operation strategy. Whenever the total power of PV and diesel exceeds the load demand, the BESS will be charged. On the other hand, if the available production is less than consumption, the BESS will discharge to cover the deficit. The state of charge is given by the equation:

$$SOC(t)= C(t)/Cref \qquad (III.6)$$

where C(t) and Cref: the BESS capacity at time t and the reference capacity, respectively.

The state of charge SOC(t) is estimated by the previous value SOC(t-1) and the rejected /absorbed power during the time from t-Δt to t. The state of charge at hour t can be calculated by the following equation:

$$SOC\,(t) =SOC\,(t-1) + PPV\,(t) + Pgrid\,(t) - PL\,(t)\ \ Cref\,.\Delta t \qquad (III.7)$$

Δt: is a unit time interval: $\Delta t = 1$ (1 hour) Cref: is BESS capacity (kWh) In the previous equation, the SOC related constraint is expressed as follows:

$$SOCmin \leq SOC(t) \leq SOCmax \qquad (III.8)$$

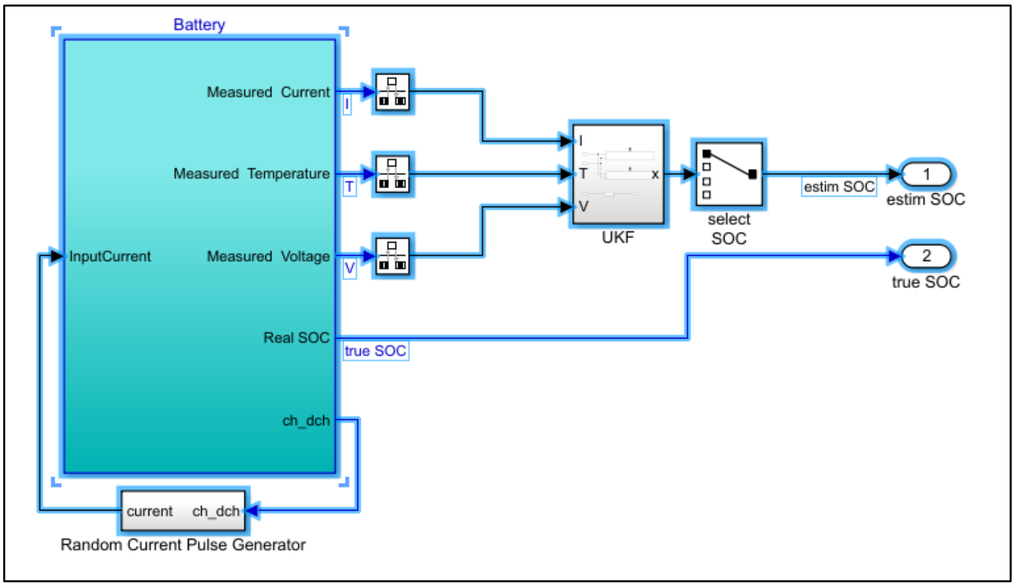


Figure III.38. Battery model

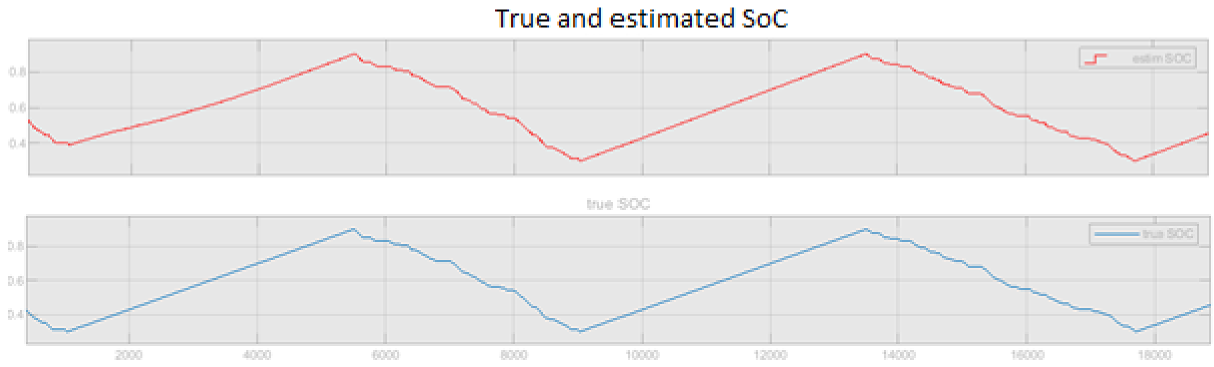


Figure III.39. True and estimated SOC

There are typically little differences between the two curves

V. Diesel generator Modeling

A diesel generator (DER) includes of an internal combustion (IC) engine coupled to a synchronous generator. The schematic diagram of DG is shown in Figure III.8.

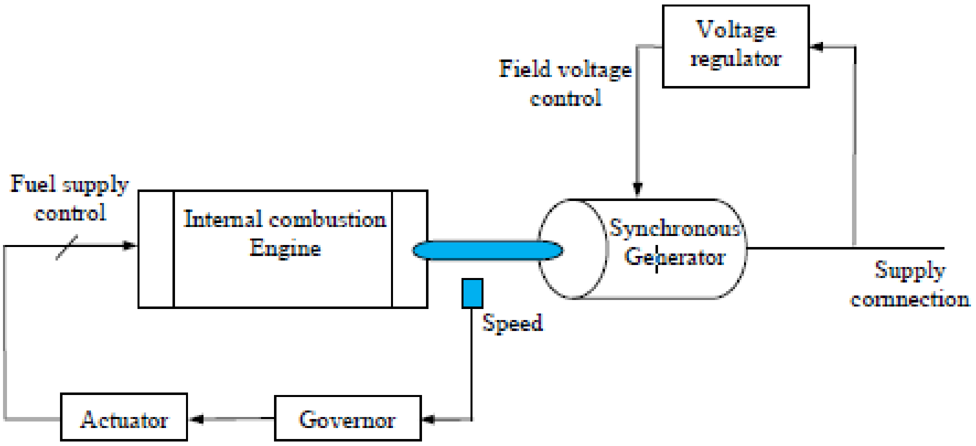


Figure III.40. The schematic diagram of the diesel genset

V.1. Diesel genset sizing

The diesel should be run at high load levels to maximize fuel efficiency and designed such that it meets the load reliability. Thus, the rated power of diesel generator (P_R) is limited between 0 and the maximum demand which a diesel has to cover. Therefore, the boundary of the diesel general sizing is given by:

$$0 \leq PR \leq PL\_peak \qquad \text{(III.9)}$$

where
P_R : The rated power of diesel generator
P_{L_peak}: The peak loads power.

When the diesel operates to cover the load, it will consume an amount of fuel which is calculated as follows

$$F(t) = (0.246.\ P_D(t) + 0.08415.\ P_R) \qquad \text{(III.10)}$$

where
F(t): the hourly fuel consumption (liter/hour)
$P_D(t)$: the diesel power at time t

From the last equation we can see that the fuel consumption of diesel generator is expressed as a function of the rated power and the generated power. Thus, the diesel generator should not be operated under its minimum value which is given by the manufacturer.

Therefore, the generated power of genset has to be bounded in range as follows

$$P_{Die\_min} \leq P_D(t) \leq P_{Die\_max} \qquad \text{(III.11)}$$

The constraint (III.10) means that the battery should not be charged or discharged when SOC is out of the limits

VI. State of the art of control and supervision strategies

Beyond its architecture and sizing, a low power system cut off from the grid cannot achieve its energy self-sufficiency objectives without good control and supervision strategies.

The first consists in controlling the behavior of different converters of the system to control the short operating point term; the second adapts the constraints of the first according to the state of charge of the units of storage, to protect components when one is empty or full. We will go around the strategies already studied in the literature for power systems to ensure their autonomy.

VII. Conclusion

In order to optimize the sizing and the controlling, the microgrid components are modeled and simulated with MATLAB/ Simulink for different investigation purposes.

Furthermore, each model has been tested and assessed through simulation results. For an optimal operation we will achieve a control system based on Python in order to give the priority to the renewable energies for powering the charge.

CHAPTER IV

Management of the Microgrid

SUMMARY

CHAPTER IV: Management of the Microgrid …..……………………………………… 70

I. Introduction

To properly integrate microgrid into ~~our~~ a current electrical networks and allow them to deliver their full potential, one essential element must be taken into account and mastered: Data Management.

Data management is indeed the key to the proper use of the information generated by the systems contained in the grid for a harmonious synchronization of the various stakeholders, their components and their interactions.

We will therefore discuss, microgrids and related technologies, their deployment on the different parts of the network, the solutions to the challenges of the energy sector and finally the management applications.

This chapter presents an energy management strategy for energy storage battery in a standalone hybrid power system using Adrar data. The MG consists of PV generator, wind turbine, storage battery and diesel generator. The PV and Wind are the primary power sources of the system, and a battery bank and diesel engine are used as backup systems.

An overall energy management strategy is designed for the system to manage power flows among the different energy sources and the storage unit in the system. A simulation model for the hybrid energy system has been developed using MATLAB/Simulink. The Wind and solar energy data are based on Adrar city. Simulation studies have been carried out to verify the system performance under different load scenarios using a practical load profile.

II. Adrar area characteristics:

Adrar is the administrative capital of Adrar Province, the second largest province in Algeria.The commune is sited around an oasis in the Touat region of the Sahara Desert.Adrar has a hot desert climate , with long, hot summers and short, warm winters, and averages just 15 millimetres (0.59 in) of rainfall per year. Summer temperatures are consistently high as they commonly approach 40 °C (106 °F). temperatures at night are still hot at around 27 °C (81 °F). Even in early May or in late September, daytime temperatures can rise to 45 °C (113 °F).

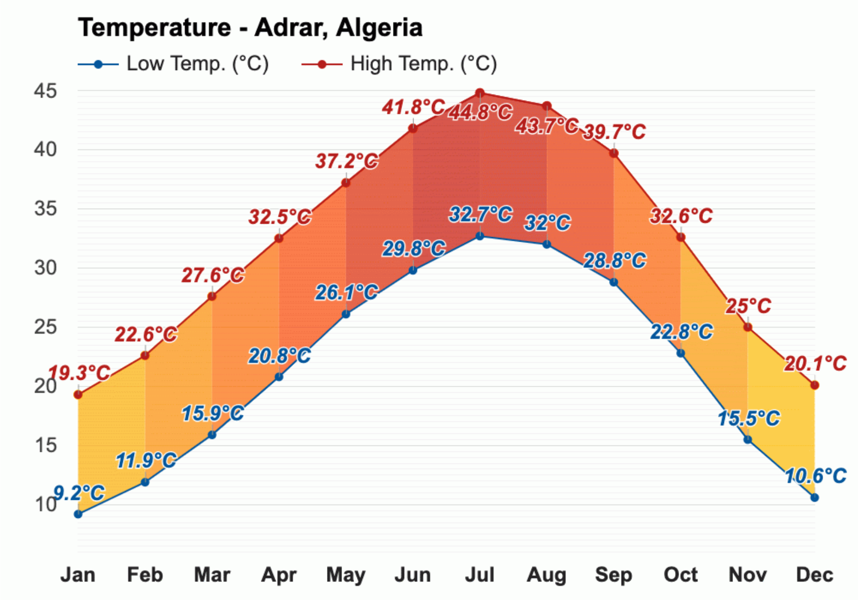


Figure IV.41. ADRAR temperature

Adrar experiences the same kind of desert heat as Death Valley, California during summertime. Winter nights can be chilly and frost is by no means unknown but the days are pleasantly warm, sunny and dry. During the summer, the Sahara region of Algeria is the source of a scorching, sometimes dusty and southerly wind called the Sirocco. These winds parch the plateaus of northern Algeria up to 40 days and reach the Tell coastal region for as many as 20 days.(Wikipedia, n.d.)

III. Energy Management System

Energy Management System (EMS) widely refers to a computer system which is designed specifically for the automated control and monitoring of electric power and utility system. The scope may span from a load dispatch center to a group of power networks. Most of these energy management systems also provide decision making facilities for operator in the operation and control in real time. The data obtained from such actions are used to train operators in a control center and for performing engineering studies for futuristic actions like planning, optimization and maintenance scheduling, etc. on a frequent basis and to produce trend analysis and annual consumption forecasts.

Energy Management System (EMS) is a collection of computerized tools used to monitor, control, and optimize the performance of generation and transmission systems. This intelligent energy management software control system is designed to reduce energy consumption, improve the utilization of the system, increase reliability, and predict electrical system performance as well as optimize energy usage to reduce cost.

Energy Management System applications use real time data such as frequency, actual generation, tie-line load flows, and plant units' controller status to provide system changes. Energy Management System had its origin in the need for electric utility companies to operate their generators as economically as possible.

Operation of the system as economically as possible required that the characteristics of all generating units be available in one location so that the most efficient units could be dispatched properly along with the less efficient. In addition, there was a requirement that the on/off scheduling of generating units be done in an efficient manner as well. Energy management systems can also provide metering, sub metering, and monitoring functions that allow facility and building managers to gather data and insight that allows them to make more informed decisions about energy activities across their sites.

The conventional power network comprises large generating stations with extra high voltage links, which connect transmission substations with distribution system for delivering power to end users. Therefore, the basic concept in traditional power system is the central controlling with unidirectional energy flow for transmitting power to load centers.

V. How to Effectively Manage a Microgrid?

The main concern with managing the operations of a microgrid is its relationship with the main grid. This relationship depends on the demand that is put on such microgrids. The extent to which a microgrid will be dependent on the main grid is decided by the load requirements and its size and scale.

The microgrid connects with the main grid at a point where an equal voltage is maintained between the two coupling points. A switch is placed at the coupling point which can automatically or manually separate the microgrid from the main grid. Microgrids are not only an emergency measure but also cut costs by using local resources which may be too small for traditional grid use. figure

VI. The Layered Structure of Managing Microgrids

Microgrids are especially difficult to manage when they operate in their "island mode" disconnected from the main grid. Hence, grid operators must have real-time insight into the load demands generated and the various distributed energy resources (also known as DER). Some of the various types of DER are controllable loads, load shedding and other forms of distribution management.

Better management of microgrids involves the use of a layered structured where each component within the layer belongs to a layer or system which can exhibit control and timescale in its domain. Such “advanced distribution management systems” (ADMS) consist of the following layers.

- DMS or the distribution management system which is primarily responsible for detecting faults and voltage fluctuations within the grid.
- SCADA or supervisory control and data acquisition, which takes care of alarm generation, managing events, and various positions.

- Outage management systems, which handles major power outages and customer demands.
- Energy management systems, responsible for monitoring the cost of demand the relationship between the grid and the market.

- Demand side management systems, for predicting and managing fluctuations and peaks in demands.

Utilizing such a layered structure, ADMS gains the capability to monitor grid activities in real-time and conduct an analysis. DMS combined with the SCADA systems manages the various energy shortages in the grid along with remote fault identification and isolation.

Utilizing such ADMS models, grid operators can easily handle the fluctuations in demand and faults in such microgrids through automated control systems. Such a layered approach leads to better optimization of grid resources and increased independence from microgrids.

Microgrids today are increasingly gaining popularity due its energy-conserving and cost-effective nature. The main advantage lies in their ability to work in the island mentioned above mode which allows them to retain functionality even when the main grid goes down. While microgrids have numerous advantages, there are certain challenges in its way. One of the main hurdles that lie in the widespread use of microgrids is the inability of traditional microgrids to couple with them efficiently. However, most of the progressive policies that are made today support the use of Microgrid.

VII. A feasibility assessment

A feasibility assessment for microgrid projects should include all aspects of historical energy use/cost analysis, individual project identification, physical site/facilities due diligence, and projected financial and environmental benefits for projects meeting energy cost savings goals and resiliency objectives for critical loads. In this article we will focus on facility-level microgrids configured with onsite solar PV generation and battery energy storage systems (also standalone battery storage systems where solar PV is not viable, and the addition of battery storage to existing onsite solar PV projects). A comprehensive feasibility assessment consists of four phases:

1. **Data Collection** (including incentives eligibility evaluation, initial analysis, site audits)
2. **Systems Sizing Analysis** (including project cost estimates and financial projections)
3. **Financial Analysis** (including cost/benefit analysis, financing options, and development of cash flow pro forms)
4. **Review of Findings** (including a discussion of next steps)

VI.1. Data Collection

The first step in pursuing a technical & financial feasibility assessment for microgrid implementation is the data collection process. The objective for this phase is to gather all relevant historical energy use/cost data and site-specific conditions and electrical infrastructure information necessary to initiate a detailed analysis of operations profiles (demand profile and electricity consumption/billing analysis), and an evaluation of physical site conditions and interconnection complexity.

Relevant data for solar PV & battery storage typically includes:

- **Electricity Use and Billing Data** for all Utility accounts/sites to be evaluated, including
    - 15-minute interval meter data, minimum 12 months of sequential data
    - Electricity bills
    - Rate tarifs
    - CCA, direct access, and demand response program participation details as applicable

- **Data Regarding Existing On-site Generation Resources** such as solar PV systems or wind turbines, including:
    - Historical performance data (minimum 12 months of sequential 15-minute or hourly interval data)
    - As-built design drawings and single line diagrams
    - Project installation agreements or power purchase agreements
- **Site-specific information** including: site plans, facilities drawings, parcel maps, as-built electrical designs and single line diagrams, as-built architectural and roof structure designs, underground utilities diagrams, documented easements, civil engineering and geotechnical reports and/or soils tests if relevant; and as applicable/available: survey data and title reports, FEMA/ACOE flood zone maps and wind zone maps
- **Inventive Eligibility** information
- **Current Market Data** for Solar PV, battery systems, and microgrid equipment and installation costs, O&M and asset management costs, financing methods, PPA rates & terms, and solar Renewable Energy Certificate values
- **Project Permitting** requirements.

VI.2. System Sizing

The next step in the feasibility process is to use the historical energy data and site conditions due diligence gathered in the data collection phase to determine proper system(s) sizing (capacity) for the identified projects), estimate economic benefits including eligibility for available incentives, and estimate implementation costs (total project costs). This process typically follows the following progression:

1. Use site audit data to inform updates to solar PV system sizing (kW) estimates, generate solar array location plans and initial layouts for each site.
2. Confirm PV system type, capacity, and projected energy production.
3. Determine optimal battery system sizing based on demand management and energy arbitrage opportunities.
4. Evaluate existing on-site, solar PV systems to determine the scope and cost of any necessary upgrades that may be triggered by adding battery storage to the existing interconnection.

VI.3. Financial Analysis

The third phase of the feasibility assessment process uses the project cost estimates, projected savings benefits, and projected revenues (as applicable) to create detailed cash flow savings proformas and cost/benefit reporting for all of the scenarios evaluated. It also includes detailed comparisons of differing financing methods that can facilitate financial decision making, and projections of resiliency benefits (load coverages and backup power durations).

VI.4. Review of Findings

The final phase of the feasibility assessment is a review of the analyses and due diligence performed during the study, the results of the financial analyses, and conclusions regarding results. This review should include a discussion of “next steps” that may include administering a solicitation, negotiating project contracts, overseeing final systems design/engineering, construction management, project commissioning, and ongoing asset management.

VIII. Collect of Data

Table IV.6. Different data and there configuration

DATA	PROVENANCE ‘’Sources’’	COLLECT SYSTEM	FREQUENCE	SIZE ‘koct’
Wind turbine	Wind	Anemometer, weather station,	1h	26280
Battery energy storage	Overload	Overload	2h	4380
Generator condition	Fuel	Fuel condition	2h	4380
Temperature	/	Thermometer, humidity sensors, temperature monitoring, Hvac, weather station, meteorology, temperature sensors	24h	730
Consummation	Wind power and PV power	Counter	1h	26280
Solar irradiation	Solar	Cell	1h	26280
Wind power	Wind farm	Smart Captor Weather station	1h	35040
PV power	Solar energy	Smart Captor	1h	35040

IX. Energy Manager

The Energy Manager optimizes system operation using information on local electrical and heat needs, power quality requirements, wholesale/retail service needs, special grid needs, demand- side management requests, congestion levels, etc. to determine the amount of power that the Microgrid should draw from the distribution system. Some key Energy Manager functions are to:

- Provide the individual power and voltage set point for each power flow/micro source controller;
- Ensure that heat and electrical loads are met;
- Ensure that the Microgrid satisfies operational contracts with the transmission system;
- Minimize emissions and system losses;
- Maximize the operational efficiency of the micro sources;
- Provide logic and control for islanding and reconnecting the Microgrid during events.

X. Microgrid Energy management system

The International Electrotechnical Commission in the standard IEC 61970, related to EMS application program interface in power systems management, defines an EMS as "a computer system comprising a software platform providing basic support services and a set of applications providing the functionality needed for the effective operation of electrical generation and transmission facilities so as to assure adequate security of energy supply at minimum cost".

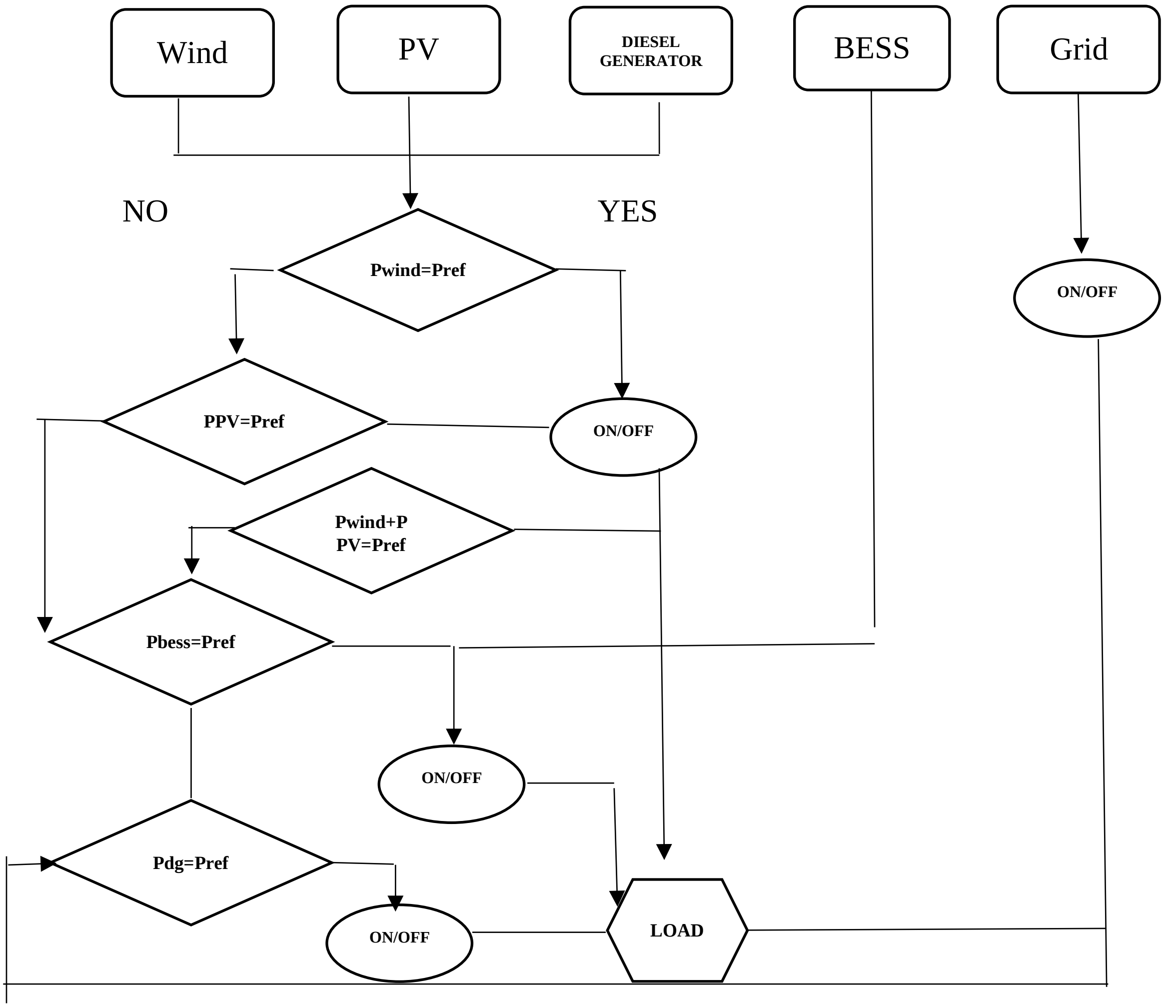
An MG EMS, also having these same features, usually consists of modules to perform decision making strategies. Modules of DERs/load forecasting, Human Machine Interfaces (HMI), and supervisory, control and data acquisition (SCADA) among others ensure the efficient implementation of EMS decision making strategies by sending optimal decisions to each generation, storage, and load units.

An MG EMS performs variety of functions as monitoring, analyzing, and for casting of power generation of DERs, load consumption, energy market prices, ancillary market prices, and meteorological factors. These functions help EMS in optimizing MG operation, while satisfying the technical constraints. The supervisory control architecture of MG EMS can be divided into two types, namely, centralized and decentralized EMSs. In centralized EMS, the central controller accumulates all the information such as power generation of DERs, cost-function, meteorological data, and energy consumption pattern of each consumer, etc.

Then centralized EMS determines the optimal energy scheduling of MG and sends these decisions to all LCs. However, in decentralized EMS architecture, the MGCC sends and receives all the information to LCs in real-time. Each LC proposes a current and future demand or generation request to the MGCC. The MGCC determines the optimal scheduling and sends it back to the LC.

XI. Simulation and discussion

In this chapter we are going to explain our entire study which is the 3MW microgrid management real application in ADRAR. This project is mainly made for data management in a micro grid by using MATLAB Simulink and Python in order to recommend data.



To the right = YES

To the left = NO

From this organigram, we can clearly see the main objective of the microgrid management also the different option that can follow by comparing PV, wind and battery power to decide which power is the greatest so that the MG use it.

We have fourprincipals' powers: Ref power, PV power, Wind power and Battery power

The comparison of these powers aims to take the best value to operate the micro grid and not use the main grid in need only. If the PV, Wind and battery power are not sufficient the diesel generator take the action.

In this methodology, the wind, PV, BESS and a diesel generator are used to keep a continuous power to meet the power required by load in MGS.

- Case1: Renewable energy source has the highest priority to supply the load demand. The excess energy is utilized to charge the BESS.
- Case 2: PV & wind energy is not sufficient to meet the power required by load, hence BESS as well as renewable energy sources are turned on.
- Case 3: BESS, PV and wind energy are not enough to meet the power required by load, then the diesel generator has turned on to supply power to the load and charge the BESS.
- Case 4: PV and/or wind energy is more than the power required by load and BESS; the surplus energy is distributed to dump loads

XII. Python contribution in OurWork:

We used Python programming language in order to process the data and calculated the results.After collecting the data, we have processed and sorted it with python, then it was compared and processed again.

The generated python data was transferred to Simulink in MATLAB to run the simulations.

Note that we have managed to link python and Simulink directly.

a. Preparation/pre-processing of data

In this step we used python to process the wind data. We started by reading the dataset file (ninja_wind_27.6699_0.8389_corrected.csv), then we read to third column corresponding to the wind speed, our algorithm calculates the power (**puissance**) using the following formula.

$$Power = 216.62 * \ speed^3 \qquad \text{(VI.1)}$$

The results are saved in a new csv file used in step 2.

XI.b. Data comparison

In this Python program, we start first by reading the two input data files (power_wind.csv and power_pv.csv) and then extracting the data according to a pre-defined format. Furthermore, we have created an empty new file to write the output results called ‘*results.csv’*. The file has four columns: 'Wind', 'PV', 'Diesel generator', ‘Bess’, and it is calculated as follow:

We parse the two input files line per line using a “*while*” loop.

- For each line we check if the input data from the two files corresponds to the same date/time, then we extract the values pv and wind from pv.csv and wind.csv respectively:
- When **Wind is equal to 3MW**, the results are:

Wind	**PV**	**Diesel Generator**	**Bess**
1	0	0	0

- Otherwise (**Wind is not equal to 3MW**),
    - If PV **is equal to 3MW**, the resultsare:

Wind	**PV**	**Diesel Generator**	**Bess**
0	1	0	1

    - If (**Wind+PV) is equal to 3MW,** the results are:

Wind	**PV**	**Diesel Generator**	**Bess**
1	1	0	0

    - Otherwise (If none of the above)

Wind	**PV**	**Diesel Generator**	**Bess**
0	0	1	1

XIII. Microgrid management results

After achieving the model with the new command, we have obtained the following results

Figure VI.2 shows the simulation after command with the breaker which command

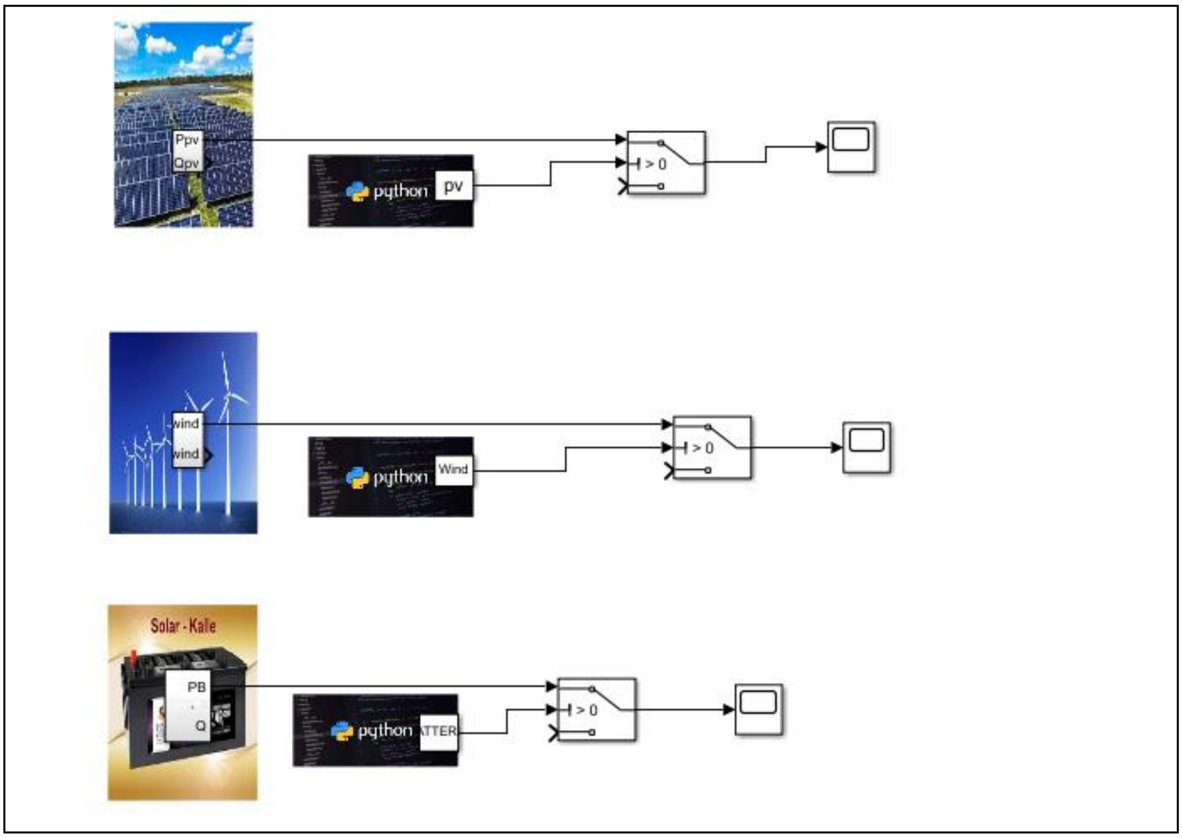


Figure IV.42. Simulation after command

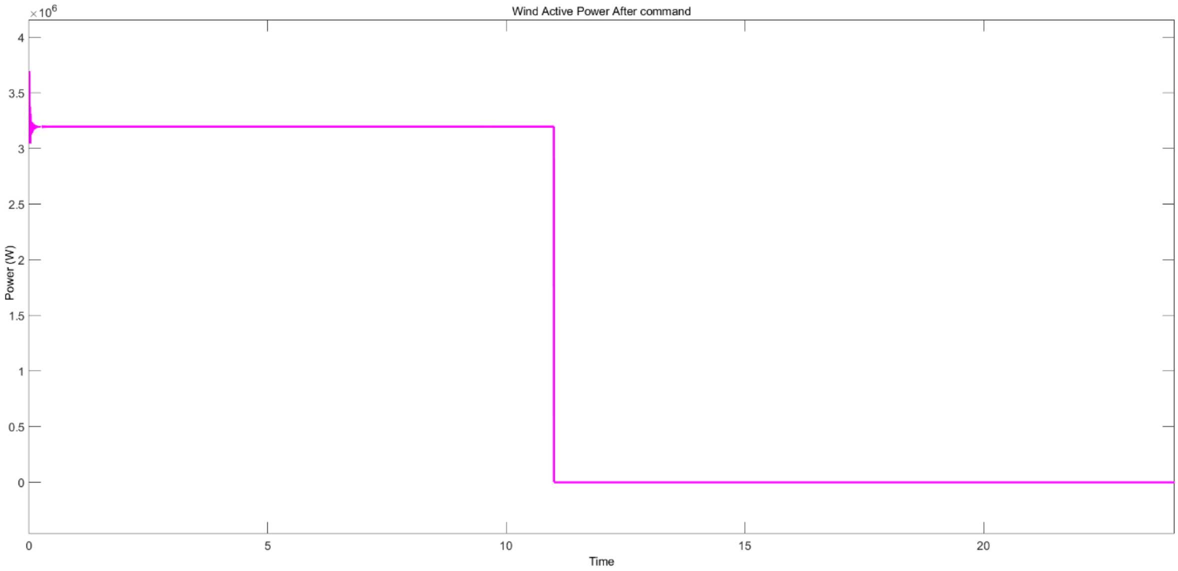


Figure IV.43.WIND active power

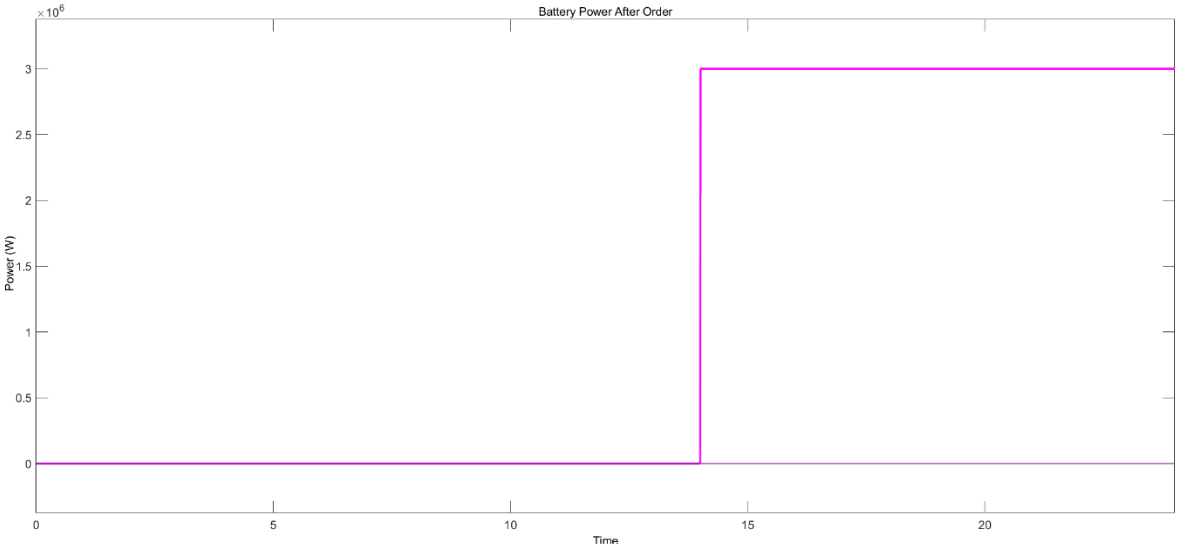


Figure IV.44. Battery Active Power after command

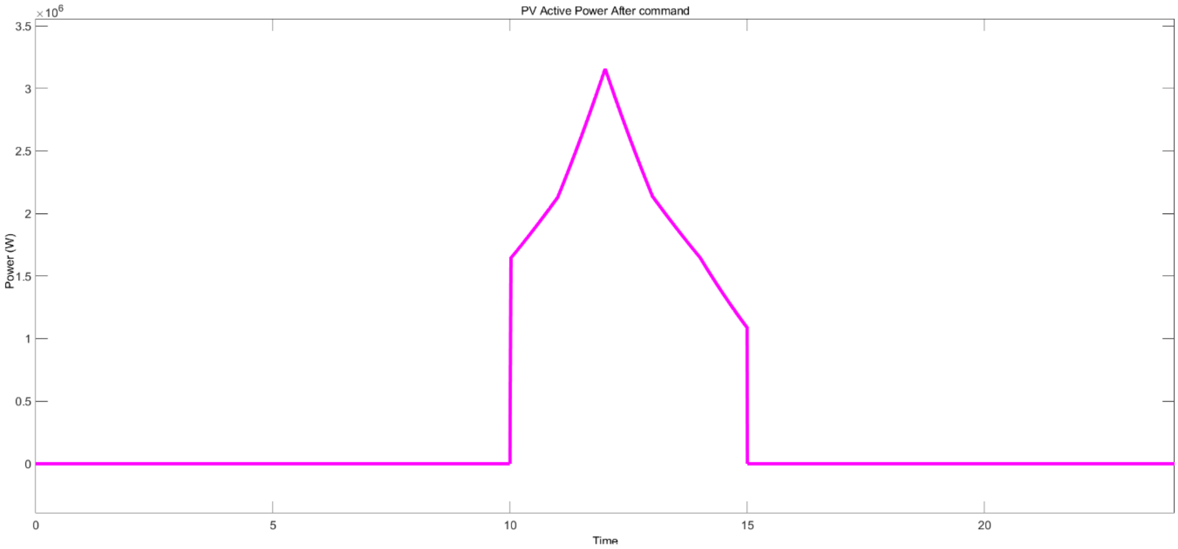


Figure IV.45.PVActive Power after command

Discussion

Bu using a management program for a test day (24hour), we can see in the curves obtained that the load is continusely powered by at least one of the MG source.

From 0h to 11h am, wind energy lead the sources and powered the load

From 11h am to 15h pm, PV pannals have the priority, when the wind power charge the battery.

From 15h pm…………

This mean that the objective of self- powered system is achieved

XIV. Conclusion

In this chapter, energy management of microgrid connected to the main Grid was presented, we have achieved our work objective which was managing data in this system

In this work we were able to answer our problem concerning the management of microgrid.

Conclusion and perspectives

In this work, a control approach for a MG system is introduced, which aims to supply, in an optimal way, the power demands. The introduced platform as well as the effectiveness of the proposed control strategy in managing the power flows.

The future work aims to develop an optimal holistic control system, which includes multi-RESs, storage devices, and the electric grid to satisfy the power demand of our building's. Furthermore, the collected data will be used to develop predictive control strategies using real-time machine learning techniques.

Our work is a proposition of a microgrid in Adrar area with a suitable management with Python.

After achieving the modeling of each component on MATLAB-Simulink software, we have used for the management the intelligent software "Python" for data treatment, and optimization of using renewable energy.

The application area is on Adrar data, also all the devices used are from wind farm of "Kebertene" and PV farm of "Zaouiet Kounta".

Results obtained show the efficiency of the control and management method we have chose.

In perspective, we plan to make an optimization study and an economic evaluation of the project.

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