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A Dissertation Submitted in partial Fulfillment of the Requirements for the Degree of Master Energetic Physic and Renewable Energy

Smart Grid and Renewable Energy in Algeria

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In the name of ALLAH The Most Merciful Gracious ; all praise belongs to him for his continuous blessings upon me throughout my life . My faith in Him kept me strong in tough times and his guidance lead me from one success to another. Thank you Allah

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Sincere thanks to my lovely parents who have continuously encouraged me throughout the years of my studies; I hope you will proud of me .I am grateful to my family for the emotional and financial support they gave me during all this period. Their enduring love kept me going even when I questioned my own ability.

Thank You All For All.

I would like to thanks everyone who helps me through their consultation in my carrier in the university and I will not forget my best friends whom help me through their support , encouragement and their advices .

So … …Thank You All For All.

Dedication

No word can express my big gratitude to my lovely parents ,whom always encouraged me and pray for me to keep going in my study. I dedicate my dissertation for you because i hope that you will be proud of me .

Also My Brothers « AbedelMalek, Sidiali»

My Sisters « Fatima, Keltoum »

And all my family

My best friends and my colleagues without exception promotion energetic Physic 2017 .

MERIEM

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General Introduction

General Introduction

One of the basic challenges of the electrical system is being implemented in a real power demand which should be absolutely reliable. Historically this challenge led to a power system based on highly controllable supply to match a largely uncontrolled demand. However, global climate change and population growth in recent decades have generated an increasing demand for abundant, clean and sustainable electrical energy in the world [1].

Today, in most countries, the growing demand for energy means a very heavy weight on the electricity infrastructure already too old and fragile, for example In Algeria, conditions such as heat waves create electrical demand that the current fragile grid cannot support. Thus, the increasing complexity of the classical power grids, growing demand, requirements for greater reliability, safety, efficiency, environmental issues and sustainable energy, require the information and communication technologies. This leap toward a “smarter” grid is widely referred to as “smart grid (SG)” The basic concept of SG is to add monitoring, analysis, control, and communication capabilities to the existing power grids.

Algeria is endowed with various types of renewable energies, namely solar energy, wind energy, hydro energy and biomass energy [1], it also meets many conditions such as largest areas, wireless communication techniques (3G networks, GPR,…etc.), it has also competent researchers in this regard and ability to finance the smart technologies which are all necessary for smart grid system. So the solution for integration of a smart electricity network is proposed, using advanced technologies to monitor and manage the transmission of data information and electricity, which means a smart grid. This smart grid integration co-ordinate the roles of all domains to operate all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience and stability[2].

The master dissertation is composed of a collection of published journal and books with the conference papers besides internet websites those are introduced and referred in this dissertation.

In this work I will define the smart grid technology and I will mentioned the potential of Algeria in renewables sources of energy and the reasons those make Algeria need to improving its power system to smart grid. The body of the master dissertation is divided into the following chapters:

Chapter1: gives an overview of the potential of energy sector in Algerian renewable, besides the hydrocarbon energy and the demand response.

Chapter2: summarizes the structure of today's electric grid and its limits , also the current statue of Algerian electric grid.

Chapter 3: describes the smart grid and its components and give a vision about Algerian smart grid.

Chapter 4: represent the modeling and simulation of a simple model scaled of microgrid in order to show the behavior of their components.

Then i will finish with a general conclusion.

Chapter 1

1.1) Introduction

Energy and its resources are considered in nowadays among the main preoccupations of the whole world. The reality says that the world faces serious energy shortages and associated high energy prices during the coming decades. Oil, natural gas, coal, and nuclear power provide more than 88% of world energy needs; the other 12% is provided by various renewable energy sources. In this term the necessity is appeared to concentrate more and more on the renewable energies as the main alternative to the conventional energies [3].

Algeria is considered among the main actors in the world energy markets as a leading producer and exporter of natural gas and oil producers because of its reserves in the conventional energies. Algeria needs a new energy model that integrates other alternatives energy to fulfill the future needs. The choice of unconventional and Renewable energy in Algeria seems to be the most promising and feasible, because of its potential in renewable energy which is relatively big that may reduce its dependence on this kind of energies and exploit of renewable [3].

1.2) Non-Renewable Energy in Algeria

1.2.1) Oil sector

Algeria holds the third-largest amount of proved crude oil reserves in Africa, all of which are located onshore because there has been limited offshore exploration. According to Sonatrach, about two-thirds of Algerian territory remains largely underexplored or unexplored.

The country produced almost 1.8 million bbl/d of total petroleum and other liquids in 2013, which includes crude oil, condensate, natural gas plant liquids, and refinery processing gain. The largest and oldest oil field, Hassi Messaoud, contributed more than 40% of total crude oil production, which averaged 1.2 million bbl/d in 2013 (Figure 1.1).

Algeria produced an estimated average of 1.2 million bbl/d of crude oil in 2013, slightly lower than the previous year. Combined with almost 600,000 bbl/d of non-crude oil liquids, which are not included in its OPEC quota, Algeria's total oil production averaged almost 1.8 million bbl/din 2013.The vast majority (about 72%) of Algerian crude oil exports are sent to Europe. The United States was the single largest destination until 2013 when U.S. imports fell to29,000 bbl/d, or by more than 75%, compared with 2012 [4].

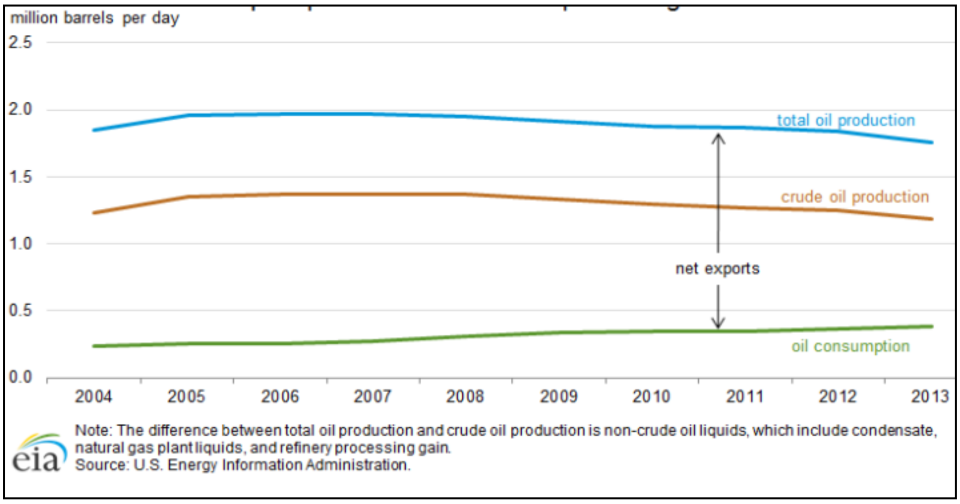


Figure 1.1: Petroleum and Other Liquids Production and Consumption in Algeria [4]

1.2.2) Natural Gas

Algeria holds the world's tenth-largest amount of proved natural gas reserves and the third-largest technically recoverable shale gas resources. In May 2014, Algeria's Council of Ministers gave formal approval to allow shale oil and gas development.

Algeria's gross natural gas production was 6.4 Tcf in 2012, a 4% decline from the previous year. Production has steadily declined over the past decade as output from the country's large, mature fields is depleting. There are several new projects planned to come online, but they have repeatedly been delayed. The figure1.2 shows the production and consumption of natural gas.

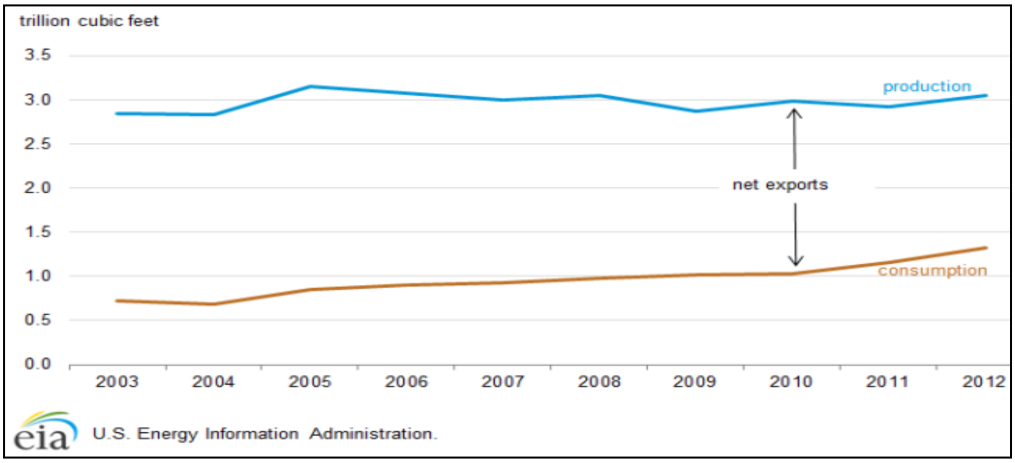


Figure1.2: Dry Natural Gas Production and Consumption in Algeria [4]

The country's gross production has been falling since its peak of 7.1 Tcf in 2008. The decline in 2012mainly reflects fewer volumes of natural gas used to improve oil recovery by reinjecting it into wells [4].

1.2.3) The Shale Gas

Algeria is the third largest national recoverable shale gas reserve after China and Argentina. Algeria’s hydrocarbon basins hold to significant shale gas, and shale oil formations, the Silurian tannaezuft shale and the Devonian fransian shale, provided the disposition of the organically rich marine source rocks in this basins. geochemical modeling indicates that these shales may have generated over 26.000 tcf of gas (including secondary cracking of generated oil), with some portion of this gas still retained in the shales. The present day total organic continent (toc) of the Silurian tannezuft shale ranges from 2% to 4%. However, the toc of the shale has been reduced by as much as half due to thermal maturation process. The present data toc of the upper Devonian fransian shale ranges more widely, from 1% to 8% westward acroos the region.

Algeria have seven shale gas basins : the Berkine Illizi basin in eastern of Algeria, the Ttimimoun, Ahnet and Mouydir basins in central, and Reggane and Tindouf basins in southwestern as it illustrated in the figure (1.3) [3].

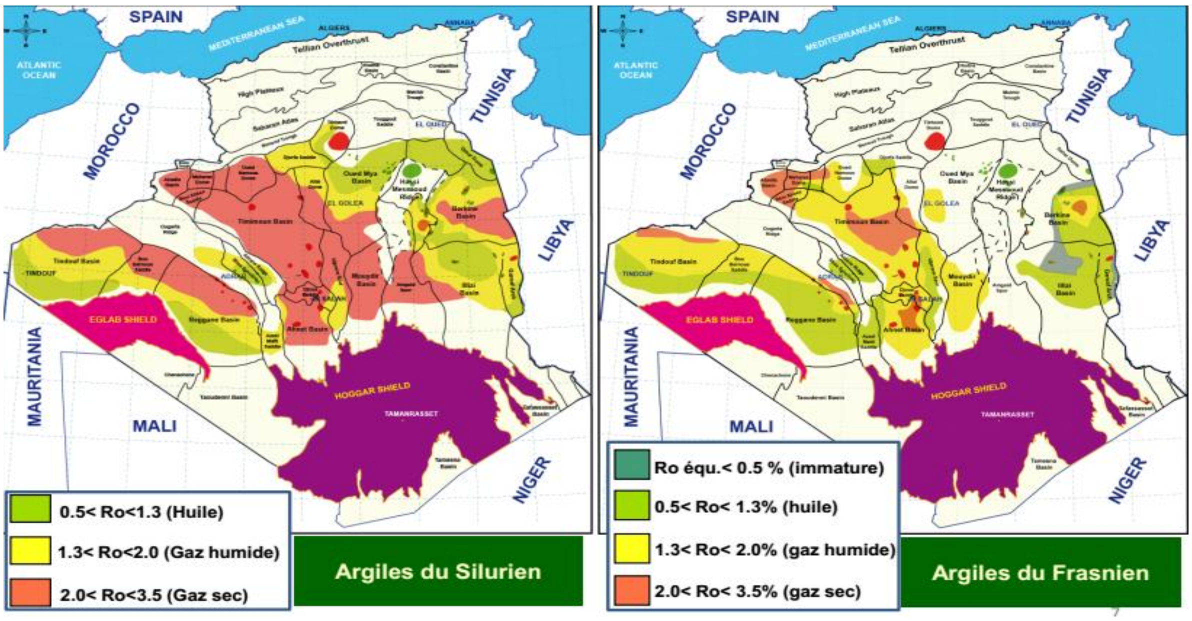


Figure 1.3: Maturity Maps Of Silurian and Fransian Hot Shales [5].

1.3) Renewable energies potentials in Algeria:

The interest for the development of renewable energies was perceived very early in Algeria with the creation of the solar energy institute as soon as 1962 (independence year). More than 2 million km^2 receive a yearly sunshine exposure equivalent to 2,500 kWh /m^2.

The government seeks to create a solar-gas synergy; taking advantage of the country's abundant resources in both energies. The figure1.4 shows the renewable energies in Algeria [6].

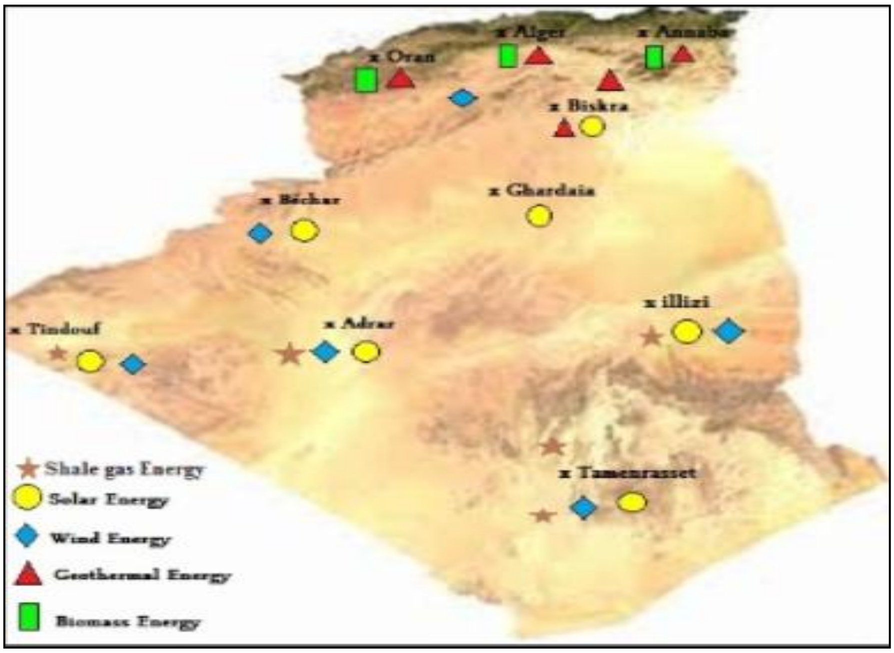


Figure 1.4 : Renewable Energies in Algeria [1]

The assessed economic potentials, by the German Space Centre (DLR), of renewable energy sources in Algeria are:

- **Thermal solar:** 169 440 TWh/year
- **Photovoltaic:** 13.9 TWh/year
- **Wind energy:** 35 TWh/year

Algeria is in urgent need of an adequate energy infrastructure so that it can achieve higher levels of economic development. This would allow all of its inhabitant's access to a quality energy supply, irrespective of their place of residence. Crucial objectives are targeted at substantially increasing and enhancing the contribution of renewable energies and favoring energy self-sufficiency. Pilot projects implemented in recent years justify the possibility to accelerate the use of indigenous energy resources, particularly for electricity supply. Algeria generated 25.8x109 KWh of electricity in 2002 and 30.06x109 KWh in 2005. The consumption of the country amounted to a value between 25 and 30 TWh/year. Conventional thermal sources of which natural gas accounted for 94.5%, contributed almost all of Algeria's electricity, supplemented by a small amount of hydroelectricity (5%) and solar photovoltaic/wind (0.5%).

Algeria has an important potential for power generation from renewable sources, for the domestic market as well as for export to the European market. The current share of renewables is not very significant in the total energy balance, but an ambitious development program was set up, with a specific law in 2004, including incentives for electricity production from renewable, and the creation of a support fund and a renewable energy institute (IAER: Institut Algérien des Energies Renouvelables). Through a March 2004 decree, the government also introduced incentives for electricity production from renewable energy plants, including a feed-in tariff [6].

1.3.1) solar energy

On account of its geographical location, Algeria holds one of the highest solar potentials in the world which is estimated at 13.9 TWh per year. The country receives annual sunshine exposure equivalent to 2,500 KWh/m^2. Daily solar energy potential varies from 4.66 kWh/m2 in the north to 7.26 kWh/m2 in the south[3].The insulation time over the quasi-totality of the national territory exceeds 2000 hours annually and may reach 3900 hours (high plains and Sahara). The daily obtained energy on a horizontal surface of 1m^2 is of 5 KWh over the major part of the national territory, or about 1700 KWh/ m^2 / year for the North and 2263 KWh /m^2/ year for the South of the country [6] such as it showed in the table 1.1 and figure1.5.

Table1. 1: Solar potential in Algeria [6]

Areas	Coastal area	High plateau	Sahara
Surface(%)	4	10	86
Average duration of sunning(Hours/ year)	265	3000	3500
Received average energy(KWh/m^2/year)	1700	1900	2650

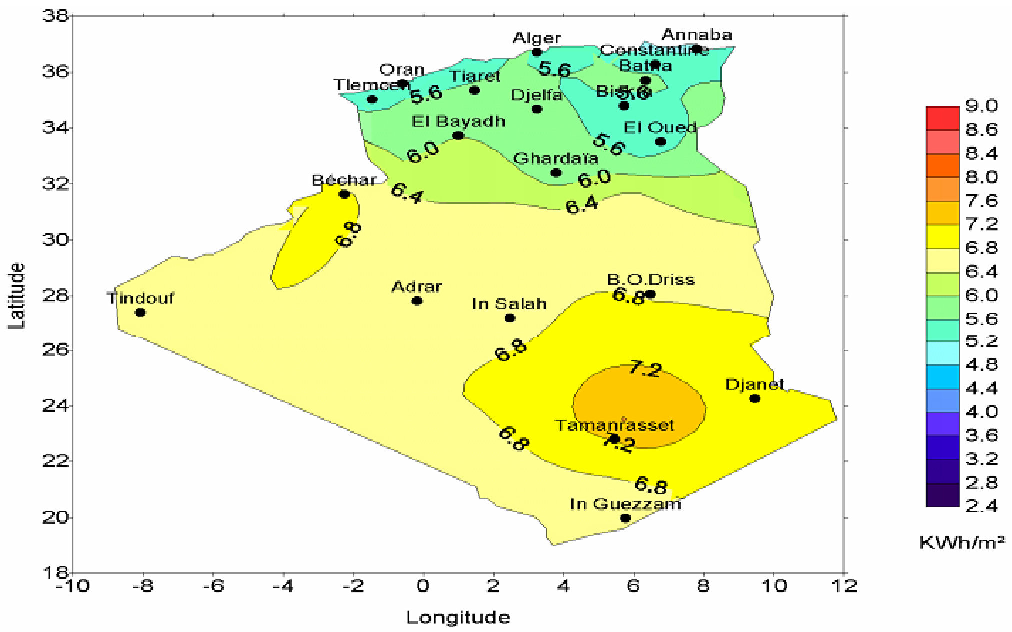
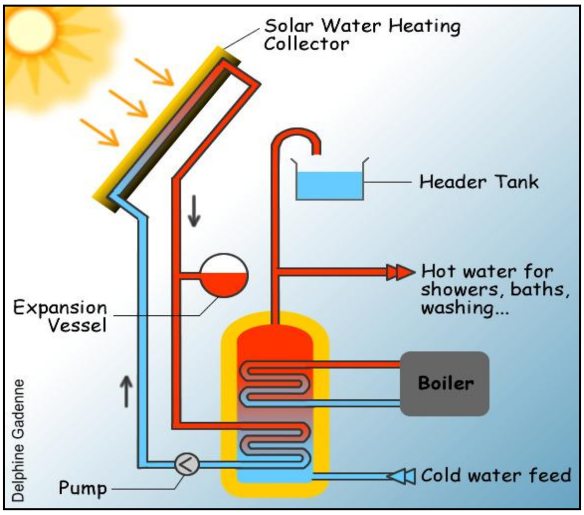


Figure 1.5: Solar Potential in Algeria [6]

The solar energy has two main technologies: solar thermal and photovoltaic (or PV). Solar thermal technology can provide both heat and electrical energy(Figure 1.6 1.7).About 169,440TWhr/year, which is equivalent to 5000 times the current energy usage in the country, may potentially be harnessed and used to support various applications. Solar energy potential in Algeria is the equivalent of 60 times the current electrical consumption of the European Union. For domestic use, Algerian houses can be fitted with solar thermal systems, exploiting solar radiation to heat water through flat plate collectors or evacuated tubes.



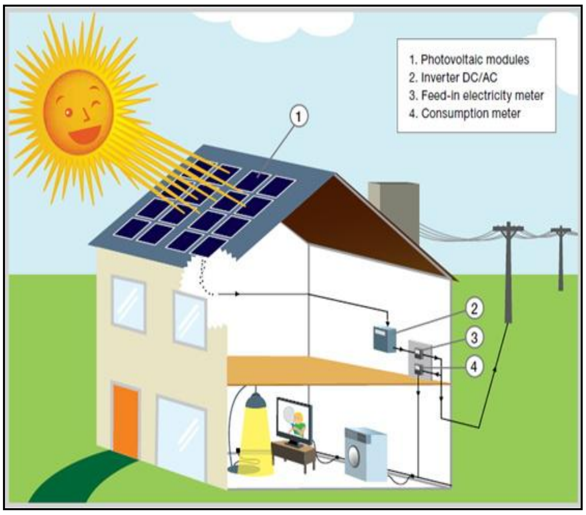


Figure 1.6: Production Electricity with PV [7] **Figure 1.7: Solar Energy for Heat System [8]**

For electricity generation, it is possible to use concentrating solar technology to focus solar energy and run steam and gas turbine plants that drive electric generators. On the MW scale, solar farms (with many solar units) may be installed in the Algerian desert using solar towers (as operational in Spain) where solar radiation is focused onto the top of a tower from concentrating mirrors. With PV panels, solar radiation is directly converted into electricity. This technology is widely used around the world and is considered a well-developed and mature technology. Algeria's capacity from PV is estimated at 13.9Twhr/year and can be applied in various contexts, such as attaching small panels to the roofs of houses, large panels on schools, hospitals and super markets, and installing large scale PV farms [3].

As the national capacity for renewable energy is strongly dominated by solar power, Algeria considers this form of energy as an opportunity and a lever for economic and social development, specifically throughout the implantation of industries which create wealth and jobs. The strategy adopted by the Algerian Government partly rests on prioritizing the development of the CSP sector, even if the other technological sectors cannot be removed. The priority given to CSP can be justified by a limited wind power capacity and the need for greater technological and commercial maturity on the part of the centralized PV sector. The objective sought is to produce 7,200 MW from the CSP sector. Two pilot projects for concentrated thermal plants with stock, each with a total power of around 150MW, shall be launched between 2001 and 2013. Over the period 2016 to 2020, there is a plan to build four thermal plants with the ability to stock a total power of 1,200MW then the introduction of

500MW per annum until 2023 and 600MW per annum until 2030 These projects have just completed the program of solar energy which started with the installation of the first hybrid plant - natural gas-solar - built at HassiR'mel in July 2011 (see plan below figure 1.8). This plant, built by NEAL in partnership with the Spanish company ABENER50, brings together combined cycle technology with that of cylinder-parabolic solar concentrators. This is the first combined cycle deployed far from the coast, thanks to a technology of refreezing vapor with aero condensors. The market to build the plant has been attributed to ABENER which is in charge of Engineering Procurement Construction (EPC) and maintenance operations [9].

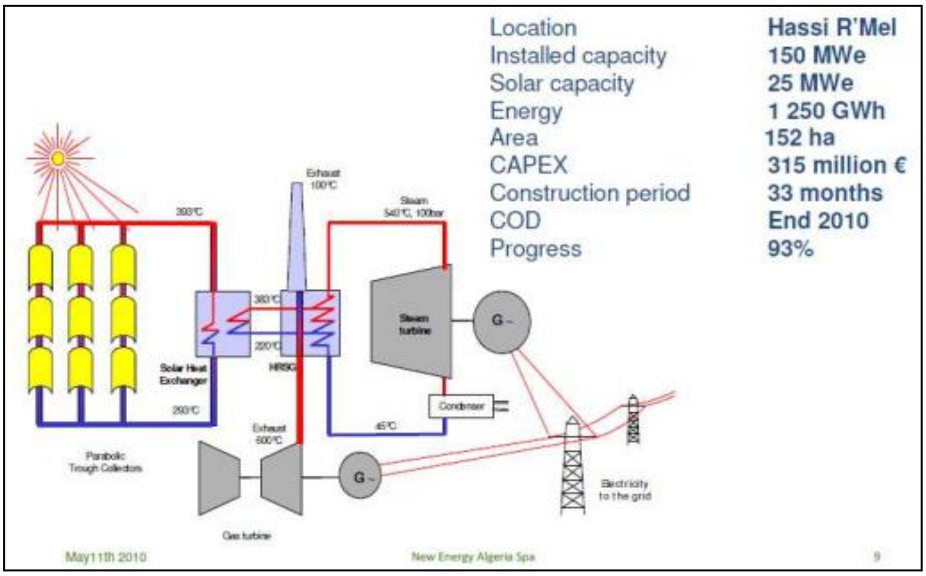


Figure 1.8: Simplified plan of the natural gas/solar hybrid plant a Hassi R'Mel [9]

1.3.2) wind energy

Algeria has promising wind energy potential of about 35 TWh/year. Wind energy resources vary from one place to another (geographical reasons): Average speed up to 6m /s in the South, and higher than 5m/s in the coast. Almost half of the country experience significant wind speed. This energy capacity is ideal for pumping water to the Tablelands, but is marginal for large commercial projects [3].

The country has a huge plan to develop wind energy. Studies of indigenous wind resources, performed by the CDER during recent years, show that the climatic conditions in Algeria are favorable for wind energy utilization. The wind map of figure 1.9, established by the MEM, shows that 50% of the country surface presents a considerable average speed of the wind. The map also shows that the South-Western region experiences high wind speeds for a significant fraction of the year as it seen in the table 1.2 showing the annual average wind velocities and power in the three sites of the South-West region of Algeria. This energy potential is ideal for the water pumping especially in the high plains [6].

The wind resource has also been assessed by the developer, Sonelgaz, and at present, there are six pilot projects for electrification and telecommunication which are identified and quantified. These are Adrar, Tindouf, bordj Badji Mokhtar, Bechar, Tamanrassat and Djanet

Table1.2: The Annual Average Wind Velocities in The Six Identified Places [6]

Sites	*Adrar*	*Tindouf*	*BordjBadji Mokhtar*	*Bechar*	*Tamanrassat*	*Djanet*
Annual Average Speed(m/s)	***6.3***	***5.1***	***4.6***	***4.4***	***3.7***	***3.3***

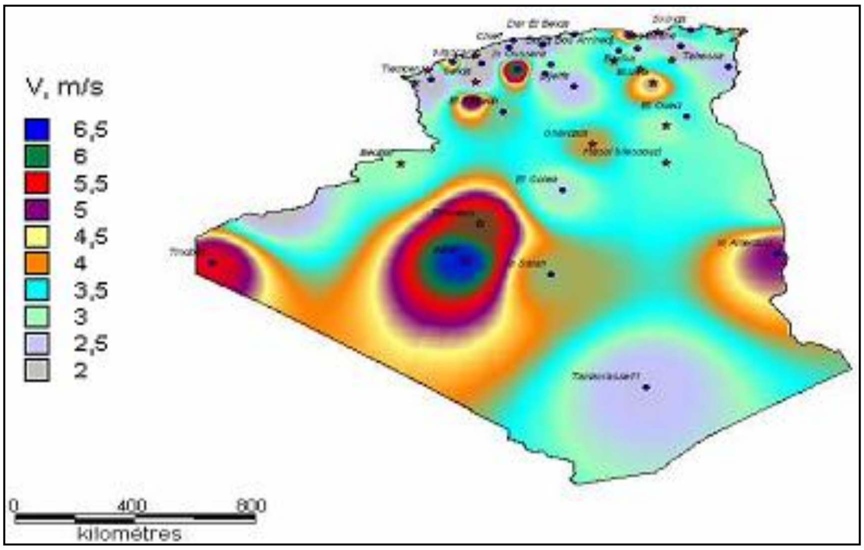


Figure 1.9: Wind chart of Algeria [10]

The region of Adrar receives the most wind in the country judging from the results of the preliminary survey. Evaluations of powers recoverable at heights from 10 to 50 m could conclude in registering this region as a favorable site for the establishment of a windy farm [6].

The country's first wind farm is being built at Adrar with installed capacity of 10MW with substantial funding from state-utlity Sonelgaz [3] in the sites Kaberten (75 north of Adrar), the wind resources of this zone of interest was performed, it indicates that wind speed reach 8.44 m/s at a height of 80 meters. Other sites (North, High Plateaux) hide non-negligible energetic potentials (usable energy, figure 1.10).

The installation, by Sonelgaz, of a 30 MW wind farm in Adrar region and the nine assessment stations in different regions of Algeria is seen as a second step in stimulating much faster the use of the wind power. The topography and terrain roughness of these prospective wind sites are also measured and quantified to better simulate and understand the wind flow [6].

Figure1.10: The Wind Farm is located at Ksar Kabertene

1.3.3) Geothermal Energy:

Geothermal energy is the energy derived from the heat of the earth's core. It is clean, abundant, and reliable. If properly developed, it can offer a renewable and sustainable energy source. Concerning the geothermic energy in Algeria, Algeria has a large geothermic capacity, estimated in terms of electricity production, at 700MW. More than 200 heat sources have been identified to the north of the 10 country of which almost 33% have a temperature higher than 45°C. The inventory of the thermal springs has been updated to show more than 240 sites. The temperatures of Algerian hot waters vary from 22 to 98 °C. The highest spring temperatures recorded are: 68 °C for the western area (Hammam Bouhnifia), 80 °C for the central area (H ammam El Biban) and 98 °C for the eastern area (Hammam Meskhoutine) in northern Algeria and 118°C in Biskra[6], as it illustrated in the map bellow:

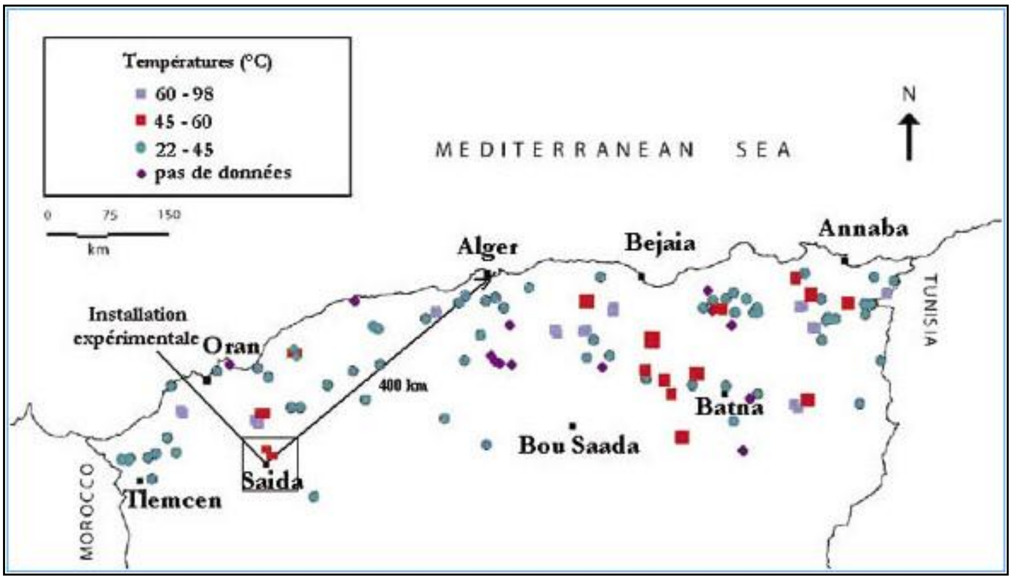


Figure 1.11: Source Geothermic In the Nord of Algeria [11]

In the southern area, there are some thermal springs with a mean temperature of 508°C. The geotectonic framework suggests that Algeria should not be lacking in commercially exploitable sources of geothermal energy. Geothermic is not to be excluded from the electric option of the renewable energies network. Some of these sources can be exploited for the purpose of renewable electricity production. This view is further strengthened by the presence of a fairly large number of hot springs in different parts of the country.

These hot springs are numerous but unfortunately not exploited for industrial ends. Geothermal energy represents one of the most significant sources of renewable energies in the Algeria. In general, geothermal resources can be classified as low grade (low temperature) or high grade (high temperature) [3].

1.3.4) Biomass Energy:

Algeria has good biomass energy potential in the form of solid wastes, crop waste and forestry residues. Solid waste is the best source of biomass potential in the country.

According to the National Cadaster for Generation of Solid Waste in Algeria, annual generation of municipal wastes is more than 10 million tons. Solid wastes are usually disposed in open dumps or burnt wantonly Sewage effluents can be digested in Sewage treatment plants. Green and municipal solid wastes can also be converted into biogas in solid waste digester units. This is practiced at a sewage treatment plant at Baraki near Algiers. Dimensioned to treat150000m^3/day of waste water, it might generate up to 41000 Nm^3/day of biogas, enough to provide 50% of the electricity need of the plant. Some other sewage treatment plants of lesser capacities are under construction and the biogas expected will be enough, for most of them, to provide energy for the plant [3].

The oldest and simplest way of using energy is to burn the biomass. The generation of electricity and heat from biomass is a particularly attractive form of energy conversion from the climate point of view. The biomass in Algeria potentially offers great promises with bearing of 3.7 million of TOE coming from forests and 1.33 million of TOE per year coming from agricultural and urban wastes (365 kg per Algerian as urban wastes); however this potential is not enhanced and consumed yet. A pre-survey showed the feasibility of production of electricity by modals of 2 MW that can reach a peak of 6 MW from the discharge of Oued Smar in Algiers [6]; such as appear in the figure 1.12.

Figure1.12: The open Dump of Oued Samar

The study integrates the drainage of the site. Regulations from the MEM which support using of biomass from energy crops rapidly caused an increase in interest for connection agriculture and energy sector. This is seen as a first step in stimulating much faster the use of biomass in Algeria.

Biogas is also considered to be an attractive and relatively cheap energy source. In addition, disposal of biogas by combustion is absolutely necessary to protect the environment; in particular, to protect the atmosphere against emission of unburned methane contained in biogas. A gradual growth of the use of biogas, particularly from landfills, has commenced at the UREERMS (Solar Equipment Experimentation Unit in the Sahara Area) which is seen as a step forward in the use of biogas in Algeria. A very promising alternative for burning is the gasification of biomass. Using gaseous biogenic fuels, it is possible to apply proven and efficient techniques like gas turbines and cogeneration units [6].

1.3.5) Hydroelectric Energy

Both the kinetic energy and the potential energy from flowing water can be converted into mechanical power by a turbine wheel, which in turn can drive machines or generators. Hydropower is a mature technology which, worldwide, generates the second largest share of energy from renewable sources, after the traditional use of biomass. 17% of the electricity consumed in the world today is generated by hydroelectric power stations. The overall flows falling over the Algerian territory are important and estimated to 65 billion m^3 but of little benefit to the country: restrained rainfall days, concentration on limited areas, high evaporation and quick evacuation to the sea. Schematically, the surface resources decrease from the North to the South. Currently the evaluation of useful and renewable energies is about 25 billion m^3, of which the 2/3 approximately is for the surface resources. 103 dam sites have been recorded. More than 50 dam are currently operational. The share of these small-sized production parks is about 5 % which supplements the natural gas production of electricity. The total capacity of 13 of them is 269.208 MW[6] as shown in table 1.3

Table 1.3: HydroelectricProduction Park [6]

plant	Installed power(MW)	plant	Installed power(MW)
Darguina	71.5	Ighzernchebel	2.712
IghilEmda	24	Gouriet	6.425
Mansouria	100	Bouhanifia	5.700
Erraguene	16	OuedFodda	15.600
Souk El Djemaa	8.085	BeniBehde	3.500
Tizi Meden	4.458	Tessala	4.228
Ghrib	7.000	Total	269.208

3.6) Solar Hydrogen

The solar-hydrogen energy system for Algeria would could extend the availability of fossil fuels resources, reduce pollution, and establish a permanent energy system. It could do so by solar production of hydrogen and then utilizing hydrogen as an energy carrier as well as exporting it to Europe. This would provide Algeria with a clean permanent energy system, and would enable it to maintain and improve its overall GNP, as well as improving its quality life. Algeria and the International Energy Agency agreed on technological cooperation in developing solar-hydrogen economy. The Algerian Hydrogen Association (2AH) has been created in June 2005 during the hydrogen conference held in Algiers. Initial work has already began in the areas of utilizing solar energy in producing hydrogen (CDER) for fuel cell but have not yet resulted in power generation and are rather in primary stages as compared with the work on solar and wind energy sources.

At the moment natural gas steam reforming is a likely initial source of hydrogen, due mainly to being a highly established process and having both natural gas distribution infrastructure and large scale hydrogen production facilities already in place.

NEAL tries achieving, in the near future, a solar hydrogen production as announced by the president of NEAL. Therefore, the sustainability for the environment is obvious. He also insists upon clean power to sustain the economic development of Algeria [6].

1.4) Demand Expectations:

In the past decade, an electricity consumption of approximately 1.9 TWh/y has been added every year in Algeria, reaching an annual demand of 45 TWh/y in 2010 (DLR 2013). The growth rate of demand in 2010 was 12%/y. If the linear trend would continue in the future Algeria would consume about 65 TWh/y by 2020 and 120 TWh/y by 2050 (Figure I.12). According to AUE 2011 the national expectations are higher, indicating a demand of 95 TWh/y by 2020. Extrapolating this expectation linearly after 2020, Algeria would consume about 240 TWh/y by 2050.

This model predicts a demand that is well in line with the national outlook and its linear extrapolation almost until 2040. Starting with 45 TWh/y in 2010, this model predicts about 87 TWh/y in 2020. After that, the model shows a linear growth and a beginning saturation after 2040, leading to a value of 200 TWh/y in 2050. As Algeria today is a country with relatively high per capita income among the NA countries, the model function shows a beginning saturation effect that can be expected in the long term. Per capita electricity consumption will increase from 1.3 MWh/cap/y in 2010 to around 4.3MWh/cap/y in 2050[14].

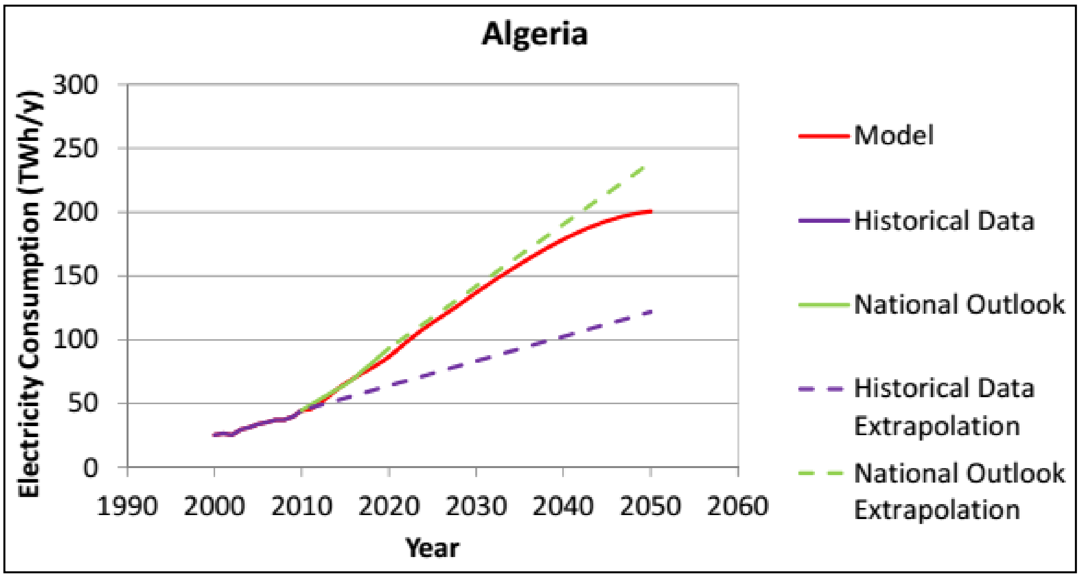


Figure 1.14: Gross electricity consumption in Algeria [14]

Most of the generated electricity consumption is focused in domestic as it illustrated in the figure 1.14.

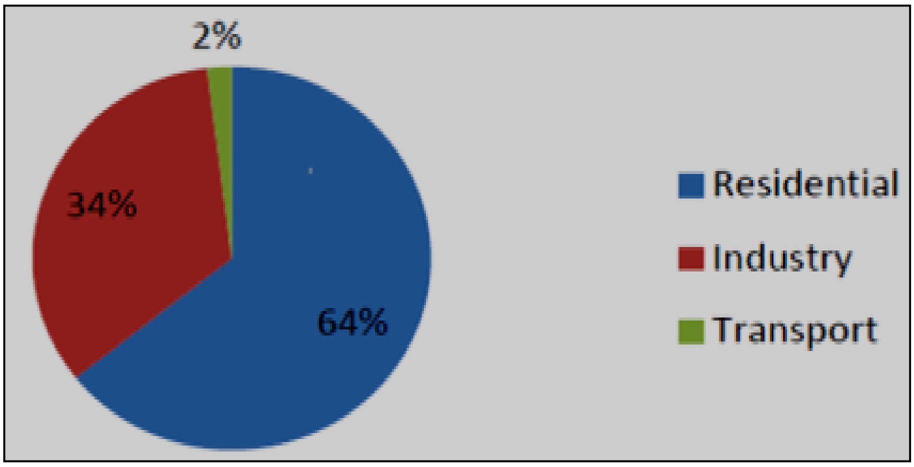


Figure1.14 : Electricity Consumption in Algeria [13]

An hourly load curve for Algeria for the year 2010 was provided by AUE 2012. This load curve was scaled for all consecutive years until 2025 for detailed scenario modeling of the electricity mix (Figure 1.15). Scaling was done in a way that maintains the relation of annual electricity demand and peak load just as scheduled by the national outlook data provided by AUE 2011. The load curve shows two peaks during summer and smaller peaks during the winter season [14].

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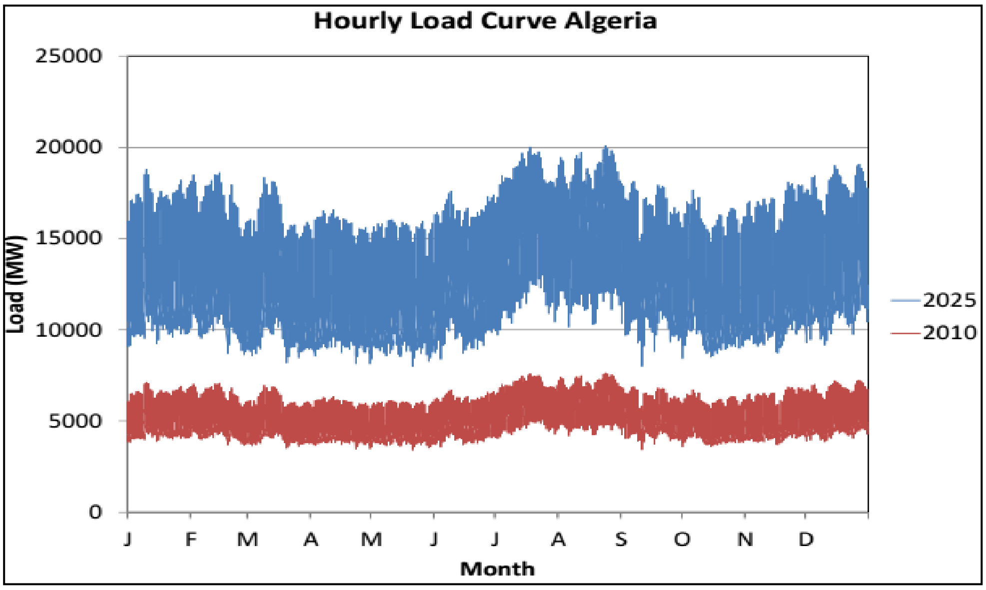


Figure 1.15: Hourly load curve for the years 2010 and 2025 for Algeria [14]

1.5) Conclusion

From this chapter, i conclude that Algeria is endowed with large reserves of energy sources, mainly hydrocarbons and solar energy. That there is a considerable potential for the utilization of renewable energy sources especially with respect to solar and wind power. However the level of development of such energy sources is rather primary with the growth of the population and the increasing demand for electricity.

Algeria should increase all the efforts because of the ever growing concern about the environment friendly sources of energy for demand response. It is now important in educating the public as well as introducing special energy legislation to increase the usage of this clean form of energy whether in private or public sectors and shows the importance of energy efficiency and conservation Renewable energies are now one of the major elements of Algeria's energy policy.

Chapter 2

2.1) Introduction:

The electricity grid is a complex and incredibly important system, and one of the most impressive engineering feats of the modern era. It transmits power generated at a variety of facilities and distributes it to end users, often over long distances. It provides electricity to buildings, industrial facilities, schools, and homes and it does so every minute of every day, year-round [14]. In this chapter i will give an overview about the electric grid structure and its problems, besides the status of Algerian power grid.

2.2) Electric Grid:

An electrical grid is an interconnected network for delivering electricity from suppliers to consumers [15] .It performs three major functions: power generation, transmission, and distribution, as it appear in the figure2.1:

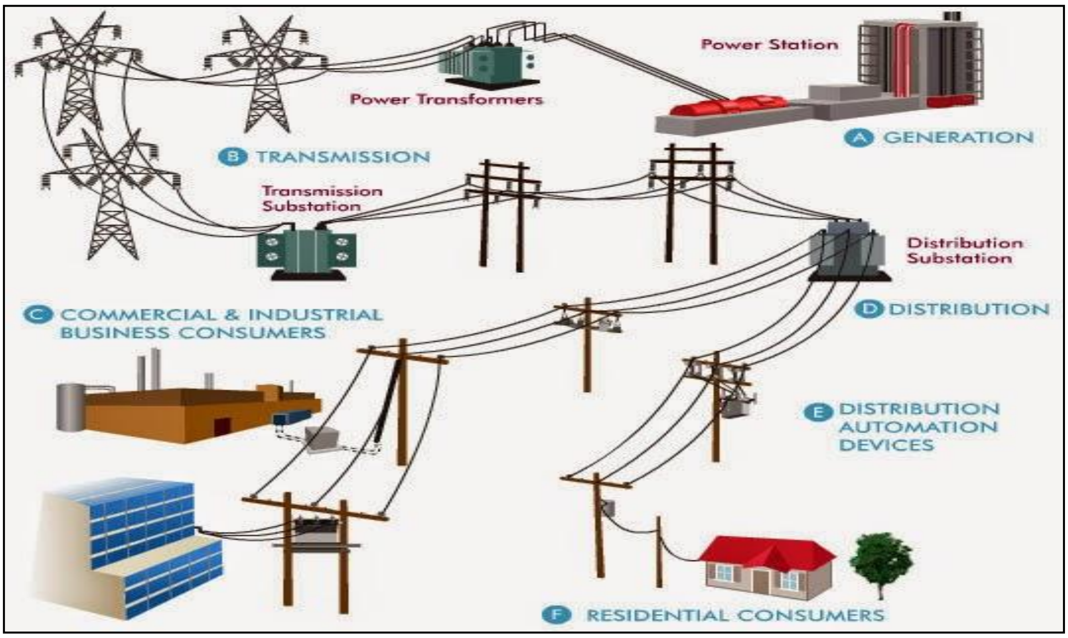


FIGURE 2.1: Today's Electric Power System [16]

2.3) Electric Grid Components:

2.3.1) Power Station:

Power generation is the first step in delivering electricity and it's performed at power station. The most of this stations burn fossil fuels such as coal, oil, and natural gas to generate electricity [17]. Others use nuclear power, but there is an increasing use of cleaner renewable sources such as solar, wind, wave and hydroelectric [18].Almost all of power station operates by heating water in a boiler unit into super-heated steam at very high pressures. The source of heat from combustion reactions may vary in fossil fuel plants from the source of fuels such as coal, oil, or natural gas. In some areas solid waste incinerators are also used as a source of heat. In a nuclear power plant, the fission chain reaction of splitting nuclei provides the source of heat. The super-heated steam is used to spin the blades of a turbine, which in turn is used in the generator to turn a coil of wires within circular arrangements of magnets. The rotating coil of wire in the magnets results in the generation Three-phase AC electricity power. After the steam travels through the turbine, it must be cooled and condensed back into liquid water to start the cycle over again. Cooling water can be obtained from a nearby river or lake. The water is returned to the body of water 10 -20 degrees higher in temperature than the intake water. Alternate method is to use a very tall cooling tower, where the evaporation of water falling through the tower provides the cooling effect this cycle [19]. That is summarized in the figure 2.2.

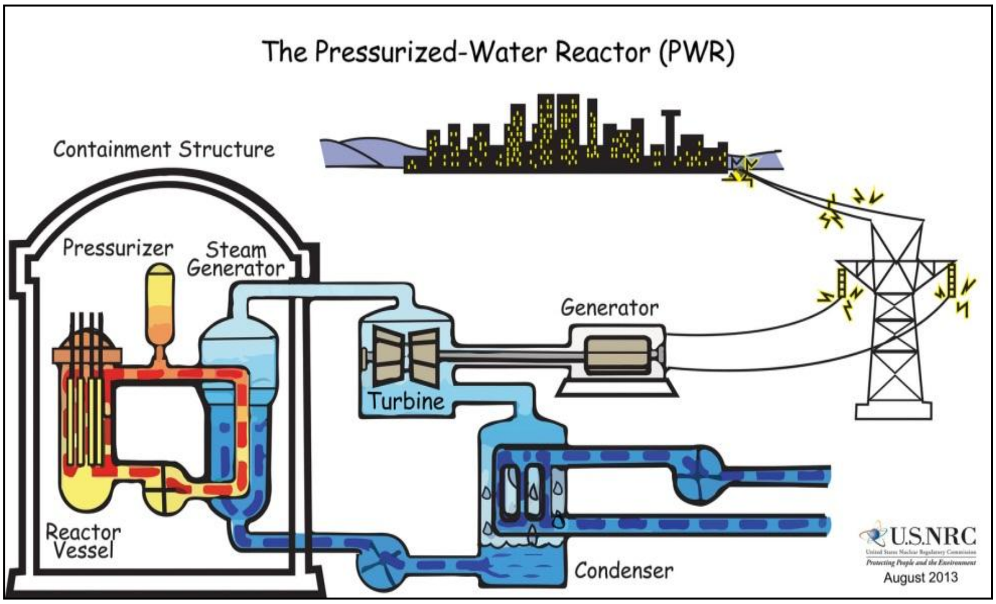


Figure 2.2 : Power Station of Generation Electricity[20]

2.3.2) Transmission Grid:

Transmission grid is the second step in delivering electricity and involves the transfer of electricity over long distances from the power stations to power companies' distribution systems [17]. There are two way for the electricity transmission by overhead transmission lines or underground power cables as it appeared in the figure (table 2.1).

Table 2.1: Overhead vs. Underground Systems [21]

Overhead System 	**Underground System** 
1.The size of conductor for same amount of power is small	1.The size of conductor is quite large in underground system.
2.The amount of insulation is less as overhead lines are open to atmosphere and hence air provides the necessary insulation.	2.Very high degree! of insulation is required as the underground system is laid under the ground hence area is very compact.
3.Heat can be dissipated easily in the surroundings as overhead lines are open to atmosphere.	3.Heat dissipation is very difficult and. hence number of insulating layers are added to the cable.
4.Overhead system is very cheap as no insulation coating is used over the conductors i.e., the conductors used are bare conductors	4.Very costly, because a number of insulation layers has to be used to provide sufficient insulation.
5.Faults can be detected easily	5.Fault detection is very complicated.
6. Maintenance work is very simple.	6. Maintenance work is very complex.
7. It is used for long distance transmission.	7.It is used for short distance transmission or distribution.
8.Public safety is less.	8.Public safety is more.
9.Faces problems due to interference with neighbouring communication system.	9.No interference with the communication lines.
10.They are liable to hazards from lightning discharges.	10.Not liable to the hazards from lightning discharges.
11.This system can’t be used near submarine crossings.	11.It can be used near submarine crossings.

The main components of high-voltage electric transmission grid and associated facilities include:

2.3.2.1) Transmission Towers

Transmission towers support the high-voltage conductors of overhead power lines, from the power station to the source substations are the most visible component of the power transmission system. Their function is to keep the high-voltage conductors (power lines) separated from their surroundings and from each other. Their shape, height and sturdiness (mechanical strength) depend on the stresses to which they are exposed. Towers do not transmit electricity themselves unless lightning strikes the ground wire strung along the top of the structure. This cable is designed to protect conductors by allowing lightning discharges to reach the ground through the tower [22], its components are appeared in the figure2.3

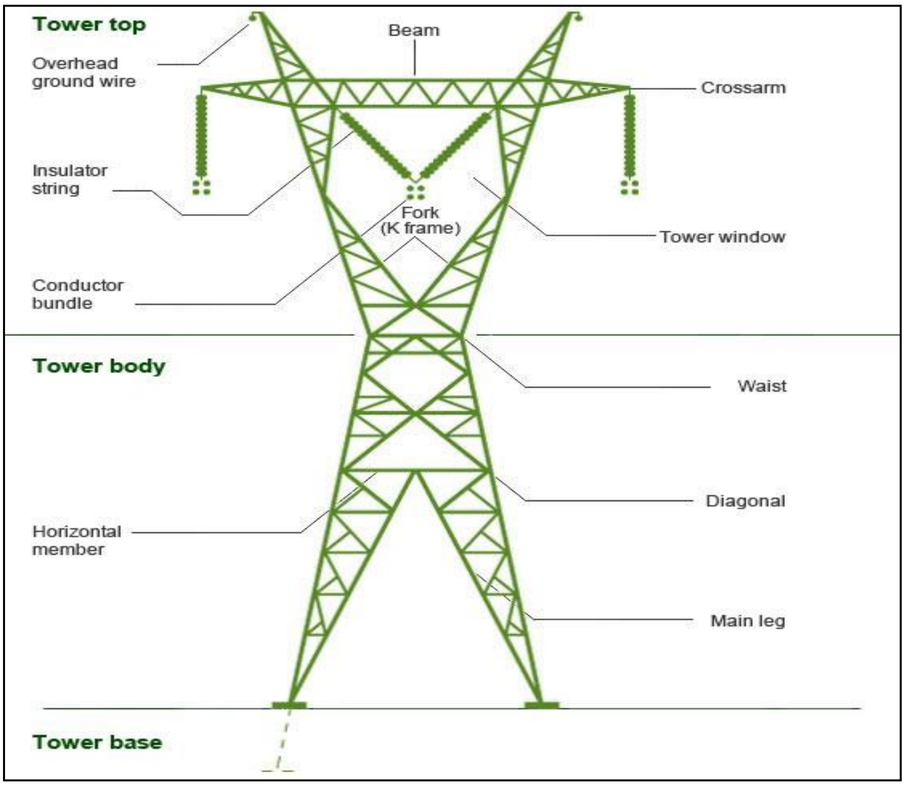


Figure 2.3: Transmission Electric Tower HV Components [22]

A variety of tower designs exist that generally employ an open lattice work or a monopole, but generally they are very tall (a 500 KV tower might be 150 feet tall with crossarms as much as 100 feet wide), metal structures (figure2.4).

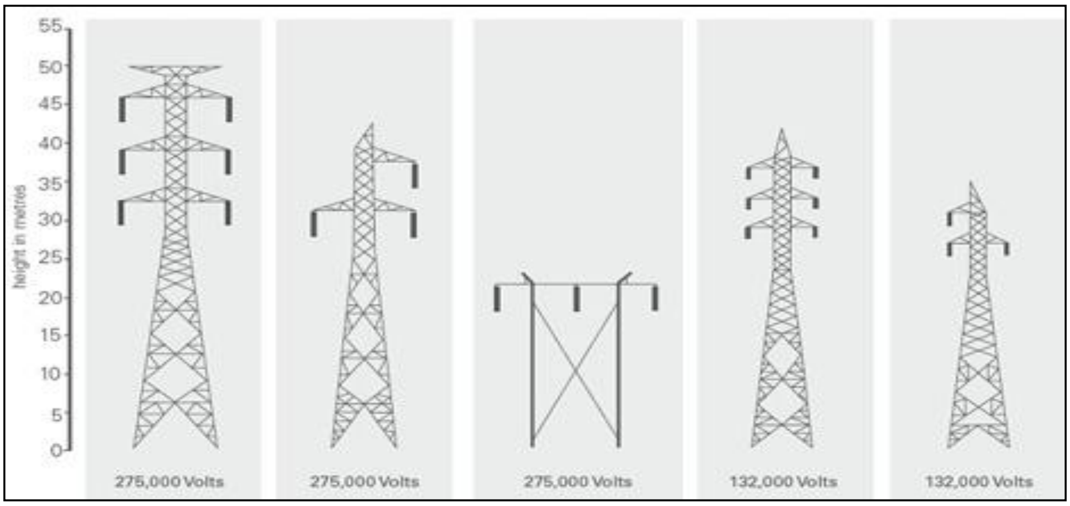


Figure 2.4: Type of Transmission Towers

2.3.2.2) Conductor Power Lines:

Conductors are the power lines that carry the electricity through the grid to consumers. Generally, several conductors are strung on a tower for each electrical circuit. Conductors are constructed primarily of twisted metal strands, but newer conductors may incorporate ceramic fibers in a matrix of aluminum for added strength with lighter weight [23]**.**The distiguish of the types of conductors that can be found in an electrical tower depending on the configuration of the transmission line and the type of the tower, one or two wires can be found at the top and a series of conductors on the sides of the tower are usually distributed vertically.

The top cable is the ground wire or wire guard: it is a steel cable whose function is to protect the other drivers before possible lightning strikes. If lightning strikes, the beam impact the ground wire conductors preventing damage, ensuring, thus, the continuity of power. In addition, between the ground wires we can find the OPGW cables (Optical Ground Wire): these ground wires have inside with fiber optic cables that allow communication between both ends of the line, which facilitates the sending of data between different electrical substations.

The other wires are electrical conductors themselves and serve as means of transport of electrical energy between the beginning and the end line. The number of drivers may vary depending on the number of circuits transported and the number of conductors per phase as needed. Traditionally, these drivers were copper cables. however despite their competitive electrical and mechanical properties, their high weight and price led to the development of other alternatives suitable to maintain these properties that are more efficient and cost effective.

Aluminum also has a similar electrical conductivity copper. However, aluminum has a lower breaking load. For this reason, and as shown, different types of aluminum conductors in which alloys or steel wires are used to give the driver the necessary mechanical strength while maintaining its electrical properties were developedsuch as illustrated in the figure2.4. These conductors usually have an overall diameter between 15 and 50 mm, depending on the current they are transporting[24].

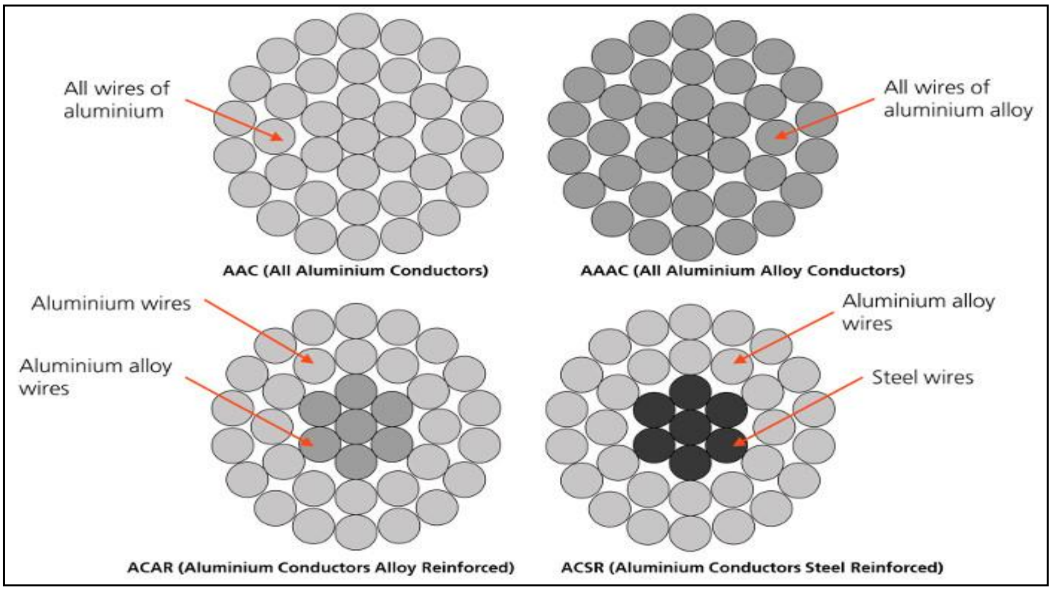


Figure 2.4: Aluminum Electric conductor in Transmission Line [24]

2.3.3) Substation

Power generators, however, produce electricity at low voltages. In order to make high-voltage electricity transport possible, the electricity must first be converted to higher voltages with a transformer at substations (figure2.6).; another transformer converts it back to a lower voltage before it enters the distribution network. Substations vary in size and configuration but may cover several acres;. In general, substations include a variety of structures, conductors, fencing, lighting, and other features that result in an "industrial" appearance.

These high voltages are also significantly greater than the need in of hoses, so once the electricity gets close to end users; another transformer converts it back to a lower voltage before it enters the distribution network [14].

Figure 2.6: A High Voltage Electrical Substation [25]

2.3.4) Distribution

Power distribution completes the electric grids' functions by delivering power to consumers. The distribution network is simply the system of wires that picks up where the transmission lines leave off. These networks start at the transformers and end with the consumers.

The transmission grid comes to an end when electricity finally gets to the consumer, The patterns of our lives add up to a varying demand for electricity by hour, day, and season, which is why the management of the grid is both complicated and vital for our everyday lives[14].

2.3.5) Control center

The flow of electricity through the power grid is controlled from several control centers throughout the country these control centers use computers and communication systems to enable the operators to monitor both the flow of electricity and the condition of power grid [26].

2.4) Power Quality Disturbances

Power utilities normally generate power in the form of alternating current (AC) and voltage with specified magnitude and frequency. Thus, most electrical equipment used by the customers are also designed to operate within a narrow band of voltage and frequency and any deviation from that band may lead to deterioration in the performance of these equipment. Power quality disturbances arise when certain deviations in magnitude and frequency of the power waveform beyond the specified range take place, creating problems to a customer. Analysis and assessment of power quality disturbances deal with the nature and frequency of occurrence of these variations, the types of loads mostly affected by them in terms of voltage and frequency sensitivity and the measures that may be adopted by the customers to safeguard their sensitive loads from these disturbances. The basic types of power quality disturbances are as follows [27]:

2.4.1) Transients

Transients are sub-cycle voltage disturbances in the form of very fast voltage change. They are characterized by frequencies ranging from tens to hundreds of kilohertz or even megahertz, Transients are caused by the injection of energy due to lightning, electrostatic discharge, load switching, line switching, energizing of a capacitor bank or interruption of an inductive load. The disturbances may be either impulsive or oscillatory. Transients generated from direct lightning strokes have the greatest potential for damaging the utility- or customer-end equipment. Even a lightning strike in the vicinity of the lines can cause a significant transient.

Transients may be eliminated by installing lightning arrestor systems with separate grounds or transient voltage surge suppressors (TVSS) at the service entrance or cheaper dedicated systems for individual equipment. More sensitive equipment like computer systems would, however, require additional protection equipment like computer grade power conditioners and ferro-resonant line conditioners.

2.4.2) Voltage Sags and Swells

Voltage sags and swells are defined by variations in the root mean square (RMS) voltage magnitude from around a half cycle to several seconds. Sags refer to drops in the voltage while swells refer to voltage rises. A voltage swell is usually caused by single line-to-ground faults on the system resulting in a temporary voltage rise on the healthy phases, removal of bulk loads, switching on a large capacitor bank, etc. Equipment that are affected mostly due to voltage sags and swells are industrial process controllers, programmable logic controllers (PLCs), adjustable speed drives and robotic systems. Sags may corrupt data in microprocessor-based digital control devices while swells may damage device power supplies or may cause them to reset.

2.4.3 Over-Voltages and Under-Voltages

Voltage sags and swells lasting more than 2 minutes are classified as under- and over-voltage conditions, respectively. Under-voltage conditions may be caused by sudden loss of lines or transformers, loss of adequate generation or loading a line beyond its capacity leading to low voltage at the consumers' terminals.

Under-voltage conditions may cause overheating in constant speed motors due to the increase in current density as well as may hamper the functioning of electronic equipment. Longer-term under-voltages can usually be corrected by changing the tap settings on a load tap hanging transformer.

Over-voltages, on the contrary, may occur due to problems with voltage regulation capacitors or transmission and distribution transformers. Over-voltage problems are usually eliminated by installing voltage regulator devices at key distribution sites within the customers ‘premises. The main distribution panel or the computer room panel or by installing UPS systems both to regulate the voltage to sensitive loads when utility power supply is available and to provide backup power in case of utility supply failure.

2.4.4 Outage

Outage or voltage interruption refers to the complete loss of voltage over a certain period of time. Outages may be short term (less than 2 minutes) or long term. These are normally caused by the opening of an isolating device (circuit breaker or line recloser) or by a physical break in the line. In case of any fault in a transmission or distribution feeder, the circuit breaker or recloser will immediately open in an attempt to clear the fault and the customers connected to the faulted feeder will experience one or more interruptions, depending on the type of fault and reclosing practices of the power utility. Temporary faults are usually cleared after one or two reclosing attempts and the normal supply is restored whereas for permanent faults, the circuit breaker locks out after a set number of reclosing attempts, resulting in a longer-term outage on that line. Outages to a system can be alleviated by installing UPS systems with battery storage and power-conditioning equipment, by storing mechanical energy.

2.4.5 Harmonic Distortion

Harmonic distortion arises when the shape of voltage or current waveform deviates from the standard sinusoid. Harmonic distortion implies that apart from standard power frequency component, higher-frequency components are also present in the power flow. These components can degrade equipment performance and may even cause damage to it. Some possible problems caused by harmonics are overheating of distribution transformers, disrupting normal operation of electronic equipment and system resonance with power factor correction banks. Potential sources of harmonics may be computers, lighting ballasts, copiers and variable frequency drives. Harmonic disturbances may be avoided or controlled by using equipment like 12-pulse input transformer configuration, impedance reactors or passive and active filters.

2.4.6 Voltage Notching

When silicon-controlled rectifiers (SCRs) are used in electrical control systems, line voltage distortion in the form of ‘notches’ may occur in the waveform. Line notches typically occur in the waveform either during SCR commutation or when a single-phase SCR is turned off and the next one is turned on. During this small period of time, a momentary short circuit exists between the two phases, resulting in the current rising and the voltage dropping. This appears as a notch in the voltage waveform. The most severe and damaging form of notch is the one that touches the voltage zero axis. The types of equipment that frequently use SCR control schemes and experience notching include DC motor speed controls and induction heating equipment. A voltage waveform with a typical line voltage notch is shown in Figure 2.7 Proper functioning of various electronic equipment is based on the detection of zero crossing in the voltage waveform. Some equipment need to be triggered at the zero crossing in order to avoid the possibility of any surge currents or inrush currents while some, like digital clocks, use the zero crossing for an internal timing signal. Notches touching the zero voltage axis may appear to be a zero crossing to such equipment, thereby causing them to malfunction. Sensitive equipment connected to the same voltage source as the equipment producing the notching can be protected by installing a 3% impedance reactor which eliminates multiple zero crossing and mitigates interference with neighboring equipment [26].

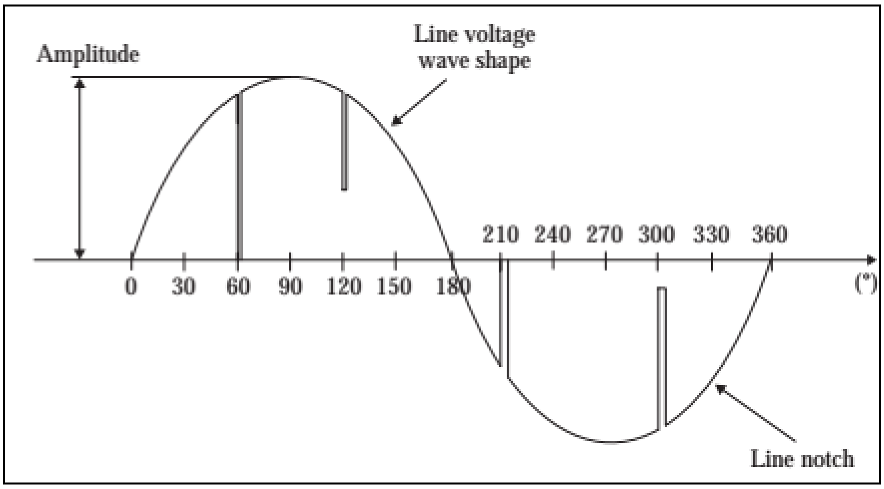


Figure 2.7: Voltage notching [27]

2.4.7 Flicker

Flicker is defined as a modulation of the voltage waveform at frequencies below 25 Hz, detected by the human eye as variation in light output from standard bulbs. Voltage flicker is normally caused by arcing on the power system from welding machines or electric arc furnaces. Flicker problems can be eliminated by installing filters, static VAR systems or distribution static compensators [27].

2.5) Today's Electric Grid Characteristics

The traditional power grid is unidirectional in nature. Electricity is often generated at a few central power plants by electromechanical generators, primarily driven by the force of flowing water or heat engines fueled by chemical combustion or nuclear power. In order to take advantage of the economies of scale, the generating plants are usually quite large and located away from heavily populated areas. The generated electric power is stepped up to a higher voltage for transmission on the transmission grid. The transmission grid moves the power over long distances to substations. Upon arrival at a substation, the power will be stepped down from the transmission level voltage to a distribution level voltage. As the power exits the substation, it enters the distribution grid. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage(s).

The challenges: As the supply and demand for electricity has skyrocketed through the computer revolution, growth of the Internet, and proliferation of electronic devices, there has been no significant investment in the transmission and distribution infrastructure that connects the two[31].

Presently, the grid is facing a multitude of challenges that can be outlined in four categories. First there are infrastructural problems due to the fact that the system is outdated and unfit to deal with increasing demand. As a result, network congestions are occurring much more frequently because it does not have the ability to react to such issues in a timely fashion. Ultimately such imbalances can lead to blackouts which are extremely costly for utilities especially since they spread rapidly due to the lack of communication between the grid and its control centers. A second flaw is the need for more information and transparency for customers to make optimal decisions relative to the market, so as to reduce their consumption during the most expensive peak hours. Finally, a third problem is the inflexibility of the current grid, which can't support the development of renewable energies or other forms of technologies that would make it more sustainable [28]. So the characteristics of today's grid are:

- Dominated by central generation- many obstacles exist for distributed energy resources interconnection.
- Limited wholesale markets, not well- limited opportunities for consumer.
- Focus on outages - slow response to power quality issues.
- Little integration of operational data with asset management - business process silos.
- Responds to prevent further damage- focus is on protecting assets following fault.
- Vulnerable to malicious acts of terror and natural disasters.
- Responds to prevent further damage. Focus is on protection off assets following system faults.
- Consumers are uniformed and non-participative with the power system.
- Vulnerable to malicious acts of terror and natural disasters.
- Focused on outage rather than power quality problems slow response in resolving PQ issues.
- Relatively small number of large generating plants. Numerous obstacles exist for interconnecting DER.
- Consumers are uniformed and non-participative with power system.

- Limited wholesale markets still working to find the best operating models. Not well integrated with each other [29].

2.6) Algerians electric grid

The electricity grid in Algeria is sub-divided into transmission grids (High voltage) and distribution grids (Medium and low voltage)

The National Interconnected Network (NIR): spread over the north of the country and covering the Bechar, Hassi Messaoud, Hassi R'Mel and Ghardaia regions, it is powered by 40 power stations connected Through a transmission network in 220 kV and 400 kV, enabling the transfer of energy from the production sites to the consumption centers.

The Pole in Salah - Adrar - Timimoun: This pole is powered by the Turbines power stations in Gas of Adrar and In Salah, interconnected through a 220 kV network extending from In Salah to Timimoun via Aoulef and Adrar.

The Southern Isolated Networks: These are 26 sites in the southern, feed by local networks through diesel or TG groups, given the distances involved and the relatively low consumption levels [30].The figure2.8 shows the map of Algerian electric grid.

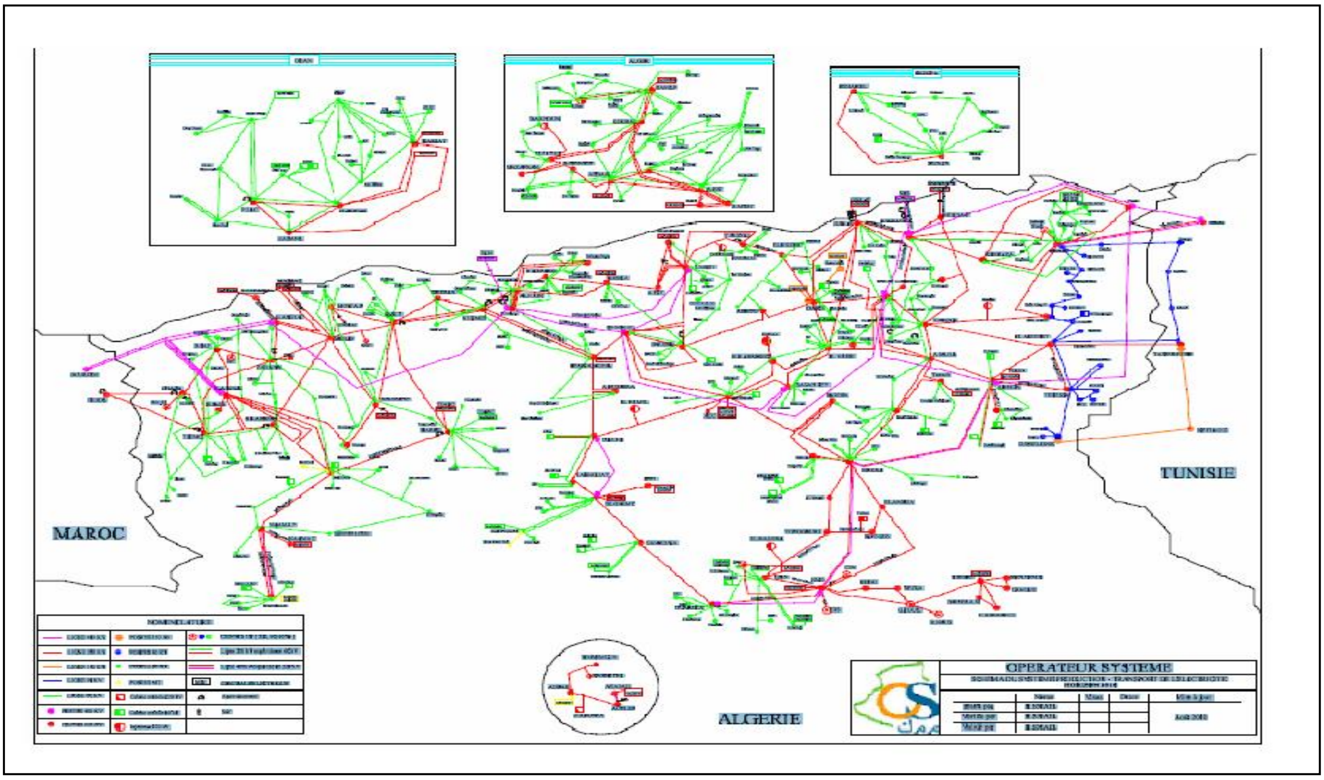


Figure 2.8: Algerian Electric Grid [30]

The total length of the national electricity transmission network, with all levels of tension (60 to 400 kV), managed by the Electricity Transmission System Operator (GRTE), is estimated at the end of 2011 by 22 370 km, and increase of 21.3% compared to 2007.

Dorsal Electric 400 Km: The national power grid was reinforced by a THT400 kV electrical backbone from east to west of the country. The interconnection of the national electricity system with Morocco in 400 kV has been completed and put into service in 2010; the interconnection with Tunisia is being finalized.

- North Dorsal: The overall consistency of the northern ridge in progress is 3,572 km.

- North - South Electric Dorsal: This ridge complementary to that of the North, with an overall consistency of 1,912 km, will enable to strengthen the overall security of the network, also strengthen the network between Hassi Messaoud and Hassi R'Mel.

The electricity grid in Algeria is sub-divided into transmission grids (High voltage) and distribution grids (Medium and low voltage) [30].

Table 2.2 : The electricity grid in Algeria [30]

	Voltage Level	Total length	Responsibility
Transmission Grid	400kV	2872 Km	TSO
Transmission Grid	150 to 220 kV	13390 Km	TSO
Transmission Grid	60 kV to 90kV	10398 Km	TSO
Medium Voltage	10 kV to 30 kV	131 213 km	DSO
Low Voltage	220V to 380 V	159 721 km	DSO

2.5.1) Current Status of the Algerian National Transmission Network

Algeria has an extensive AC network, not only covering the densely populated coastal areas, but also due to the presence of its oil and gas industry – reaching far into the largely unpopulated center of the country. Owner of the grid is the state utility Sonelgaz, which is also responsible for operation, management and development of the grid. Sonelgaz states that the total length of its transmission network is around 18,000km. According to the company's definition, this number includes lines with voltage levels down to 60kv. Transmission lines with 400 kV sum up to less than 1.300km length. Currently, Sonelgaz is putting strong efforts into upgrading these grid lines. Projects under construction include a 400 KV east –west transversal lines, as well as a 400 KV lines reaching into the deep south of the country. Reinforcements of cross-board connections with neighboring country Morocco, Tunisia and Libya, also on the basis of 400KV technology, are progressing. In September 2009, a new interconnection with Morocco featuring a transfer capacity of 1.000MW was inaugurated. Algeria's transnational interconnection projects with Maghreb neighbors are part of larger framework program, the so-called Mediterranean Ring Project (MED-RING), a 400KV electricity circuit encompassing all countries of the Mediterranean basin.

Besides the terrestrial interconnections, Algeria also has plants for submarine electricity links with its European neighbors on the other shore of the Mediterranean. Discussion of interlink projects with Italy and Spain already started in the late 1990s –a time long before the Idea of Desertec or the Mediterranean solar plan appeared on the international agenda.

For the interconnection with Spain, a feasibility study was carried out in 2003. It foresees a 250- km- long 400KV DC underwater cable spanning from the western Algerian coast (at the location Terga) to Almeria in southern Spain. The underwater links to Italy via Island or Sardinia represents a similar but more ambitious project due to the longer distance. The feasibility study for this project was accomplished in 2004. It has to be pointed out that the main driving force behind the above –mentioned studies were the low gas prices in the 1990s. The assumption was that by exporting (gas-generated) electricity, Algeria could achieve higher revenues than by selling the gas itself to the European markets, where prices were low. It was forecast that the export lines would be constructed in parallel with large gas power plants exclusively designed for export purposes. At the moment, however, these projects seem to have been put on hold, most likely due to the higher gas prices of the last year [31].

Algeria owns great natural sources of power, but the latter is not enough exploited because of the excessive dependence on petrol and gas. Unfortunately, current projections estimate that the country's oil reserves will only cover the next 50 years while those of natural gas will only be available over the next 70years. Algeria thus faces a mounting challenge between its dependence on fossil fuels and its capacity for exploiting vast renewable sources.

Some ambitious plans to develop renewable energy over the period of 2011-2030 have been put in place by aspiring to generate 40% of local electricity by2030 from solar and wind, with an estimated capacity of 22,000 Megawatts (MW) dedicating 12,000 MW to domestic use and 10,000MW to exports at a cost of $60 US billion [18].Despite liberation of the energy production market, till the moment national electric power company SONELGAZ still the monopolist of this sector in Algeria.

2.7 Conclusion

The increasing complexity of the classical power grids, growing demand, requirements for greater reliability, safety, efficiency, environmental issues and sustainable energy, the promotion of technology and infrastructure are factors that greatly contribute to instability, insecurity and inefficiency in the use of electrical energy. To overcome the energy sustainability of the environment it is better to use renewable energy for sustainable because of the problems of today's electric grid in this chapter; I have mentioned all these problems of electric grid and discuss the Algerian power system, in order to make our electric grid more intelligent.

Chapter 3

3.1) Introduction

The energy sector plays a vital role in today's industrial and scientific development. The main energy sources, that are currently being used around the world are based on fuel and nuclear reactors [32]. The complexity of Power systems due to the steady increase of electrical energy consumption, the population increase, and the industrial development has awakened power systems designers of safety problems Governments and power companies across the world have recognized that the traditional grid, which has not significantly changed in 100 years, must be replaced by more efficient, flexible and intelligent electric networks, called the smart grids. In this chapter I will define this technology and show the vision of Algerian smart grid in the future.

3.2) Smart Grid Definition

The term 'Smart Grid' refers to the next-generation power grid network, which integrates information, communication and power technologies to deliver energy in the optimal way from many sources to many destinations. The main goal of a smart grid is to improve reliability of the energy network, by providing alternative routes after grid fail, and efficiency due to distributed generation and energy management systems also energy storage. A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it generators, consumers and those that do both in order to efficiently deliver sustainable, economic and secure electricity supplies (Figure 3.1), in the smart grid there are two flows:

• ***Electric flow:*** from the plant generation to the end customer which is the main flow of the classical power grid However, in the vision of the SG, the electric flow could be bidirectional, where the end-customer will buy and could also sell energy.

• ***Information flow:*** A large-scale *two-way* communication flow between the different shareholder and components of the SG. Most of the communication flow is due to the massive use of sensors/actuators and other smart objects alongside the transmission and distribution areas, in addition to the use of smart meters and other smart objects (smart appliances, electric vehicles, etc.) at the end-customer side [33].

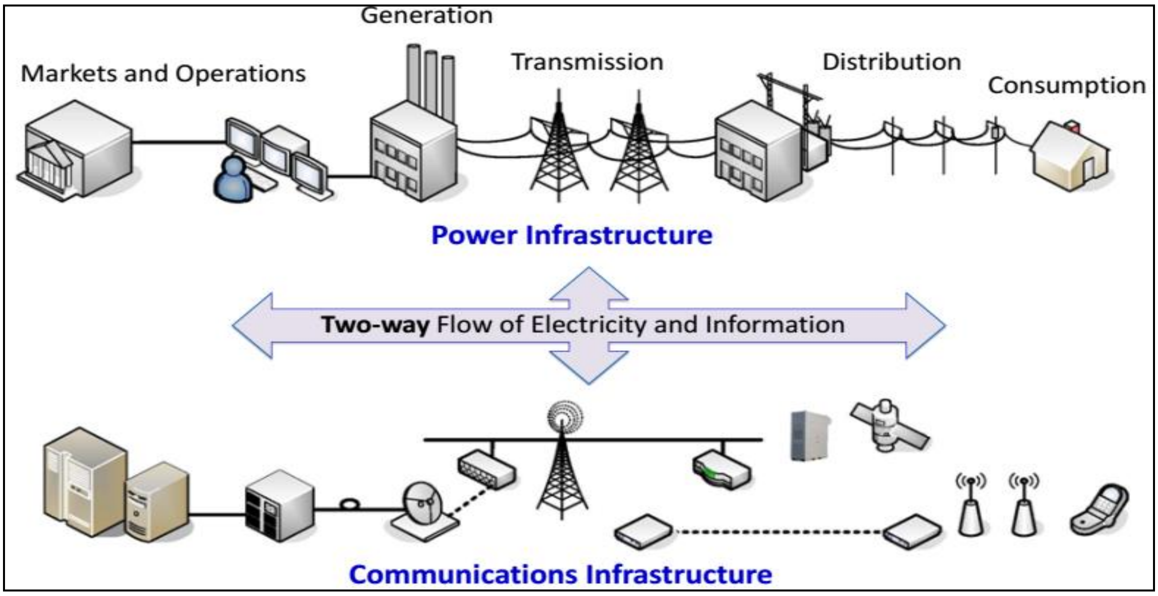


Figure 3.1 : Smart Grid Infrastructure [34]

3.3) Smart Grid Characteristics

A Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies toward:

- **Provides the power quality for the range of needs:**

Not all commercial enterprises, and certainly not all residential customers, need the same quality of power. A smart grid supplies varying grades (and prices) of power. The cost of premium power-quality features can be included in the electrical service contract. Advanced control methods monitor essential components, enabling rapid diagnosis and solutions to events that impact power quality, such as lightning, switching surges, line faults and harmonic sources.

- **Enables informed participation by customers:**

Consumers help balance supply and demand, and ensure reliability by modifying the way they use and purchase electricity. These modifications come as a result of consumers having choices that motivate different purchasing patterns and behavior. These choices involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives.

- **Accommodates all generation and storage options:**

A smart grid accommodates not only large, centralized power plants, but also the growing array of customer-sited distributed energy resources. Integration of these resources including renewables, small-scale combined heat and power, and energy storage – will increase rapidly all along the value chain, from suppliers to marketers to customers.

- **Enables new products, services and markets:**

Correctly designed and operated markets efficiently create an opportunity for consumers to choose among competing services. Some of the independent grid variables that must be explicitly managed are energy, capacity, location, time, rate of change and quality. Markets can play a major role in the management of these variables. Regulators, owners/operators and consumers need the flexibility to modify the rules of business to suit operating and market conditions.

- **Optimizes asset utilization and operating efficiency:**

A smart grid applies the latest technologies to optimize the use of its assets. For example, optimized capacity can be attainable with dynamic ratings, which allow assets to be used at greater loads by continuously sensing and rating their capacities. Maintenance efficiency can be optimized with condition-based maintenance, which signals the need for equipment maintenance at precisely the right time. System-control devices can be adjusted to reduce losses and eliminate congestion. Operating efficiency increases when selecting the least-cost energy-delivery system available through these types of system-control devices.

- **Provides resiliency to disturbances, attacks and natural disasters:**

Resiliency refers to the ability of a system to react to unexpected events by isolating problematic elements while the rest of the system is restored to normal operation. These self-healing actions result in reduced interruption of service to consumers and help service providers better manage the delivery infrastructure.

- **Scalability of the system and devices:**

Using open standards for devices and systems to facilitate data exchange and interoperability, ensuring compatibility for wider deployment across the network management systems.

- **Upgrades to the grid may be delayed or avoided:**

There are fast and cheap solutions for new connections and provide continuing grid to meet the highest standards of safety and reliability [35].

3.4) Smart Grid Components

For the generation level of the power system, smart enhancements will extend from the technologies used to improve the stability and reliability of the generation to intelligent controls and the generation mix consisting of renewable resources [36].

3.4.1) Bulk Generation

Figure 3.2 depicts the bulk generation site that generates power from renewable and non-renewable energy sources in bulk capacity. Electrically, it is connected to the transmission systems [37].

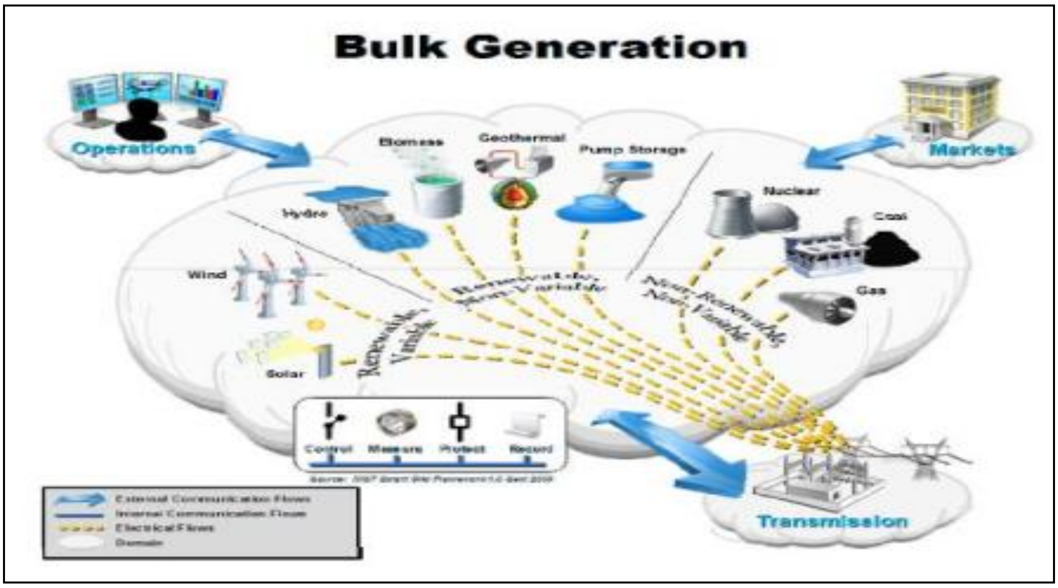


Figure 3.2: Bulk Generations [37]

From the perspective of smart grid bulk generation communication with transmission systems is the most crucial element to communicate, share and exchange key information performances with the operations and market domains. Typical applications include:

- Control: managing system power flow and reliability, such as using phase angle regulator.
- Measurement: providing data collection or digital measurement for all systems performances through SCADA system for control center in the operation domain.
- Protection: maintaining a high quality of supply and providing fast response to faults that might cause power disruption.

• Asset management: identifying and recording major equipment details, such as due date for maintenance, operation history or working life expectancy.

• Record: recording data for evaluation and forecast purposes.

In order to enable these applications, it requires an intelligent and powerful device that is field-proven where advanced protection, control and monitoring applications can be communicated through fiber optic, microwave, audio and radio communication paths. Such a device will use the energy more efficiently so that power losses or power outages, for example, can be tracked faster [37].

3.4.2) Transmission Subsystem Components

The transmission system that interconnects all major substation and load centers is the backbone of an integrated power system. Efficiency and reliability at an affordable cost continue to be the ultimate aims of transmission planners and operators. Transmission lines must tolerate dynamic changes in load and contingency without service disruptions. To ensure performance, reliability and quality of supply standards are preferred following contingency. Strategies to achieve smart grid performance at the transmission level include the design of analytical tools and advanced technology with intelligence for performance analysis such as dynamic optimal power flow, robust state estimation, real - time stability assessment, and reliability and market simulation tools. Real – time monitoring based on PMU, state estimators sensors, and communication technologies are the transmission subsystem's intelligent enabling tools for developing smart transmission functionality (figure3.3)[35].

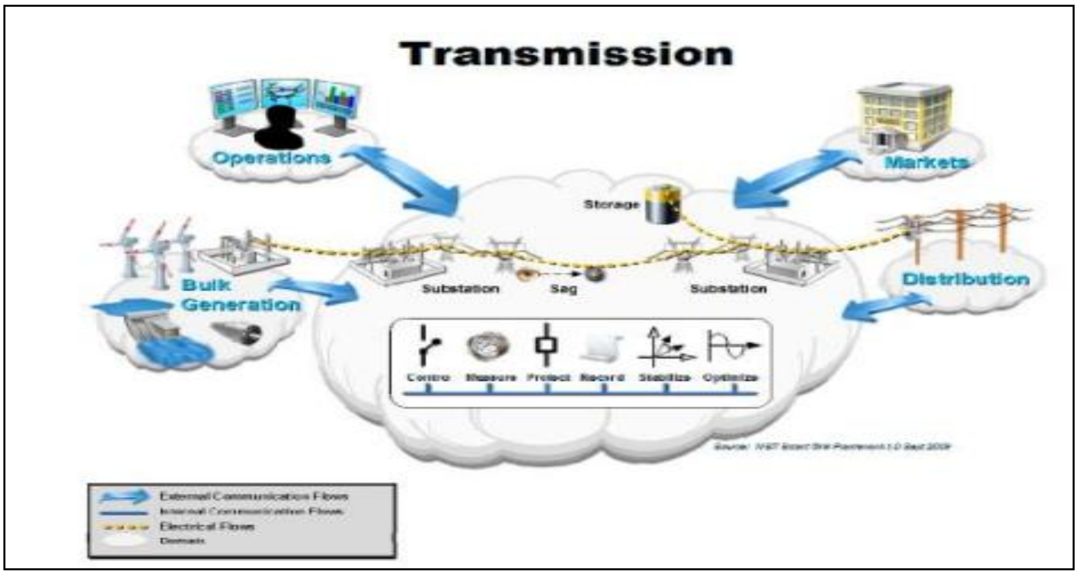


Figure 3.3: Transmission networks [37]

In this unique vision of smart transmission grid, it aims in promoting technology innovation to achieve an inexpensive, reliable, flexible and sustainable delivery of electric power. It also enables some of the key features such as:

- ✓ Increased flexibility in control, operation and expansion.
- ✓ Development of embedded intelligence.
- ✓ Foster resilience and sustainability of the grids.
- ✓ Improve customer benefits and quality of service [39].

3.4.3) Intelligent Grid Distribution Subsystem Component

The distribution system is the final stage in the transmission of power to end users. At the distribution level, intelligent support schemes will have monitoring capabilities for automation using smart meters, communication links between consumers and utility control, energy management components, and AMI. The automation function will be equipped with self - learning capability, including modules for fault detection, voltage optimization and load transfer, automatic billing, restoration and feeder reconfiguration, and real – time pricing such as illustrated in the figure 3.4[39].

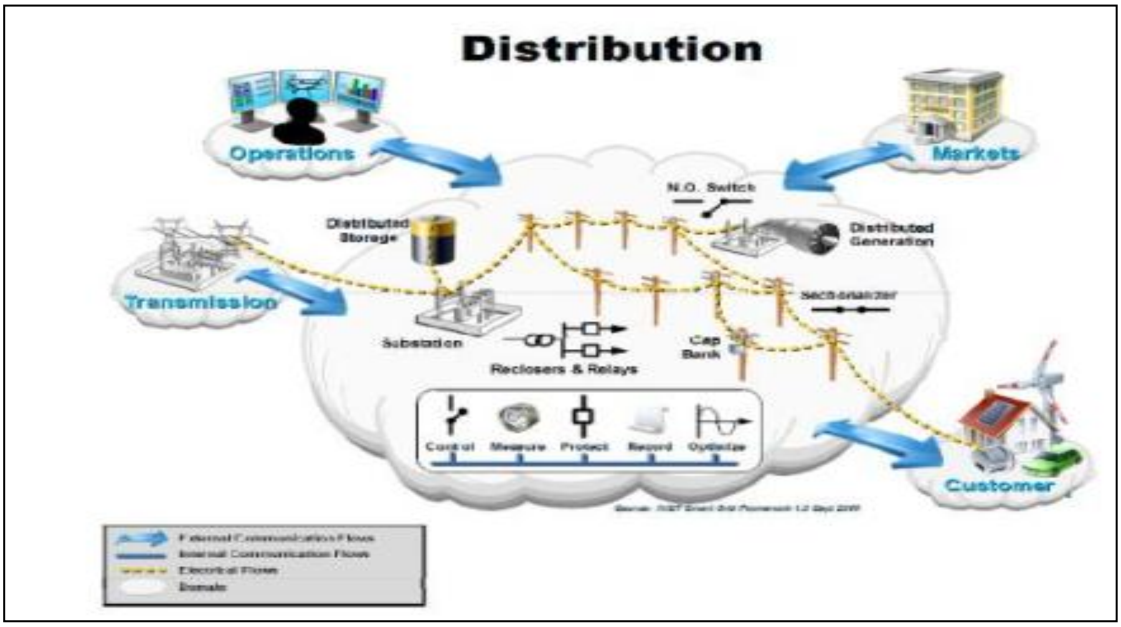


Figure 3.4: Distribution Networks [37]

3.4.4) Distributed Generation

Driesen and Belmans define distributed generation as a small-scale electric power generation, which is located near the consumer load, typically having a rating of <10 MW and is not included as a major power plant .Meanwhile, the Electric Power Research Institute (EPRI) defines distributed generation as generation from a few kilowatts up to 50 MW‘. The Gas Research Institute defines it as generation which is typically between 20 to 25 MW‘ However, this definition is not compulsory as there are no universal agreements on the distributed generation definition. Thus, each country and power-working group has different views on defining distributed generation; some countries describe this technology in terms of voltage level, whilst others base it on the generation capacity, interconnection and location . The main objective of distributed generation is getting the electricity from point of generation close to the point of consumer (figure3.5).

The liberalization of electricity markets and environmental policy has increased the use of distributed generation units for a range of applications, such as stand-alone, peak load shaving and remote applications. These units can be classified into two different categories:

- Distributed generation based generation, including micro turbines, photovoltaic, fuel cells, wind turbines and biomass.

- Distributed generation based storage, including flywheels, battery, supercapacitor and superconducting coil system [37].

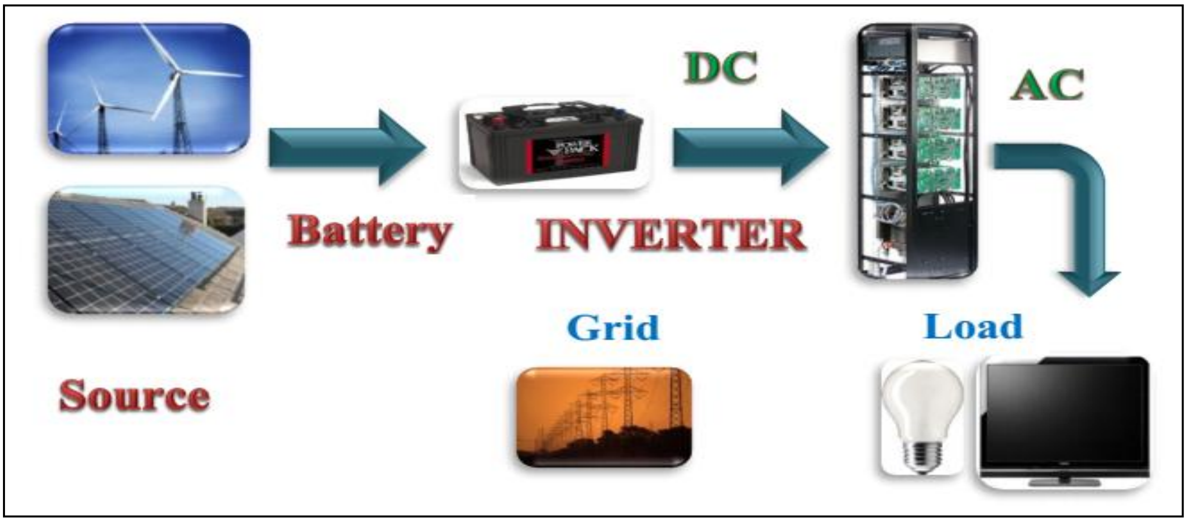


Figure 3.5: Distributed Generation Interfacing

3.4.5) Monitoring and Control Technology Component

Transmission and distribution networks are designed to deliver the electricity at the consumer side at a predefined voltage level. Photovoltaic power generation is in general connected at the distribution level of the power system. For this reason, it is possible for the power produced by the PV to cause a ‘counter’ power flow from the consumer side to be delivered to other consumers through the distribution network. This phenomenon may present two challenges: an increase in the voltage in areas with high PV production and voltage fluctuation throughout the system due to the intermittency characteristics of the PV production. Intelligent transmission systems include a smart intelligent network, self-monitoring and selfhealing, and the adaptability and predictability of generation and demand robust enough to handle congestion, instability, and reliability issues [36].Some of key features of Smart Grid control and monitoring have been discussed as follows [38]:

3.4.5.1) Self-Healing

To ensure grid stability and improve the supply quality, avoid or mitigate power outages, power quality problem, and service disruption using real-time information from embedded sensor and automated control to anticipate, detect and respond to system problem, is conferred to be a self-healing power network. Such systems are independent of user interaction, where decisions making are based on the knowledge from the pre-estimated and pre-monitored results. In general, the self-healing is distinguished in two levels: selfhealing in the physical (monitored hardware) layer and the logical (monitored application/system) layer, according to situation of concerns [38].

3.4.5.2) Wide Area Monitoring and Control (WAMC)

Wide Area Monitoring and Control (WAMC) and Wide-area monitoring, protection, and control(WAMPAC) encompasses the use of system-wide information and the communication of specific local information to a remote location to counteract the propagation of large disturbances in a system. With the invasion of adaptive system of smart power grid; a dynamic, stochastic, computational and scalable (DSCS) with innovative control technologies can be a promising trait for a reliable, secure and efficient functioning of WAMPAC. Synchrophasor Measurement Technology (SMT) is an important element to WAMPAC which includes both short-term objectives such as enhanced visualization of the power system, post disturbance analysis, and model validations, and long-term objectives such as the development of a WAMPAC system. Such type of conceptual architecture has been employed in Eastern Interconnect Phasor Project (EIPP) in United States. With the increased international research and development, several monitoring and control application are based on Synchrophasor-based Wide-Area Monitoring, Protection and Control System (WAMPAC).Though with small scale adoption, it has played a major role in some large transmission system operators. The WAMPAC system consists of a measurement device, the Phase Measurement Units (PMUs), their supporting infrastructure which is formed by communication networks and computer systems capable of handling PMU data and other information, usually called the Phase Data Concentrators (PDCs). The set PMUs and their aiding ICT infrastructure are termed as Synchrophasor Measurement Technology (SMT).The basic components of a WAMC system are the following: PMUs, PDCs, a PMU-based application system, and a communication network to connect the interfaces, similar to traditional SCADA systems [38].

3.4.6) Demand Side Management Component

Demand side management options and energy efficiency options developed for effective means of modifying the consumer demand to cut operating expenses from expensive generators and defer capacity addition. DSM options provide reduced emissions in fuel production, lower costs, and contribute to reliability of generation. These options have an overall impact on the utility load curve [36]. A standard protocol for customer delivery with two - way information highway technologies as the enabler is needed. Plug - and - play, smart energy buildings and smart homes, demand- side meters, clean air requirements, and customer interfaces for better energy efficiency will be in place [39].

3.4.6.1) Smart Metering Technology

Smart metering system has been considered as an effective method for improving the pattern in power consumption and efficiency of energy consumers thus reducing the financial burden of electricity. It is the combination of power system, telecommunication and several other technologies. Indisputably, with the development of science and cutting edge technology, more facilities have been added to this area. Smart meter is an advance energy meter that measures the energy consumption of a consumer and provides added information to the utility company compared to a regular energy meter. The bidirectional communication of data enables the ability to collect information premeditated with communication infrastructure and control devices. In addition, the meter is used to monitor and control home appliances and devices, collect diagnostics information about the utility grid, support decentralized generation sources, energy storage devices, and consolidate the metering units Advanced metering Infrastructure (AMI), an appellation of smart metering technology which consists of set of smart meters, communication modules, LAN, data collectors, WAN, network management system(NMS), Outage Management System (OMS), Meter Data Management Systems (MDMS), and other subsystems[38].With an advance feature of data collection, the system procures a safe, secure, fast and self-upgradable with developed vision of reliable and flexible access to electricity consumption of the subscribers using power and distribution grid. An important technological device called the In-Home Display (IHD) is an imperative development for the advancement and implementation of smart metering system [38].

Figure 3.6 : Smart Meter [40]

3.4.6.2) Storage Component

Renewable energy sources, such as wind and PV, are intermittent in nature because of the dependence on weather conditions (and the time of the day) and therefore require storage of surplus energy to match with the energy demand curve on the grid. As mentioned before, to avoid expensive grid energy storage, the smart grid concept can be used, where smart metering can condition the demand curve(demand-side energy management) to match with the available generation curve by offering lower tariff rate. In contrary, suitable energy storage devices can be incorporated with these DG system to store energy and then discharge be providing power back to the network which when the RES power generation sources are out. The following are few major energy storage devices which are preferred to be used in the energy storage facility and an optimized research are made on it for efficient and reliable operation.

- ✓ Pumped storage in hydroelectric plant.
- ✓ Battery storage.
- ✓ Flywheel (FW) storage.
- ✓ Superconducting Magnet Energy Storage (SMES).
- ✓ Ultra-capacitor (UC) storage.
- ✓ Vehicle-to-Grid (V2G) storage.
- ✓ Hydrogen gas (H2) storage, and Compressed Air Energy Storage (CAES) [38].

3.4.6.3) Electric vehicles

Forecasting horizons for electric vehicle deployment are still under discussion, but the current situation is favorable to their development and recharging infrastructures are appearing. The technology now offers a certain maturity and ecological concerns may trigger the decision to purchase an electric vehicle.

For the grid, electric vehicles are new loads with specific profiles and mobility, which brings in new variability. For example, the variability of the load from a sports ground, already very high by nature, will increase further if all of the spectators recharge their vehicles during the game! Conversely, these constraints may be offset by the services that these vehicles could provide to the network, thanks to their charge controller and storage capacity. Uses in primary regulation, secondary regulation and reserves have not yet been clearly demonstrated, but can be achieved in theory.

In conclusion, these future uses entail major changes for distribution. Nevertheless, they will have mean real impact and create opportunities for transmission, with lower consumption peaks, less congestion, new reserve and regulation services, etc. The new flexibilities that will be available to operators will add new resources to be planned by production forecasting systems and energy markets, and significantly enhance the role of dispatching applications. The pilot projects undertaken in various regions of the world will be essential in the correct assessment of the potential and the related risks of these solutions [40].

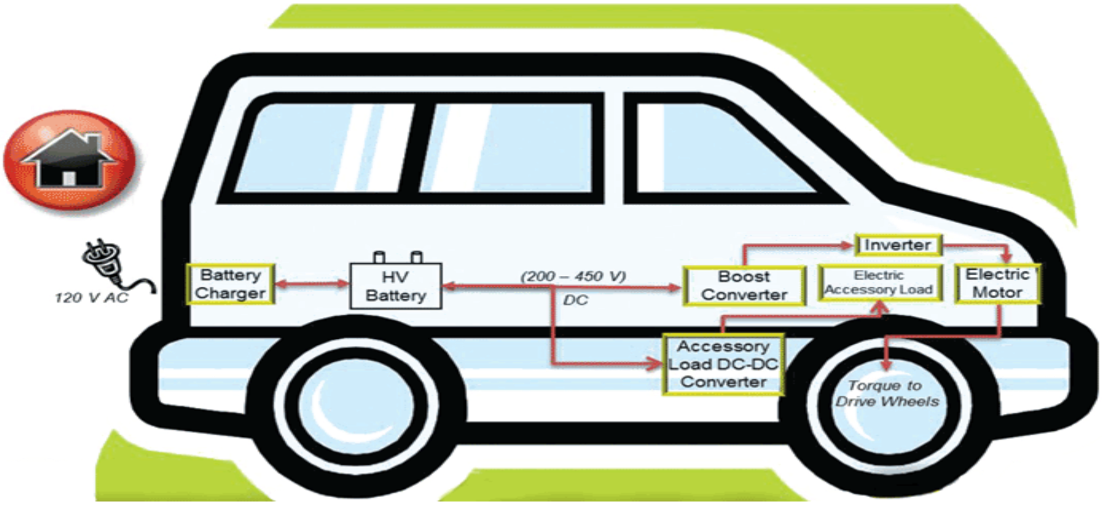


Figure 3.7: Electric Vehicle [41]

3.4.7) Information and Communication Technology (ICT)

With the incorporation of advance technologies and applications, the smart grid architecture increases the capacity and flexibility of the network and provides advance sensing and control through modern communication protocols and topologies. Wired and Wireless modes are being complied for the transmission and communication of data and information between the smart consumers and the utility sectors. Each of the modes of the communication has its own advantages and disadvantages over each other, depending on the various factors such as geographical location, capital investment, economy of use etc.

Two-way flows of electricity and information lay the infrastructure foundation for the smart grid. Smart communication subsystem or the ICT are a dynamic sector of the Smart Grid infrastructure. The communication infrastructure of a power system typically consists of SCADA systems with dedicated communication channels to and from the System Control Centre and a Wide Area Network (WAN). Some long-established power utilities may have private telephone networks and other legacy communication systems. The SCADA systems connect all the major power system operational facilities, that is the central generating stations, the transmission grid substations and the primary distribution substations to the System Control Centre. The WAN is used for corporate business and market operations. These form the core communication networks of the traditional power system. However, in the Smart Grid, it is expected that these two elements of communication infrastructure will merge into a Utility WAN [38].

An essential development of the Smart Grid (Figure 3.1) is to extend communication throughout the distribution system and to establish two-way communications with customers through Neighborhood Area Networks (NANs) covering the areas served by distribution substations. Customers' premises will have Home Area Networks (HANs). The interface of the Home and Neighborhood Area Networks will be through a smart meter or smart interfacing device.

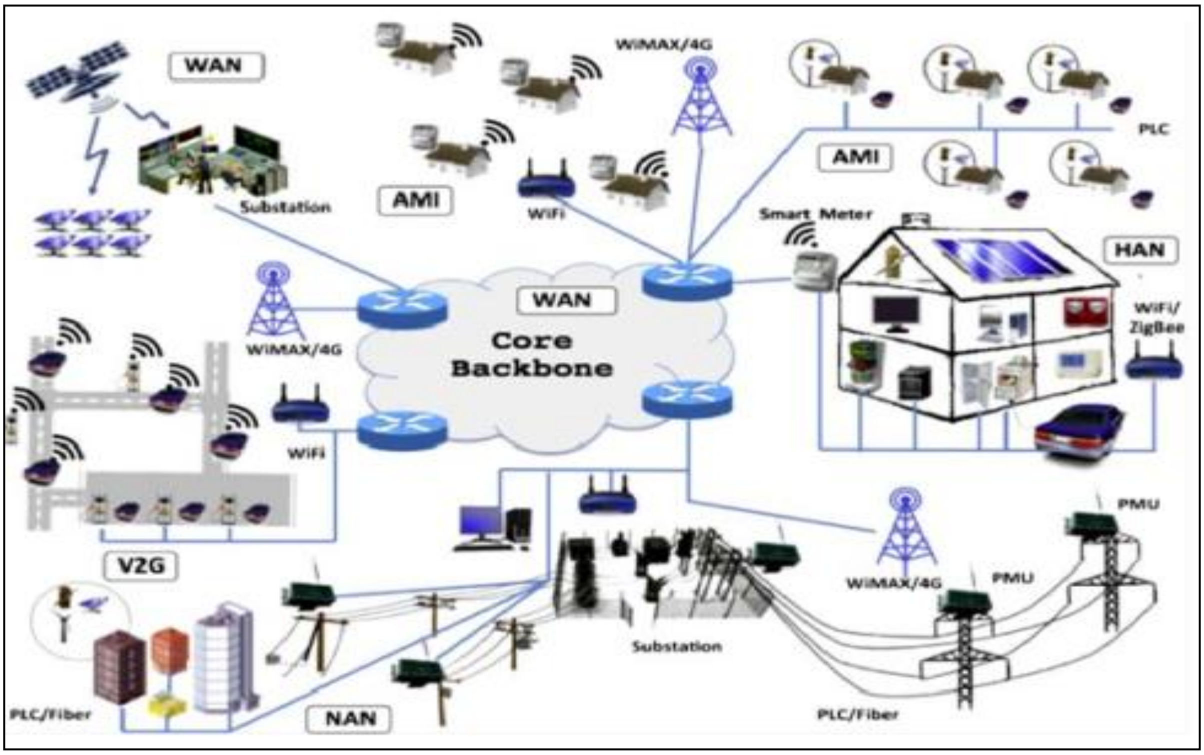


Figure3.8: Detailed Communication Infrastructure in Smart Grid [1]

The infrastructure mainly visualizes the communication pattern in two conduits viz. sensor and electrical appliance to smart meters, moreover between smart meters and utility data center. The communication infrastructure between energy generation, transmission, and distribution and utilization requires two-way communications; interoperability between advanced applications and end-to-end reliable and secure communication with low-latencies and sufficient bandwidth. Along with advancement of system security and robustness towards cyber-attacks which provides system stability and reliability with advanced control adds to its essentials. Table 3.1 articulates some of the important communication topologies along with their brief details, with emphasis on its advantages and disadvantage.

Table3.1: Smart Grid Network Topologies [38]

NETWORK TOPOLOGIES	APPLICATIONS
ZIGBEE COM	Advance Metering Infrastructure (AMI) and Home Area Network (HAN)
WIRELESS MESH NETWORK	Advance Metering, Infrastructure (AMI), Home Energy Management and Home Area Network (HAN)
CELLULAR NETWORK	Advance Metering Infrastructure (AMI), Home Area Network (HAN), Outage management, Demand side management
POWERLINE COMMUNICATION (PLC)	Advance Metering Infrastructure (AMI), Fraud Detection, System monitoring and control
DIGITAL SUBSCRIBER LINE (DSL)	Advance Metering Infrastructure (AMI) and Home Area Network (HAN)

3.5) National initiatives

In spite of the common view that the power industry would enter the smart grid development stage, the smart grid research is still on evolutionary stage.

Many national governments are encouraging Smart Grid initiatives as a cost-effective way to modernize their power system infrastructure while enabling the integration of low-carbon energy resources. Development of the Smart Grid is also seen in many countries as an important economic/commercial opportunity to develop new products and services. Table 1 characterizes the comparison of development and advancement of Smart Grid among the major nations in details.

Table3.2: Smart Grid Initiatives in Major Nations [38]

Countries	Improvements	Implementablity	Outcomes
USA	Smart Metering, AMI,VPP, WAMS etc.	Smart Grid related projects to be around $13bn per year, estimated $20bn per year to be spent on T&D projects, pilot studies on WAMS etc	Reduction in annual electricity Bill by 10%, savage up to $200bn in capital expenditure On new plant and grid Investments by $30bn.
EUROPE	Renewables, Smart meters, Plug-in EVs, Energy Storage etc.	Development of RES, Smart metering with ToU pricing, intelligent appliances etc.	Load Management, power quality improvement, grid stability, energy efficiency.
CHINA	Expand T&D capacity, reduce line losses, uplifting transmission voltage, installing high efficiency distribution transformer etc.	Development of UHVAC and UHVDC, use efficient distribution transformer, more stress on HV transmission network	Wide area power network, efficient and economical transmission and distribution of power across the country
FINLAND	AMI, IHDs, ICTs, Smart Meters etc.	Installation of AMI and smart meters equipped with advance ICT_S like Rf, PLC, Broadband GPRS, 3G zigbee wi-fi HAN etc	Fault diagnosis, fault location, Service restoration, voltage and reactive power control and network reconfiguration.
INDIA	Reduction in T&D losses, WAMS, SGMM, Qo Setc	Using DSM to selectively curtail electricity use, improving power quality, increase use of renewables, intelligent energy efficiency in the form of DG etc	Rural Electrification, on-line condition monitoring, improvised market strategy by real-time pricing technique.

3.6) Vision Of Algerian Smart Grid

The technological development and the richness of the Algerian environment, especially with the growth of the population and the increasing demand for electricity **Benahmed Khelifa** and **Douli Amel** proposed a new vision to integrate an Algerian smart grid in order to solve the problems of the current grid As an excellent solution, smart grid will inevitably put the existing electrical system in a serious revision to increase the efficiency, reliability and response to the end user, but at the same time provides more controllability, highest security and user-friendly access. So in this respect, the proposed Algerian smart grid architecture is presented in figure 3.9, which can be helpful to implement in Algeria and to achieve the objectives of this vision.

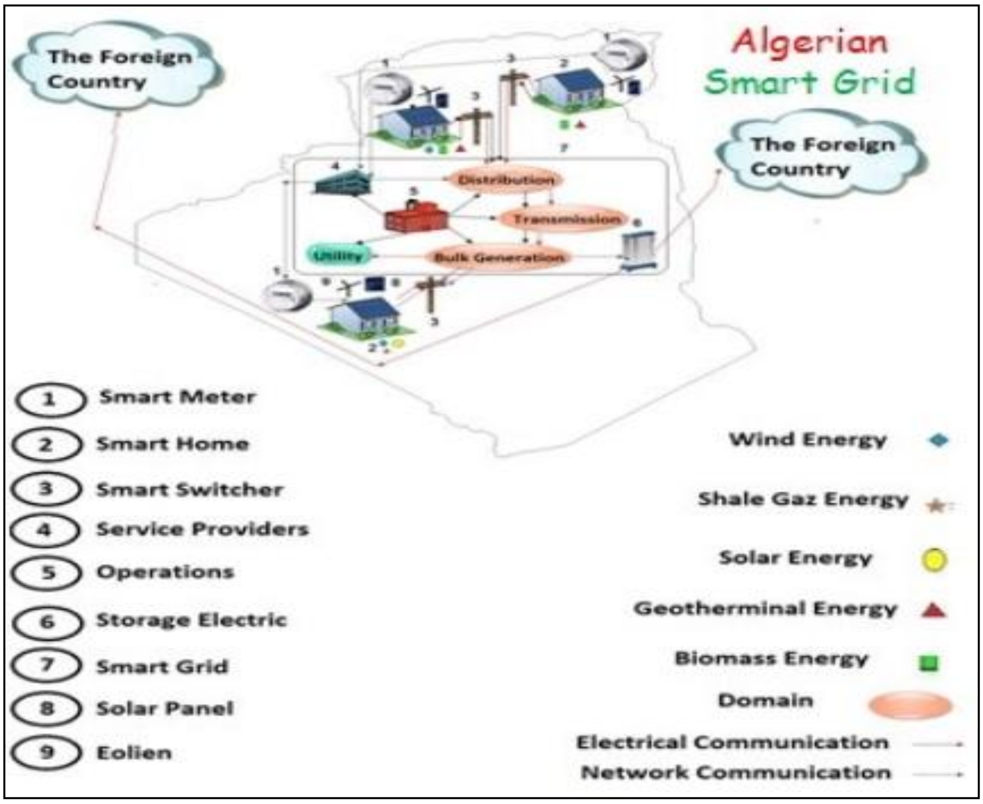


Figure 3.9 : Algerian Smart Grid [1]

The implementation of smart grid in Algeria is one of the most important initiatives of public services. They help to develop public services, implement and optimize the vision of a distribution infrastructure that distributes electricity to customers using efficient, reliable and secure way. So in this section we will represent how to manage effectively a complex feeding system which requires large numbers diversely functional devices, a communication infrastructure is required to coordinate the functions distributed through the electrical system. This system consists of seven functional blocks which are bulk generation, transmission, distribution, operation, market, customer, and service provider.

First, starting with the important domain in smart grid which is bulk generation this domain generates electricity by using renewable energy such as solar, wind hydro, biomass, geothermal and pump storage and nonrenewable energy sources such as nuclear, coal and gas. The bulk generation domain is connected to the transmission domain. It also communicates with services providers over the Internet and with the operations domain over the wide area network, after that this domain transmitted electricity to the transmission domain via multiple substations and transmission lines. The transmission domain is typically operated and managed by the RTO (regional transmission operator); it also transmitted electrically to distribution domain which distributes the electricity to the end customers in the smart grid. The RTO is responsible for maintaining the stability of regional transmission lines by balancing between the demand and supply. The distribution network connects the smart meters and all intelligent field devices, managing and controlling them through a wireless or wire line communications network. The generated energy will be consumed by several customers such as homes, building, Industry ,etc, which are connected to the distribution network through the smart meters, and the surplus of energy is stored in the energy storage in order to guarantee the availability of energy and may also export it to the foreign countries such as the Europeans environment, with condition, that they export to Algeria all devices and equipment (smart technologies) necessary to implement a smart grid system. And also provide us with a team specialist for smart grid in order to form our researches in this regard, The operations domain manages and controls the electricity flow in all other domains of the smart grid by using wireless communication. Ina smart grid, real-time prices enable wider voluntary participation by consumers through either automatic or manual response to price signals, or through a bidding process based on direct communication between the consumer and the market/system operator or through aggregators and/or local utilities [42].

3.7) Algerian Smart Home

Smart home is often presented as an object of the future that is positioned as the successor of home automation, benefiting from advanced computer including in particular the Internet of Things to manage heating, cooling, lighting, flow management (water, energy, information, etc) and security, in interaction with the occupant needs, using renewable energy resources (such as solar energy and wind energy) for the production of electricity in a way less threat to the environment, with or without wiring.

The traditional home appliances that are operated locally and manually, usually by pressing a button have little control, and management of the energy which makes their use may be unnecessary in the future. In addition, consumers receive electricity bills once each month and more typically more than 20 days after they have used the service. The customer has no way to correlate the amount of money spent on electricity with how it was used. The following figure 3.10 shows the proposed future smart home in Algeria.

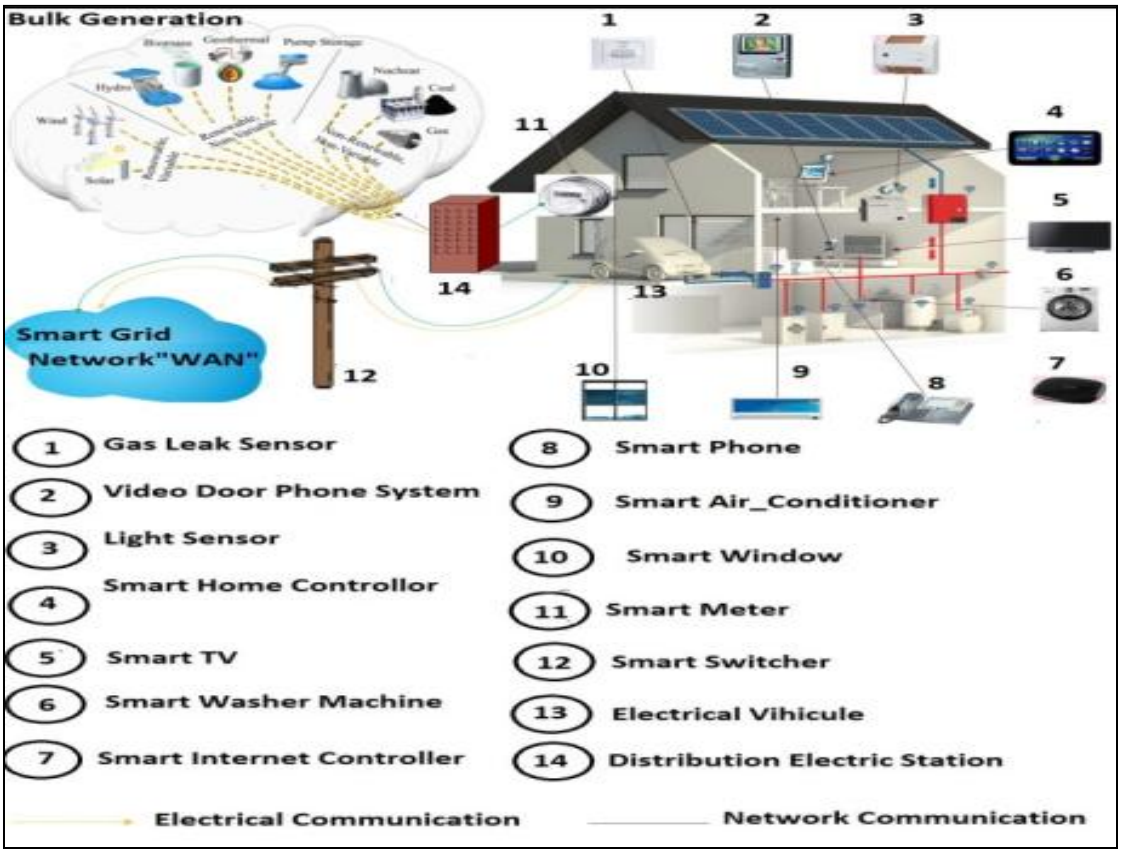


Figure 3.10 : Algerian Smart House [42]

A new way of living smarter is the integration of smart grid in the smart home; it represents the convergence of energy efficiency, controllable appliances and access in real-time to data of the energy consumption. This integration of smart devices and smart grid enables customers to proactively manage energy in a way that practical, cost effective and good for the environment. Using the Internet and a computer, or mobile device makes it possible to remote control of home appliances, and monitoring the energy usage by supplying up to date information about energy consumption.

This integration of smart devices and smart grid enables customers to proactively manage energy in a way that practical, cost effective and good for the environment. Using the Internet and a computer, or mobile device makes it possible to remote control of home appliances, and monitoring the energy usage by supplying up to date information about energy consumption.

The Communication with the utility is made possible by messages sent via the smart home controller. These messages could include advice from saving energy and warnings, as well as current information to when power outages will be restored. Smart homes satisfy customers through more efficient and cost-effective demand response programs, so that when customers want energy, it’s there. The smart home works together with the smart meter and the smart grid for the interaction of consumers with the utility. The smart home has many advantages and characteristic among them are the following:

a) Convenience: Convenience is one of the biggest reasons that people build and purchase smart homes. These homes give users remote access to systems including heating and cooling systems, intercoms, music and multimedia devices throughout the home.

b) Security: Smart homes include advanced security systems with cameras, motion sensors and a link to the local police station or privacy.

c) Efficiency*:* Smart homes offer enhanced energy efficiency. Lights can shut off automatically when no one is in a room, and the thermostat can be set to let the indoor temperature drop during the day before returning it to a more comfortable level just before residents arrive in the evening the security company.

d) Accessibility: For elderly or disabled residents, a smart home may feature accessibility technologies. Voice command systems can do things like control lights, lock doors, operate a telephone or use a computer.

In addition, the smart home turns out to be simple to install and use the product: a simple connection of electronic modules in your home with your electrical appliances, and use of the application for Smartphone, tablets and computers. The benefits of using Smart Home are several. Smart home can reduce your electricity bill by nearly 20% by the remote control of your electronics, your heating or your appliances on standby. So, smart home integrates security dimension you can control your home when you're traveling, or simulate a presence. The installation and use of a smart home are an inexpensive investment quickly pays for itself by saving energy and bringing you total comfort [42].

3.8) Conclusion

Today the mutation of traditional power grids to the smart grid has become an inevitable future for all countries; especially those possess renewable energy resources, financial resources, and smart technologies. Actually, the smart grid is a fashionable topic to talk about. It consists of a modernization of the whole current electric power grid by instilling and exploring the new popular technologies to provide more secure and reliable electricity. Many countries in the world are trying to get this promising technology In this work I presented the basic principles of smart grid and we hope to implement this new technology in our country Algeria, because it contains all the necessary means for the integration of smart grid: the financial side, scientific side, environmental side ... etc.

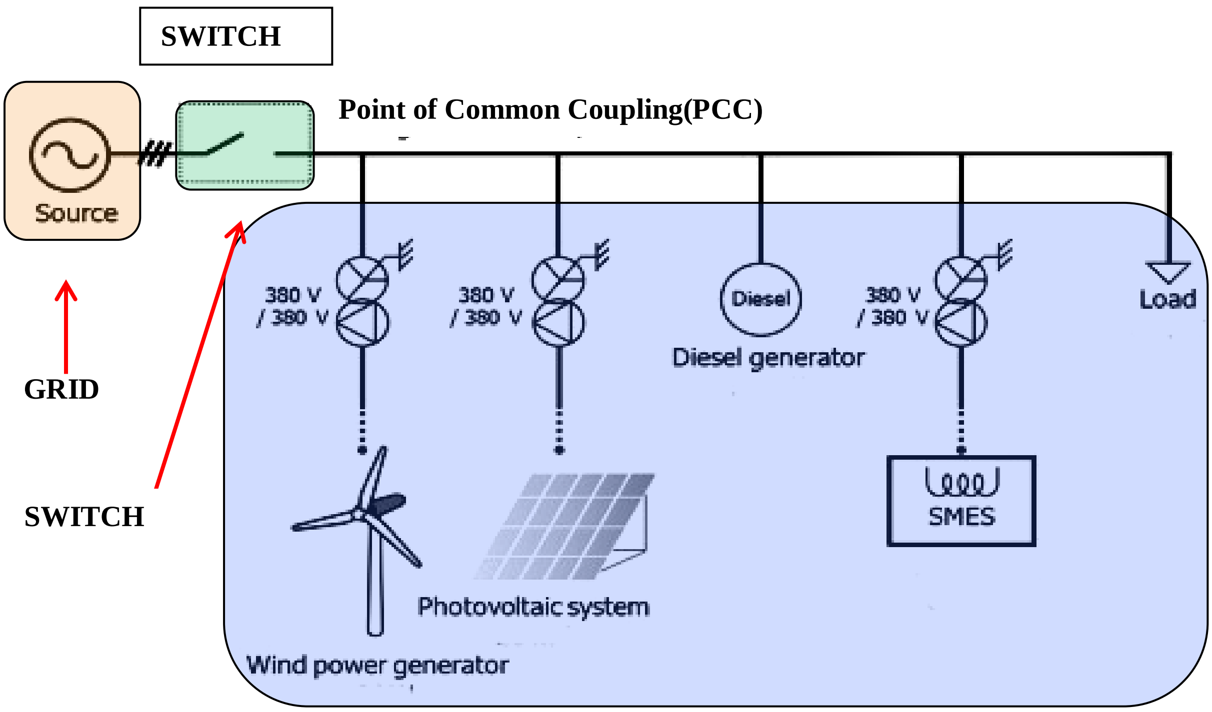
Chapter 4

4.1) Introduction

Recent innovations in small-scale distributed power generation systems combined with technological advancements in power electronic systems led to concepts of future network technologies such as microgrids. These small autonomous regions of power systems can offer increased reliability and efficiency and can help integrate renewable energy and other forms of distributed generation (DG). Many forms of distributed generation such as fuel-cells, photo-voltaic and micro-turbines are interfaced to the network through power electronic converters. These interface devices make the sources more flexible in their operation and control compared to the conventional electrical machines. However, due to their negligible physical inertia they also make the system potentially susceptible to oscillation resulting from network disturbances. This chapter discusses the detailed modeling of Microgrid components [43].

4.2) Micro grid

A Microgrid could be defined as a low-voltage distribution network with distributed energy sources altogether with storage devices and loads. Generally speaking, Microgrid could be operated in either grid-connected or islanding mode. As it illustrated in Figure 4.1



Grid-Connected mode **Figure 4.1 : Micro Grid Modes** **Island mode**

The Microgrid structure assumes an aggregation of loads and microsources operating as a single system providing both power and heat. The majority of the microsources must be power electronic based to provide the required flexibility to insure controlled operation as a single aggregated system. This control flexibility allows the Microgrid to present itself to the bulk power system as a single controlled unit, have plug-and play simplicity for each microsource, and meet the customers' local needs. There are a cluster of radial feeders in the basic Microgrid architecture. The connection point to utility grid is called point of common coupling (Lasseter 2002). Critical loads on feeders A-B require local generation (diesel generator, PV cell, wind turbine, Micro-turbine and fuel cell etc).As local control of distributed generations dominate in power system, the conventional central dispatch is not necessary. During disturbances, the static switch is able to autonomously separate the subsystem from the distribution. The static switch recloses immediately after the fault is cleared. The size of emerging generation technologies permits generators to be placed optimally in relation to heat loads allow for use of waste heat [38].

4.2.1 Load and Utility Grid Modeling

The utility grid is modeled as a 3 phase ideal voltage source with infinite power rate. This simplified model is only used for analyzing the dynamic behavior of the proposed systems. A 200kV utility grid model is shown in Figure 4.2. The models of three dynamic load and three phase fixed load with constant impedances are available in the standard SimPowerSystems library. The active power and reactive power can be controlled via the external control signals. It is especially useful when the demand response or demand side management is taken into account, which is included in next chapter. The application of one phase load will not be covered in my dissertation.

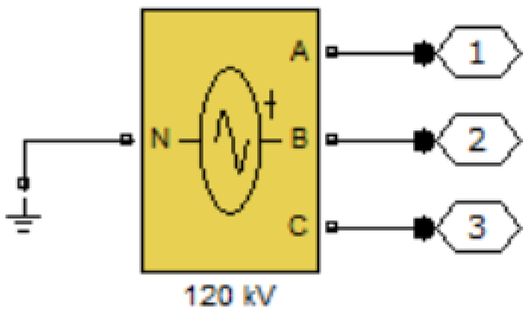


Figure 4.2: 200kV utility grid model in Matlab/Simulink

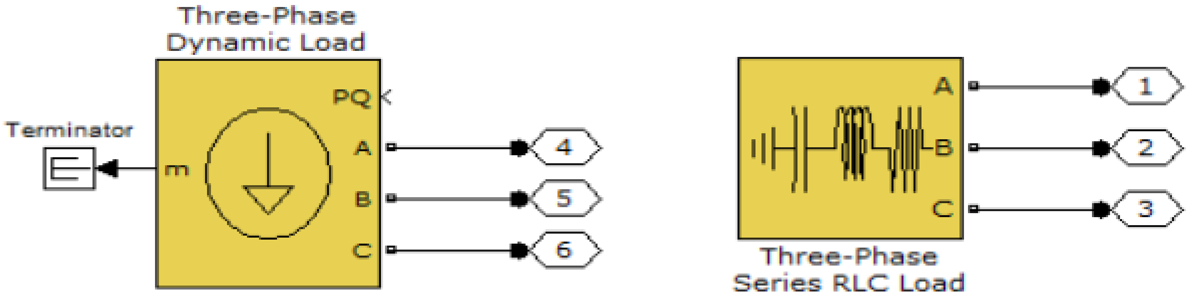


Figure 4.3: Three phase load model in Matlab/Simulink

4.2.2) Transmission Line Modeling

In the simulation, most transmission lines are represented by the three phase PI section line model which is available in the standard SimPowerSystems library. The three phase PI section line model is chosen to implement a balanced three-phase transmission line model with parameters lumped in a PI section. On contrary to the distributed parameter line model where the resistance, inductance, and capacitance are uniformly distributed along the line, the Three-Phase PI Section Line block lumps the line parameters in a single PI section. [40].The three phase PI section line model is shown in Figure 4.4.

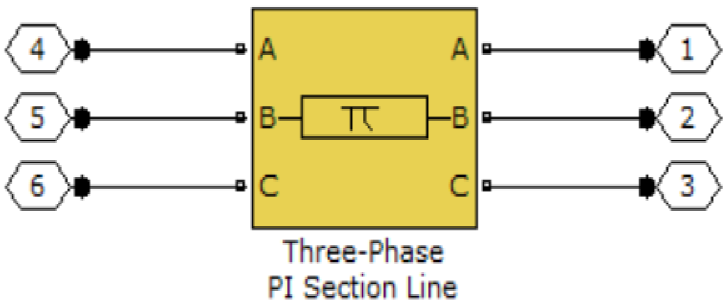


Figure 4.4: Three phase PI section line model in Matlab/Simulink

4.2.3) Distributed Generation Modeling

Photovoltaic Cell (PV Cell): The simplest model can be considered as a diode. When exposed to light, the electrons and holes are separated when the photos energy is greater than the band gap energy. Under the influence of the electric field of the p-n junction diode, the electrons and holes flow through an external circuit. Finally, the light energy can be converted into the electrical energy. The behavior of photovoltaic (PV) cells can be modeled with an equivalent circuit shown in Figure 2-4 (Duffie and Beckman, 1991). The letter “V” represents the voltage at the load. The accurate PV model is presented based on 5-Parameter or 4-Parameter equations. The basic model includes a photocurrent source, a single diode junction and a series resistance and a shunt resistance. It has to be mentioned here the shunt resistance in parallel with the diode is ignored in4-parameter model [40].

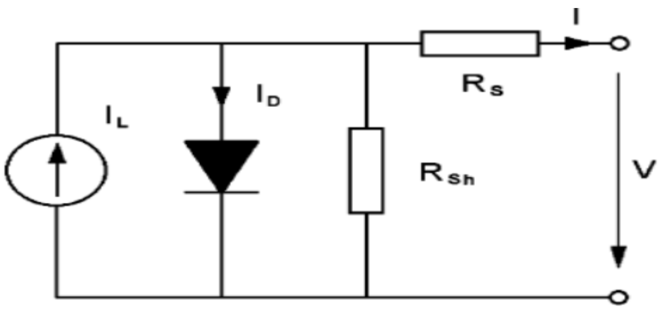


Figure 4.5: Equivalent circuit of PV cells

The equations which describe the characteristics of PV cell are presented below.. Current I is described as:

$$I = I_L - I_D \times \left(e^{\frac{V+I\times R_S}{n\times Vth}} - 1\right) - \frac{V+I\times R_S}{R_{Sh}} \qquad \textbf{(4.1)}$$

Where I_L is the photocurrent; I_D is the reverse saturation current of the equivalent diode; R_S and R_{Sh} are the series and shunt resistances of the PV cell, respectively; and n is the diode quality factor. V_{th} is the temperature dependent thermal voltage given by:

$$V_{th} = \frac{K\times T}{q} \qquad \textbf{(4.2)}$$

Where *Vth* is temperature dependent variable; the Boltzmann constant K is $\mathbf{1.3806 \times 10^{-23} J/K}$; T is the operating temperature in Kelvin degrees; the electron charge q is 1.6022 10 × $10^{-19}\,C$

$$I_L = \frac{G_T}{G_{T,ref}} \times \left[I_{L,ref} + \mu_{I_{SC}} + (T_C - T_{C,ref})\right] \qquad \textbf{(4.3)}$$

Where G_T is the actual irradiance; $G_{T\ ref,}$ is the reference irradiance; μ_{Isc} is the temperature coefficient for short circuit current; T_C is the operating temperature; and $T_{C\ ref}$, is the reference temperature.

$$I_D = I_{D,ref} \times \left(\frac{T_C}{T_{C,ref}} \right)^3 \times e^{\frac{-q\theta}{nK}\left(\frac{1}{T} - \frac{1}{T_{C,ref}} \right)} \quad (4.4)$$

And gap energy θ is assumed as 1.12eV in this case. For modeling the modules under non-standard conditions, the series and shunt resistances have to be taken care. These values are not provided by manufactures. They are not easy to estimate with enough accuracy. The shunt resistance R_{Sh} controls the slope of the I-V curve at short circuit condition. R_S gives a more accurate shape between the maximum power point and the open circuit voltages. According to Equation (2.1), the derivative of current with respect to voltage is[40].:

$$\frac{dI}{dV} = -\frac{I_D e^{\frac{V+IR_S}{nKTIq} + \frac{1}{R_{Sh}}}}{1 + \frac{R_S}{R_{Sh}} + \frac{R_S I_D q}{nKT} e^{\frac{V+IR_S}{nKTIq}}} \quad (4.5)$$

The Equations (2.1) and (2.5) are recurrence equations. The current is dependent on several variables such as voltage, irradiation, temperature, etc. As a result, each term of the equation is defined as a function of the preceding terms.

4.2.4) Battery

There are several approaches to model a battery. A commonly used battery model is the Thevenin equivalent circuit. As is seen in Figure 2-40, it consists of an ideal no-load voltage (*Eo*), internal resistance (*R*), an overvoltage resistance *Ro* and *Co*. *Co* represents the capacitance of the parallel plates. *Ro* represents the non-linear resistance contributed by the contact resistance of plate to electrolyte. The major disadvantage of this model is that all values are unrealistically assumed to be constants. It is possible to extend the Thevenin battery model to a more complex model [40]..

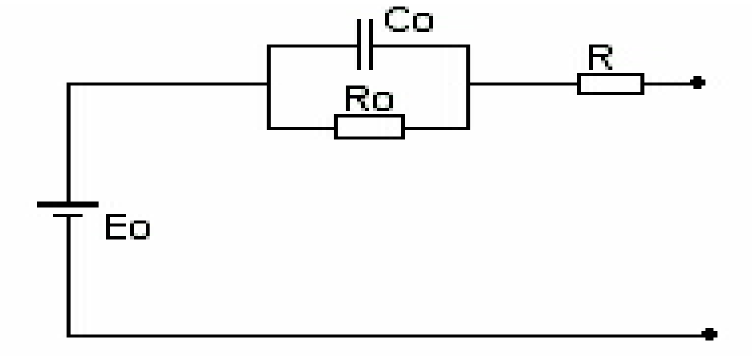


Figure 4.6:The Thevenin Equivalent Circuit of the Battery Model

The battery is also modeled using a controlled voltage source in series with a constant resistance. As proposed in [34], the battery block implements a generic dynamic model parameterized to represent most popular types of the rechargeable batteries.

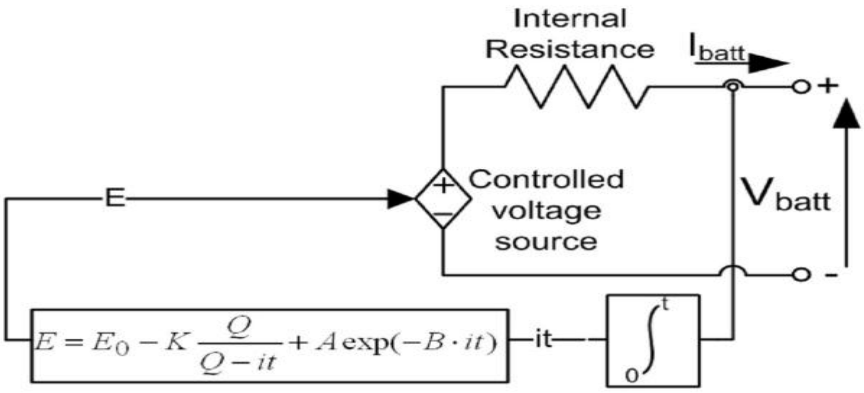


Figure 4.7: The equivalent circuit of the rechargeable battery

To prevent the battery from overcharging or discharging, the State-Of-Charge (SOC) of the battery is no greater than 100% (fully charged) and no less than 0% (empty condition) in Simulink model. SOC is defined as:

$$\mathbf{SOC} = \mathbf{100}\left(\mathbf{1} - \frac{\int_0^t \mathbf{i}\,\mathbf{dt}}{\mathbf{Q}}\right) \qquad \textbf{(4.6)}$$

4.3) Simplified Model of a Small Scaled Micro-Grid

The power micro grid is good example that shows the behavior of a simplified model of a small-scaled micro grid during 24 hours on a typical day. The model uses Phasor solution provided by Specialized Technology of SimPowerSystems in order to accelerate simulation speed.

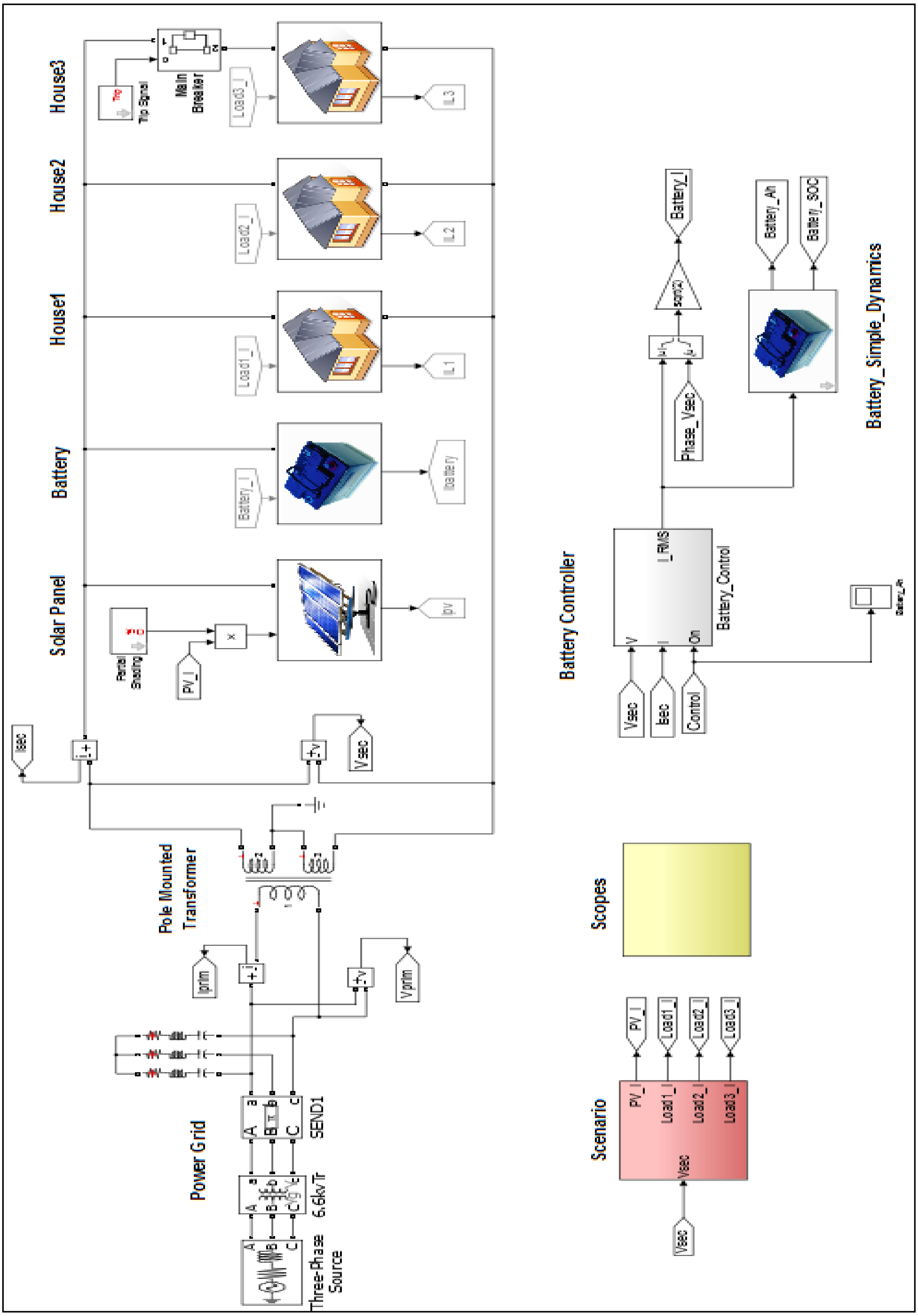


Figure 4.8: Simplified Model of a Small Scaled Micro-Grid

4.4) Description

Micro-grid is small scale energy network with its own energy supply source, electric load and power transmission method, and which, to extent possible, doesn't rely on existing power networks.

The model contains the following components:

Micro-grid is expressed as a power network of single-phase AC (200 V). Solar power generation (maximum 5kW) is a renewable energy source. Power sources are system power, solar power generation, and a storage battery (150 V, 30 Ah). The storage battery is controlled by a battery controller, and it absorbs surplus power if there is surplus power in the micro-grid or it supplies insufficient power if there is a power shortage in the micro-grid. Three ordinary houses consume power (maximum 2.5kW) as electric loads.

The micro-grid is connected to the system power via a pole-mounted transformer. The voltage source (66 kV) of three phase alternating current of the system power is connected to a transformer (primary 66 kV /secondary 6.6 kV) which decreases voltage from 66KV to 6.6 KV. The pole-mounted transformer (primary 6.6kV /secondary 200 V) changes the voltage from 6.6 kV to single-phase AC (200 V). The frequency of AC cycles is set to 60 Hz. The solar power generation and the storage battery are DC power sources converted into single-phase AC. These are both connected to the micro-grid. It is assumed that in control strategy, the micro-grid does not depend on system power for power consumption, and required power is provided by solar power generation and the storage to the extent possible.

4.5) Simulation Results:

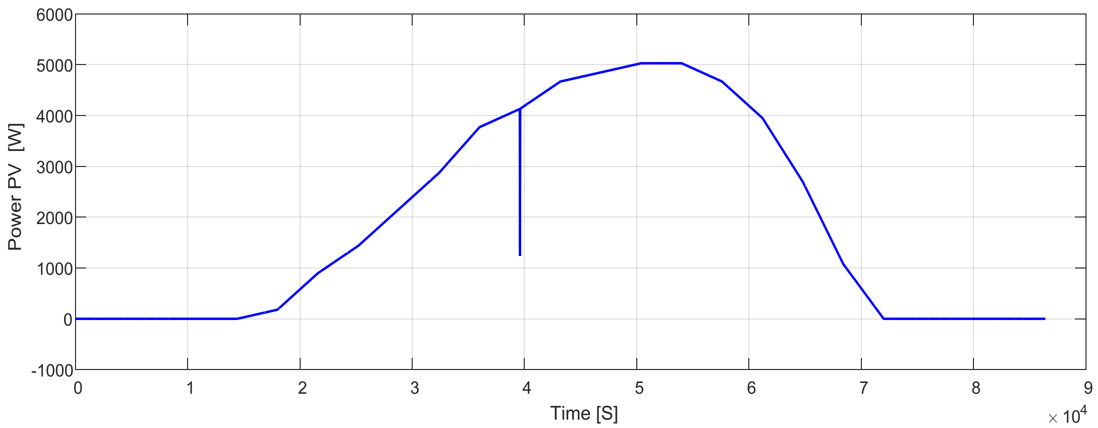


Figure 4.9: Pv power simulation

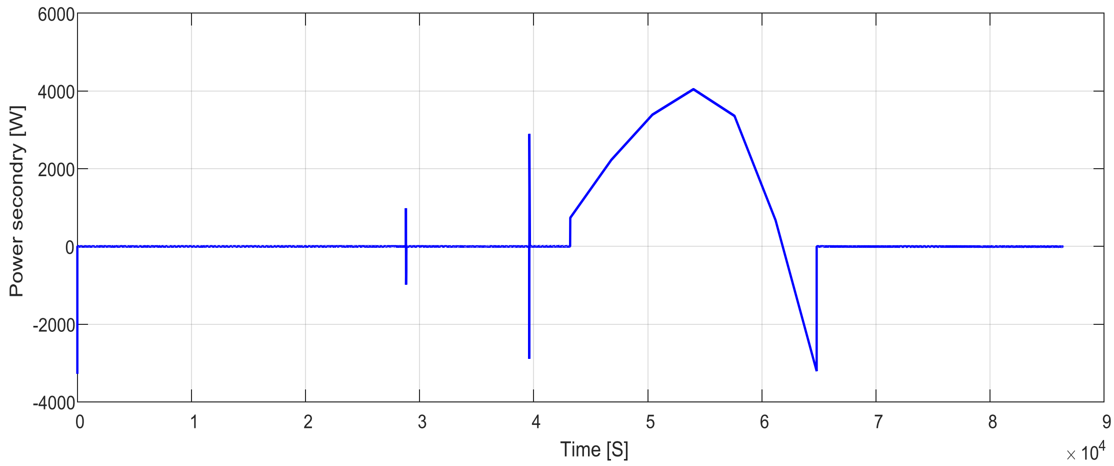


Figure 4.10: power secondary simulation

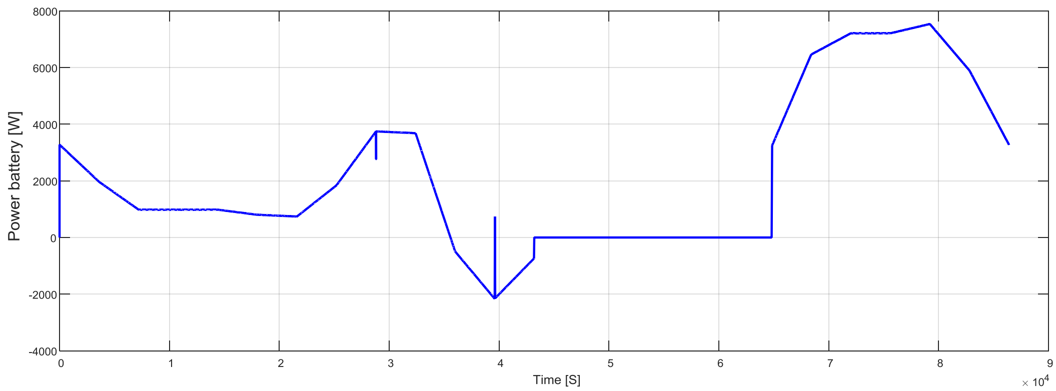


Figure 4.11: power battery simulation

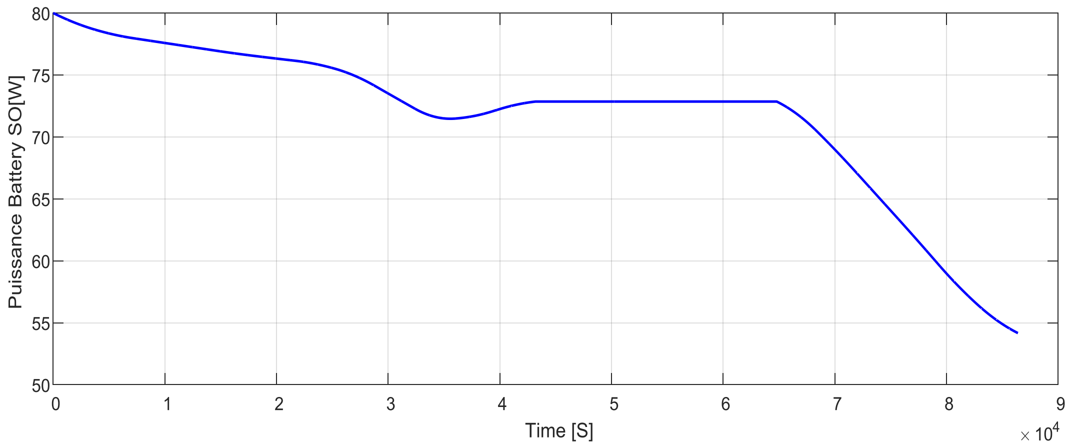


Figure 4.12: power battery soc simulation

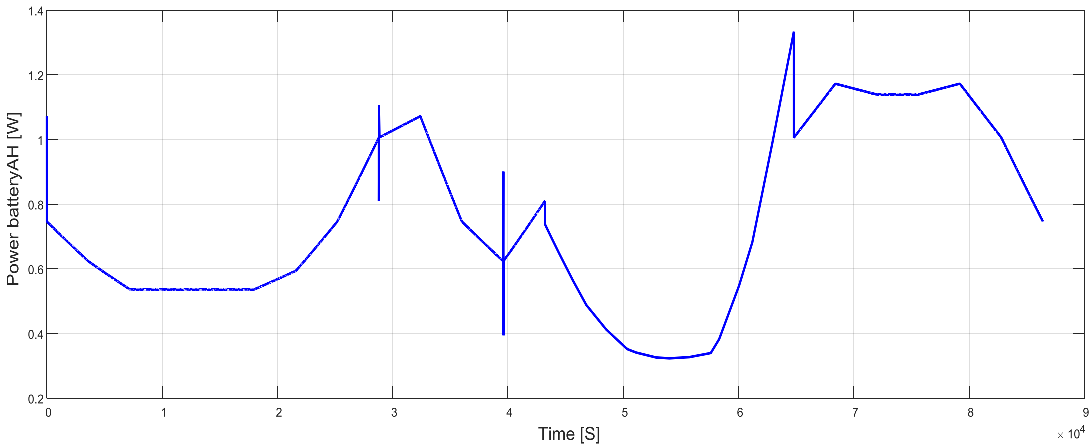


Figure4:13 power Battery AH simulation

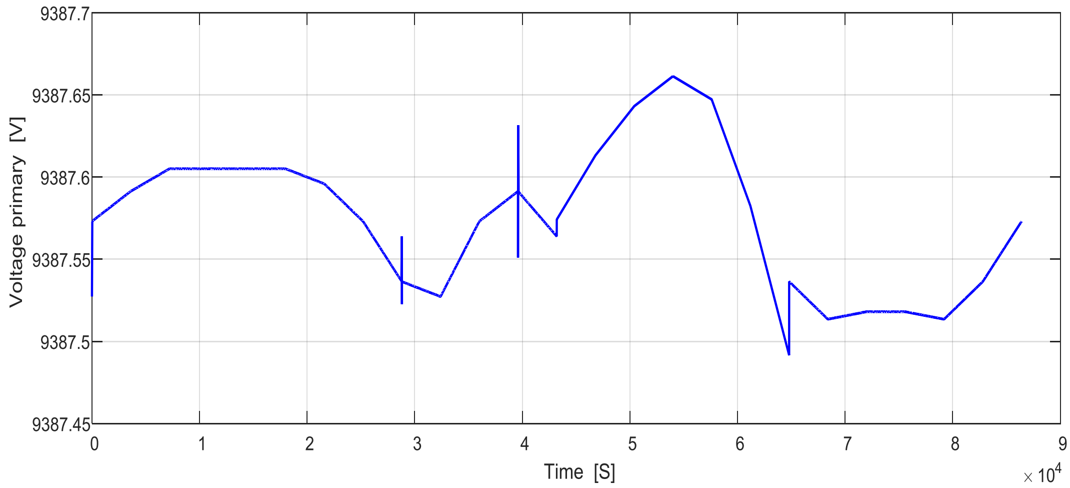


Figure 4.14: voltage and current simulation

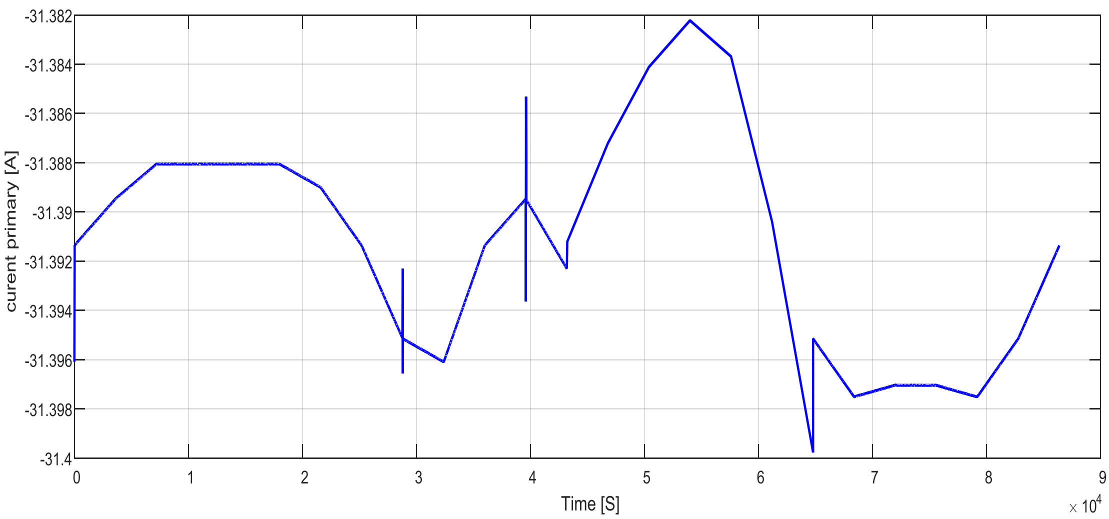


Figure 4.15: current simulation

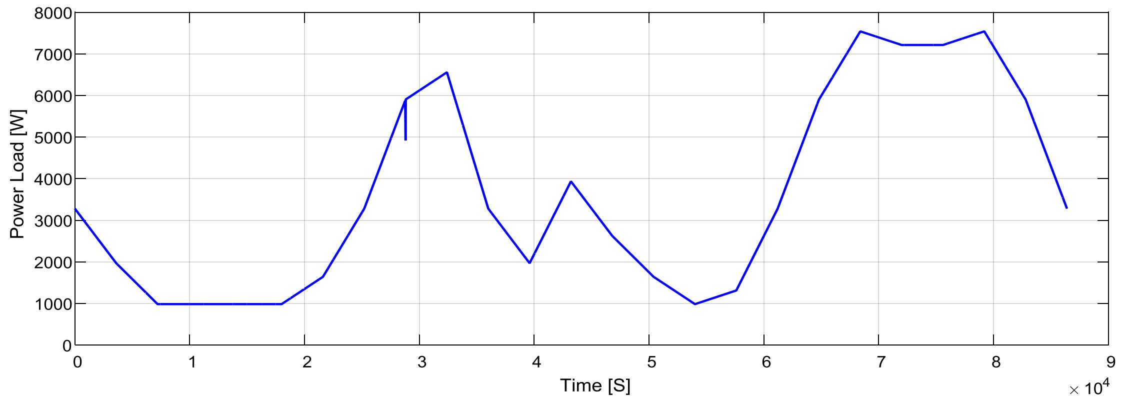


Figure4.16: power load simulation

4.6) Results Analyze

From 20h to 4h, solar power generation is 0W. It reaches the peak amount (5kW) from 14h to 15h. As a typical load change in ordinary houses, the amount of electric power load reaches peak consumption at 9h (6,500W), 19h, and 22h (7,500W).

From 0h to 12h and from 18h to 24h, battery control is performed by battery controller. The battery control performs tracking control of the current so that active power which flows into system power from the secondary side of the pole transformer is set to 0. Then, the active power of secondary side of the pole mounted transformer is always around zero.

The storage battery supplies the insufficient current when the power of the micro-grid is insufficient and absorbs surplus current from the micro-grid when its power is surpasses the electric load.

From 12h to 18h, battery control is not performed. SOC (State Of Charge) of the storage battery is fixed to a constant and does not change since charge or discharge of the storage
Battery is not performed by the battery controller. When there is a power shortage in the micro- grid, the system power supplies insufficient power. When there is a surplus power in the micro-grid, surplus power is returned to the system power.

At 8h, electricity load No. 3 of an ordinary house is set to OFF for 10 sec by the breaker. A spike is observed in the active power on the secondary side of the pole transformer and the electric power of the storage battery.

4.7) Conclusion

The smart grid simulation is based in the simulation of microgrids that is a simple power system compared to the smart grid which contain a lot of complexity for that reason, I choose to simulate a microgrid that contain distributed generation pv and short-term storage is conducted to analyze the dynamic performance of Microgird components. All the models derived from theoretical equations or experimental data have been built in MATLAB/SIMULINK.

Simulation result shows the behavior of small scaled micro grid and its components during a 24 hours and how the micro grid do the management of this power sources to the load.

General Conclusion

General Conclusion

Algeria is well placed to continue to be a major player in the lucrative market of renewable energies. However, transition to renewable energy will need to be accelerated. It is hoped to use the Algerian renewable energies in order to integrate a smart electric system or smart grid.

Today the mutation of traditional power grids to the smart grid has become an inevitable future for all countries; especially those possess renewable energy resources, financial resources, and smart technologies. Actually, the smart grid is a fashionable topic to talk about. It consists of a modernization of the whole current electric power grid by instilling and exploring the new popular technologies to provide more secure and reliable electricity. Many countries in the world are trying to get this promising technology. This master dissertation is Summarized all the energy potential in Algeria and the structure of traditional electrical grid to make Algerian power system smarter. Besides to Increase understanding of the costs and benefits of smart grids , also Identify the most important measures to develop the technologies of smart grid system that help meet energy and climate goals [4].

In this dissertation, we have proposed a simulation of micro grid as a part of smart grid; because it's a good example that shows the behavior of a simplified model of a small-scaled micro grid during 24 hours on a typical day.

I hope this new technology will be implemented in our country Algeria, because it contains all the necessary means for the integration of smart grid: the financial side, scientific side, environmental side ... etc. especially in the south of Algeria, where all the resources are available. I also hope to go to more areas of research especially in the areas of routing, monitoring and security of smart grid.

References

References

[1] K. Benahmed and A. Douli "Design of Smart Grid System in the South of Algeria".International Conference on Information Technology for Organization Development, IEEE , University of, Bechar.Algeria p5, 2014.

[2] K. Benahmed and A. Douli « Proposed Vision of Algerian Smart Grid » IEEE, University of Tebessa, Algeria, p5, 2014.

[3] M. Osmani , F. Loucif "Renewable Energies and Shale Gas in Algeria, between fact and perspectives" Colloque sur : Les politiques d'utilisation des ressources énergétiques : entre les exigences du développement national et la sécurité des besoins internationaux.

[4] U.S Energy Information Administration: http://www.eia.gov.

[5] M. kaced, le pontentiel shale gas on algerie, journees d'etudes : tight and shale reservoirs , institut algerien de petrole, alger, 2013.

[6] A. B. Stambouli, Z. Khiat, S. Flazi, Y. Kitamura, "A review on the renewable energy development in Algeria: Current perspective, energy scenario and sustainability issues", Renewable and Sustainable Energy Reviews, vol. 16, 2012.

[7] www.globaspec.com/learnore/optics_optical_components/optoelectnics/ photovoltaic cells.

[8] www.sbcenergyinstitute.com/Publications/SolarPower.html.

[9] The Renewable Energy Sector in North Africa Current Situation and Prospects September 2012, www.renewableseenergyworld.com.

[10] N. Kasbadji "wind energy assessment in Algeria. Proceeding of International Workshop on Physics and Renewable Energies. pp. 28-32.2010.

[11] www.sciencedirect.com/science/article/pii/s0360319910019348.

[12] Bringing Europe and Third countries closer together through renewable Energies WP3: BETTER North Africa Case Study Final Report May 2015, www.better project.net.

[13] www.cder.dz

[14] www.ucsusa.org/clean-energy/how-electricity-grid-works#.WQzoIvnyvcc

[15] https://en.wikipedia.org/wiki/Electrical_grid

[16] https://cleantechnica.com/2015/12/16/how-the-grid-works-why-renewables-can dominate/

[17] T. Flick, Justin Morehouse and Christophe Veltsos(TE), "Securing the Smart: Grid Next Generation Power Grid Security", Elsevier Inc ,USA , 2011, pp10.

[18] https://en.wikipedia.org/wiki/Power_station.

[19] http://chemistry.elmhurst.edu/vchembook/193sources.html.

[20] https://nuclear-energy.net/how-nuclear-power-plant-work.html.

[21] http://www.electricaledition.com/2016/01/comparison-of-overhead-lines underground-cables.html.

[22] http://www.hydroquebec.com/learning/transport/types-pylones.html.

[23] http://solareis.anl.gov/guide/transmission/.

[24] http://www.theenergyofchange.com/electric-conductors-transmission-line.

[25] https://www.123rf.com/photo_15152467_high-voltage-electrical-substation.html.

[26] https://www.powercor.com.au/media/1247/fact-sheet-the-power-grid.pdf.

[27] J. Seymour the seven types of power problems Shneider Electric pdf.

[28] https://smartgridtech.wordpress.com.

[29] J.Rogers "power currency" covers and illustration Ting He and Cong Yu, p201,2010.

[30] www.sonelgaz.dz.

[31] CRED "Algeria- A Future Supplier Of Electricity From Renewables Energies For Europe" August 2010.

[32] M. Jarrah "Modeling and Simulation of Renewable Energy Sources in Smart Grid Using DEVS Formalism" The 7th International Conference on Ambient Systems, Networks and Technologies (ANT 2016) , www.sciencedirect.com.

[33] C. Bekara "Security Issues and Challenges for the IoT-based Smart Grid" www.sciencedirect.com, 2014.

[34] H. Mohsenian-Rad "Introduction to Smart Grid" Department of Electrical & Computer Engineering Texas Tech University Spring 2012.

[35] Technology Roadmap, Smart Grid, International Energy Agency (IEA), http://www.iea.org/papers/2011/smartgrids_roadmap.pdf, , 2011.

[36] M. dRahat Hossain, Amanullah M. T. Oo and A. B. M. Shawkat Ali"smart grid opportunities development and trends" School of Information and Communication Technology, Springer-Verlag London, Australia 2013.

[37] N.A. Hidayatullah "Impacts of Distributed Generation on Smart Grid" Master of Engineering (Electrical Engineering), Victoria University February 2011.

[38] S. Kanti Bala"Study of Smart Grid Technology and Its Development in Indian Scenario" Bachelor of Technology in Electrical Engineering , Institute of Technology Rourkela, Odisha, India ,May, 2013.

[39] J. Momoh"'Smart grid design for efficient and flexible power networks operation and control', Power Systems Conference and Exposition, PES '09, IEEE/PES, p.203, 2009.

[40] N. Hadjsaïd and J.C. Sabonnadière « smart Grid » © ISTE Ltd and John Wiley & Sons, UK.,USA, p 355, 2012.

[41] W. Aissa smart grid presentation, ppt , Exeter University 2013.

[42] K. Benahmed and A. Douli « Proposed Vision of Algerian Smart Grid » IEEE, University of Tebessa, Algeria, p5, 2014.

[43] W. Su « Microgrid Modeling, Planning and Operation » Master's Thesis Master of Science In Electrical Engineering , Blacksburg, Virginia p120, 2009 .

ABSTRACT

The electricity demand increases by the increasing of population which causes several problems in the grid.Moreover, the use of the conventional sources cannot meet the needs of consumers; in this case the use of renewable energy will be very beneficial and economical to avoid these problems. The so-called smart grid is supposed to solve these problems through the ICTs to provide monitoring and controlling capacities. Consequently, many countries in all over the world competitively get in the countdown race to adopt this new technology. Through this master dissertation, I will do a simulation of simple scaled micro grid to show the behavior of its components besides show a vision of Algerian smart grid and the need of use it this new power system in Algeria to be our electric grid more reliable, flexible, efficient.

RESUME

La demande d'électricité augmente par l'augmentation de la population qui pose plusieurs problèmes dans le réseau électrique. En outre, l'utilisation des sources conventionnelles ne peut pas répondre aux besoins des consommateurs; Dans ce cas, l'utilisation des énergies renouvelables sera très bénéfique et économique pour éviter ces problèmes. Le réseau intelligent est censé résoudre ces problèmes à travers leTIC pour fournir des capacités de surveillance et de contrôle. Par conséquent, de nombreux pays dans le monde participent de manière compétitive à la course à rebours pour adopter cette nouvelle technologie. Grâce à cette mémoire de master, on a faire une simulation d'un microréseauà échelle simple pour montrer le comportement de son composants, en plus de montrer une vision du réseau algérien intelligent et la nécessité d'utiliser ce nouveau système d'électrification en Algérie pour devient notre réseau électrique plus fiable, Flexible, efficace.