# The Future Development of Smart Grid

## The case of Morocco

Nada Belkebir[1,2], Mohammed Maaroufi
[1] Ecole Mohammadia d'Ingénieurs
Mohammed V University
Rabat, Morocco
E-mail: nada.belkebir@gmail.com
maaroufi@emi.ac.ma

Ahmed Khallaayoun, Rachid Lghoul
School of Sciences and Engineering
[2] Al Akhawayn University in Ifrane
Ifrane, Morocco
E-mail: a.khallaayoun@aui.ma
r.lghoul@aui.ma

***Abstract*— Morocco is becoming more concerned about the protection of environment as it conducted different studies and strategies with the High Planning Commission (Haut Commissariat au Plan) and under the directives of top Moroccan managers whose purpose is to integrate sustainable energy in its economic activities. It is in this direction that Morocco prepared one of the largest studies "Prospective Maroc 2030" and in which a whole section was devoted to shine the light on the issues and challenges related to energy that the country has to face. With an expected growth of 5 to 6% in electricity consumption and with the integration of renewable energies, Smart Grid seems to be the natural transition to deal with the different fluctuations that the grid will be subjected to. This paper evaluates the current status of Smart Grid in Morocco in comparison with other developing countries. An overview of the energy sector in Morocco is presented. The regulations related to the power sector are also discussed. Then challenges and recommendations will be discussed at the end of the paper.**

***Keywords- Smart Grid; Morocco; Renewable energies; Energy; Electricity***

## I. INTRODUCTION

As the electric grid got bigger and bigger, control and monitoring became imperative to ensure its management. The aging infrastructure and the ever increasing demand render the conventional grid susceptible to recurring failures. With the revolution of communication systems and the need to make the grid smarter, the idea of the Smart Grid (SG) saw light to enhance the functionality of the electric grid. The latter is achieved by introducing sensors, controls, and communication tools to enable a better management of energy. The electrical grid is divided into three major parts: generation, transmission and distribution. Today's generation relies on two different types of resources; fossil fuels, such as coal, oil or natural gas and renewable energies, such as wind, solar, biomass or hydropower. The inclusion onto the grid of the second type of energies makes it more difficult to manage due to the inherent intermittence of those resources. As for the transmission part, the electric grid suffers from losses which if managed correctly can save a significant amount of energy. As far as the distribution is concerned, electricity was conventionally distributed from retailers to customers. Nowadays, however, a new distribution concept was introduced, which consists of distributed generation. It consists of having small production units that the customer can own and can locally produce the electricity needed. SG aims then at assuring reliability, minimizing cost and managing resources [16].

Section II describes the features, the components and the challenges facing the SG. Section III presents the situation of SG in different countries. Section IV describes the current situation of the Moroccan electric grid and how electricy is governed. In addition, the government initiatives that aim at implementing the SG in Morocco and the challenges that the country is facing are included. Section V presents a comparison between Morocco and other countries when it come to SG.

## II. DESCRIPTION OF SMART GRID

SG is a modern electric grid characterized by the use of sensors, communication technology and controls with the goal of applying intelligence to optimize generation, transmission, and distribution [15]. This section presents the main features of a typical SG and presents its main components.

### *A. SG Features*

One of major features that characterizes a SG is its ability to manage a complex network that contains central and distributed generation that use both, conventional and renewable resources. The network uses a multitude of telecommunication schemes where internet and electronic applications are used to optimize the use of energy. These features create a new energy value chain capable of mixing different technologies and in which distributed generation is encouraged. With the introduction of small and medium power farms, the introduction of technology enables customers to manage their energy depending on the local production. Energy distribution is then managed depending on the different regulations set by the retailers or the customers. With the introduction of smart meters each customer has the ability to get a closer look at its consumption and manage it depending on the dynamic energy pricing which can therefore reduce the peak

 ISBN: 978-1-61208-635-4 

demand and flatten the demand curve [2]. The SG does not only manage energy at the home/building level, but it expends to managing whole districts by creating systems that combine data coming from different energy management systems. In other words, the aim of the SG is to manage the energy produced from micro-grids and the energy coming from macro stations in the most optimized manner, enabling a reduction in energy losses and minimization of energy cost. Mainly, the SG aims at reducing Green House Gases and $CO_2$ emissions, providing a better transmission and a better distribution [3].

### B. SG Components

The SG is a set of individual technologies that cover the entire grid. In order to optimize the electric grid, different technologies continue to be deployed. The most important components of SG are the listed below [2]:

- *Wide-area monitoring and control*: concerns the generation and transmission side of the grid, it enables the grid to mitigate wide-area disturbances, and improve transmission capacity and reliability.
- *Information and communication technology*: spans the whole grid and is considered the backbone of the system. This technology starts from the generation level and goes down to the residential, industrial and service level. It can use different forms of communication networks that aim at providing the necessary support for data transmission. The communication technology used enable two way communication within the grid.
- *Renewable and distributed generation integration:* renewable energies need to be integrated at the transmission level and at different scales (High, medium, and low voltage). With the inherent intermittence of renewables, management of the various resources becomes more challenging. The introduction of storage and additional spinning reserves may then be required to ensure grid stability.
- *Advanced Metering Infrastructure (AMI)*: considered as the building blocks of the SG, smart meters allow customers to receive information about their energy consumption and inform them about other details, such as electricity prices, amount of energy consumed, losses and theft detection; which can help them better manage their electricity use and ultimately reduce their bills.
- *Electric vehicle charging infrastructure*: As the electric cars are introduced into the market, the load curve, due to the additional stress on the grid, might see a significant variation that might render the grid unstable. The advanced metering infrastructure will become the mean by which those variations are controlled.
- *Customer-side systems*: it concerns all systems that can be used either in the industrial or residential sectors that allow a better energy management and that can help increase energy efficiency. Those systems are energy management systems, energy storage devices, smart appliances and distributed generation; they connect the customer side to all the previous cited technologies that make the SG.

### C. SG Communication and security

As mentioned before, the SG needs different components to get the intelligence necessary to optimize energy consumption and reduce the customer's bill. The grid is divided into two main parts. The first one concerns the high voltage lines that connect the power plant to the distribution substations. Electricity is then transformed via the substation to medium voltages after which it is distributed to building feeders. Communication between the power plant and the transmission substations is established using high speed optical fibers. The reason behind this choice is the need to transfer high volume of SG data, with the least possible delay. The second part includes different networks. The first network is the Neighborhood Area Network (NAN) that usually manages energy at the neighborhood level. This latter serves different Building Area Networks (BANs). Each BAN manages energy of each separate building, which means that it includes a number of Home Area Networks (HANs). Each HAN gathers a number of home appliances all connected to the HAN gateway. Communication at the HAN is achieved using ZigBee, since it requires a low power compared to Wi-Fi or Bluetooth connections. As mentioned before, the BAN gateway monitors the energy consumption of different HANs. Wi-Fi can be used as a communication tool here, but when the BAN covers many households in a large area it requires the deployment of additional access points. Having multiple access points in close proximity will interfere with other access point dedicated for internet usage. An alternative can be the use of 4G technologies, which can facilitate the communication between a BAN and its HANs. When it comes to the NAN, the connection can be done using 4G technologies as well. Figure 1 presents how communication is set between different networks discussed before [16].

It is imperative that the SG is secure and has the ability to prevent unwanted data exchange and malicious threats. For that purpose, a robust encryption mechanism needs to be implemented although it might cause a significant delay in data transmission.

### D. SG Challenges

The most important challenge that the SG faces is to match supply and demand. In fact, the SG needs to adjust its generation depending on the data provided from the demand side. This latter is provided by different types of demand responses which require accurate forecast and customer participation. Privacy becomes an issue when customer consumption behavior is recorded; the SG needs to protect data coming from customers to avoid any privacy issues. Another challenge of the SG is to find a balance between minimizing the bill for the customer vs. maximizing the profit for the utility. Different types of contracts can be set between the two in order to reach an equilibrium depending on each specific case.

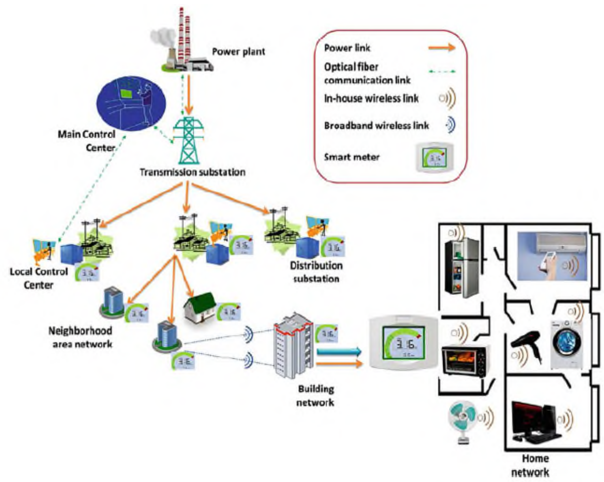


Figure 1. Hierarchical communication networks in a SG model [16]

Another challenge facing the SG concerns the transmission losses and the power loss due to storage. New algorithms need to be developed in order to optimize power distribution and transmission of electricity. Last but not least, security discussed in the previous part needs to be provided in order to prevent threats that might cause damage to the grid [16].

## III. SG in Different Countries

After looking at the components and challenges of the SG, Section III will present what some countries have undertaken to develop a SG.

### A. *SG in India*

India faces many challenges when it comes to the electric grid. Even though it has a good energy mix that includes conventional and renewable energies, the future of its economy is considered as being at risk if nothing is done regarding the quality of its electric grid. The total installed capacity of the country was 329 GW by the end of September 2017; 31.3% of its demand is met by renewable energy resources and it is expected to keep increasing by 2030-2040 in order to meet the demand [20]. As of 2014, only 79% of the population had access to electricity [19]. Moreover, the transmission and distribution losses at the end of the same year were estimated to 19% [19]. Because of the aforementioned challenges, the Central Electric Authority created the "National Smart Grid Mission (NSGM)". This new organization was created on March 27$^{th}$, 2015 in order to monitor and implement new policies and programs related to the SG [20]. The Ministry of Power also released in 2013 a SG roadmap for India, in which the vision and the targets of the country when it comes to its electric grid were stated. The SG vision of India is to change the Indian electric grid into a safe and sustainable one, in which electricity is assured for all [21]. In order to achieve this vision, many sub-goals need to be achieved:

- At the distribution level: new policies need to be launched in order to guarantee access to electricity to all households by 2017. Another target of the NSGM is to reduce transmission and distribution losses to below 15% by 2017 and below 10% by 2027. After the success of the pilot projects of AMI in 2016, the Indian government is planning to develop smart meters with the necessary IT and communication infrastructure by 2027. Moreover, the development of Microgrids is also one of the main targets of NSGM; in fact, it is expected to have 10,000 Microgrids in villages, industrial parks or commercial hubs in order to reduce the peak demand by 2022 [21].
- At the transmission level: the NSGM intend to implement a Wide Area Monitoring Systems using Phasor Measurement Units for the whole transmission system by 2017. 50,000 Kms of optical fiber cables are planned to be installed in order to facilitate the implementation of the SG technologies. The Indian government plans also to set up a Renewable Energy Monitoring Center in order to ease the integration of renewables [21].

Releasing new policies and standards for all these initiatives is part of the SG roadmap, as they will enable an active involvment of customer. In fact, policies need to include Demand Response (DR) programs and dynamic pricing that can be used once the smart meters are installed [21]. It can be concluded that India is now aware of the importance of the SG for the future of its economy. The development of smart metering is the first step that will enable the country to get a better view on its energy consumption which will enable a better introduction of renewable energies to the Indian grid.

### B. *SG in Turkey*

The electricity market of Turkey was for years controlled by the state, which created a high level of centralization [5]. By the 1980s generation, transmission and distribution started to be delegated to different companies. Small power plants started to see the light, which created a more efficient environment in which cheap energy generation was available. In 2004, new laws regarding how the privatization of the electric sector were published. All the transmission operations are led by the state control, while distribution is covered by private companies that are each responsible for their respective regions (as Turkey is divided into 21 regions) [6]. As for the distribution, private companies made some improvements in terms of the monitoring and control of electricity as they implemented the Supervisory Control and Data Acquisition (SCADA) software. This technology enables companies to get the necessary data to avoid any outages. Geographical Information Systems (GIS) is also an important tool used by the Turkish distribution companies as it enables locating places of high and low voltage consumers. Automated Meter Reading (AMR) is also used to collect data about the consumers' consumption. All data collected by the cited technologies is then integrated in a system to enable better optimization of electric energy in Turkey [7]. The total installed capacity of Turkey reached 80 GW in July 2017; 35% of this capacity is from renewable energy resources [22]. In 2014, the country was still suffering from 15% of electric power transmission and distribution losses [19]. Introducing smart metering will help reduce this percentage and increase energy supply efficiency; Turkey has dedicated $5 billion to invest in SG technologies in 2015 [5]. On the other hand, Turkey is also concerned with the introduction of renewable energies, as it launched a strategic plan between 2015 and 2019 that aims at providing energy security; by increasing the percentage by which renewable energies contribute to the energy supply and by keeping investments on transmission and distribution components as they are the connecting bridge between supply and demand [22]. Support programs for R&D in the SG domain are also very encouraged in the country [5].

### *C. SG in the U. S.*

The total electric generation capacity of the U.S. reached 1,190.5 GW in 2017 with 17% of it coming from renewable energy resources [24]. The transmission and distribution losses of the U.S. was estimated to 6% in 2014 [19]. The modernization of the U.S. electric grid started in the 1980s. In 2004 the term “Smart Grid” got its first references by Amin and Wollenberg [7]. New policies and regulations that encourages the introduction of renewable energies and distributed generation were launched which led to significant investments by the American Recovery and Reinvestment Act of 2009 that reached $9 billion in 2010 [8]. Progress followed throughout the years in order to improve the many areas of the SG. In 2014, a total of 65 million smart meters were installed in the country; this number represents more than the third of electricity customers. The U.S. also intends to develop customer-based technologies, such as building energy management systems for residential, commercial and industrial customers. Those systems, and with the integration of sensors and AMI, can provide users with a better management of their energy which can increase efficiency in different sectors [8]. The U.S. SG Initiative launched in 2007 was a formalized way to set all the objectives the nation has to achieve, including the development of new storage and peak-shaving technologies, with a pulg-in hybrid electric vehicle [7]. In 2011, the annual SG spendings hit $5.2 billion. These investments were dedicated to the advanced SG projects, distribution automation and smart metering. It was expected that in 2017, the total investments in SG would be about $3.3 billion. The number may seem to decline, because less spending are dedicated to smart metering, but in reality it will gradually increase for the case of the distribution automation as it was $1.2 billion in 2011 and was expected to be $1.9 billion in 2017 [7]. Moreover, the U.S. intend to increase its energy mix by creating more solar, wind and nuclear plants, as they account for more than 10% of the pending plants application. As for the planned power plants, wind account for one third of the proposed plants [24].

### *D. SG in China*

The Chinese power grid China was considered as being vulnerable. This conclusion was made after the snow storm of 2008 that caused a blackout in a major area of the country. Moreover, the power distribution of China’s grid had a lack of intelligence which led to either seasonal shortages or surplus in different areas. The main objective of China is to have a strong grid that can enable a better integration of renewable energies and increase energy efficiency in order to adapt to climate change. On the other hand, the country needs to attract more investors in order to have a better privatization of its electric industry and therefore have more competitiveness in the market. Providing a safe power sector is ultimate if the country wants to have more investors [9]. For these purposes, China focuses on the development of its SG on high voltage and main network intelligence. In other words, the developpement will focus on increasing the transmission capacity and security of energy supply [10]. The SG concept in China is a bit different from the one in western countries. As a matter of fact, China intends to invest largely in large power plants; and for that purpose it is building a strong Ultra-High-Voltage (UHV) power network in order to keep increasing transmission efficiency and reduce energy losses. It is in May 2009 that the State Grid Corporation of China (SGCC) shared it’s strategic plan to make the chinese grid smart. Considered as one of the priorities of the chinese government, the implementation of the SG in China follows three part [27]:

- 2009-2010: it is during this period that pilot projects were created in order to test what are the best options for the chinese grid and make the master plan for he SG
- 2011-2015: called the construction period, it is during this period that China implemented the main SG technologies that can help keep up with the extensive growth of the energy sector of the country
- 2016-2020: it is the final period where all the upgrades should be made in order to acheive a reliable and strong grid, in which China can optimize its grid at all levels

With its 1,645.75 GW of total installed capacity recorded in 2016 [26], China considerably reduced its transmission and distribution losses as they reached 5.4% in 2014 [19]. The chinese government is also aware of the importance of the energy mix. In 2016, 24.8% of the total electricity of the country was generated from renewable energy resources. This percentage is expected to reach 30% by 2020 [27]. To meet the demand, China is developping a smart dispatch and control technologies that can make energy available countrywide. The last characteristic of the chineese SG is that customer participation and demand side management are limited compared to west countries [11].

The development of the SG is specific to each country. As seen in this section, the development of a SG can only take place once the grid is robust. Making the grid strong and ready to keep up with the energy growth is the first step towards SG; this was the case in China and India. The

 ISBN: 978-1-61208-635-4 

countries can then focus on the optimization of the grid, by increasing its energy mix and including new IT and communication tools that can increase energy efficiency, as it is the case for the US. For the case of Turkey, the country still needs to improve its electrical grid, in order to reduce its transmission and distribution losses. Once the grid is secure, more improvement can be done in terms of optimization of the energy consumption of the country.

## IV. SG IN MOROCCO

This section will describe the current situation of the Moroccan electric grid. It will also present the government initiatives that aim at facing the rising demand. Challenges and barriers on how Morocco can set its SG will be given at the end.

### A. *Moroccan Current Electric Grid*

Morocco is the only North African country that does not currently possess oil or natural gas resources. The country needs to meet the rising energy demand which makes it dependent on foreign imports. The later puts the country in a vulnerable situation when it comes to energy security. In fact, the electric power consumption per capita went from 878 kWh in 2013 to 901 kWh in 2014 [19]. The electric power consumption per capita in the Middle East and North African countries reached 2,875 kWh in 2014, while it was 483 kWh in the Sub-Saharan and African countries [19]. The latter numbers show that Morocco is at an intermediate position compared to the two regions, which means that the country is making efforts to improve its energy sector. The total installed capacity in Morocco was 8,300 MW in 2016 of which 14% is based on renewables and 46.7% is based on coal [28]. In 2015, the total capacity was 8,158.5 MW with 13.4% from renewable and 49% from coal [29]. The projections show that Morocco is planning to reduce its coal based generation while increasing natural gas and renewable energy generation as depicted in Figure 2 [28][29][31].

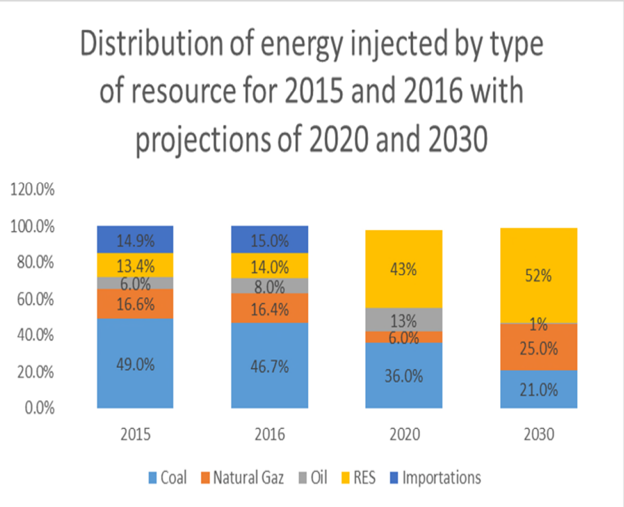


Figure 2. Comparison between 2015 and 2016 in terms of installed capacity resources with 2020 and 2030 projections

At the transmission level, Morocco contains 25,545 km of electric lines of very high and high voltage, 85,728 km of electric lines of medium voltage and 205,372 km of electric lines of low voltage [28]. The Moroccan electric grid is also connected to the Spanish and Algerian Electric grid via a 1,400 MW and 1,200 MW exchange capacity lines respectivly. The country is constently reinforcing its transmission sector to cope with the increased demand and the integration of renewables into its grid. In addition, Morocco is striving to becoming a hub that connects Europe to Africa.

At the distribution level, Morocco adopted SCADA as a management tool at the regional level. This can be considered as a first step toward a moroccan SG [30].

### B. *Moroccan Government Initiatives*

Morocco took part in major initiatives that concern the protection of climate and environment, namely, he took part in the Rio de Janeiro, Johannesburg or Kyoto agreements. In 2009, the kingdom launched its national energy strategy, pointing out the importance of the power sector in the country.

The Moroccan High Commission for Planning (Haut Commissariat au Plan) published a report “Prospective Maroc 2030” [1], in which specific goals on the energy sector were set. The most important goal is reaching a total electric production coming from renewable resources of 52% by 2030 [1]. To achieve the latter, multiple projects started in different regions of the country, the plan is to add a total capacity of 6,760 MW between 2015 and 2025 (3,120 MW of solar, 2,740 MW of wind and 900 MW of hydro-power). Concerning solar energy, the first part of NOOR project in Ouarzazate is now operational with a total capacity of 160 MW. Like NOOR 1, NOOR 2 and 3 will use solar thermal technologies and will have a total capacity of 350 MW, while NOOR 4 will be based on photovoltaic technology with a total installed capacity of 70MW. For the wind energy, 800 MW is already operational, 550 MW under construction, and 850 MW is in the planning stage. In addition, the minister of energy stated that an additional 1,000 MW wind power is planned to be installed between 2012 and 2025 [13]. It is only natural that new laws and regulations arise to cope with the energy transition that the country is undergoing. Table 1 details the laws and regulation realted to RE that were issued since 2006 [14].

TABLE I. MOROCCAN LAWS

| **Law Name** | **Issue Date** | **Main aspects** |
|---|---|---|
| **Law 54-05** | February 2006 | Allows the government and the local authorities to delegate the manegement of electricity supply services to private entites |
| **Law 13-09** | June 2010 | This law concerned renewable energies. It allowed generation by the private sector in medium and high voltage. The generation of electricity needed to fulfil some characteristics regarding the capacity of the generation of the farm; a declaration is necessary if the farm capacity |

| | | |
|---|---|---|
| | | is between 20kW and 2MW and an authorization is needed when the capacity is equal or higher than 2MW |
| **Law 47-09** | May 2012 | Described energy efficiency as a fourth energy after fossil fuels, renewable energies and nuclear energy. The law also emphasized on the importance of the implementation of energy efficiency measures in all sectors |
| **Law 57-09** | June 2010 | Concerned the creation of the Moroccan Agency for Solar Energy (MASEN) with the specific target to implement and reach the solar plan |
| **Law 16-09** | June 2010 | Published for the creation of the National Agency for the Development of Renewable energies and Energy Efficiency (ADEREE). This institution was created in order to launch sectorial programs all over the country in order to seak the potential of each region in terms of renewable energies and energy efficiency so that new solar and wind projects can be installed in order to produce electricity |
| **Law 58-15** | December 2015 | Amendment and completing law 13-09. This latter allows the generation of electricity at the low voltage. It also presents the possibility of selling excess of electrity, but the producer can not sell more than 20% of their total annual generation |

Another Moroccan initiative is the program of rural electrification that started in 1996.

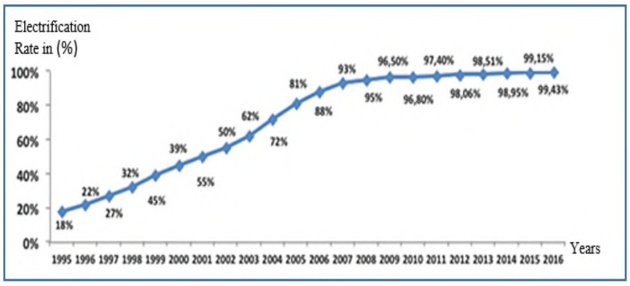


Figure 3. Evolution of the rural electrification rate [28]

At that time, the rural electrification rate was 18% only, at the end of 2015 this rate atteined 99.15%, Figure 3 presents how this rate kept increasing during these last years [28].

## C. Moroccan Electricity Power Industry

Before the 1990's Morocco faced shortage in its electricity supply and part of the country experienced regular power cuts. It was then imperative to reform the electricity sector in order to mitigate the shortage issue. Independent Power Producers (IPPs) were authorized to privately generate electricity which was monopolized by ONEE before. The reform aimed at reducing the electricity generation using oil and hydropower and shifting some of it to coal and natural gas. The reform set by Morocco did not cover only generation but it was extended to distribution. The privatization of the distribution sector helped establish and improve the distribution infrastructure. At the transmission level, ONEE still has monopoly. As for generation ONEE contributed by 29.2% of the electricity generated in 2016, mainly from hydro, thermal and wind energy resources. IPPs, which are TAQA (also called JLEC (Jorf Lasfar Energy Company)), EET (Energie Electrique de Tahhadart), CED (Compagnie Eolienne du Détroit), TAREC (Tarfaya Energy Company) and MASEN contributed by a total of 56.9%. The remaining 14% of energy were imported from the interconnections between Spain and Algeria. At the distribution level, ONEE covers 45%, another 42% is covered by different public and private utilities. The remaining 12% are direct customers. Figure 4 details the situation of the Moroccan electrical industry in 2016 [28].

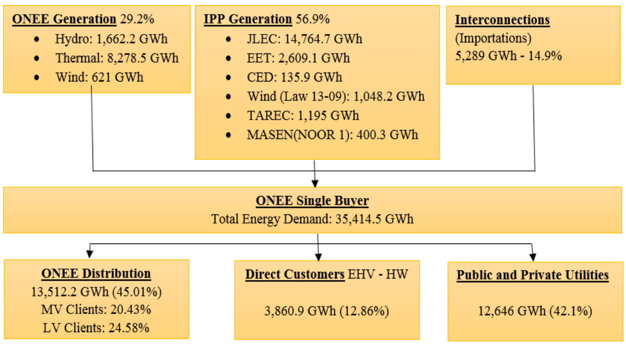


Figure 4. Supply and demand of electricity in Morocco in 2016

## D. Challenges and Recommendations Toward a Moroccan SG

The inclusion of renewable energies in the electricity generation in Morocco is imperative to its socio-economic development. The government and the top Moroccan managers are publishing new regulations in order to cope with the energy transition that the country is undergoing. New projects are planned and the generation capacity will keep increasing to deal with the increasing demand, but renewable energies remain a small part of the SG. This latter needs a wide-area control and monitoring, information and communication technologies, advanced metering infrastructure, distributed generation, customer-side systems and electric vehicle charging infrastructure. The first challenge resides at the transmission and distribution levels; as a matter of fact, these losses reached a percentage of 14.7% in 2014, therefore they definitely need to be reduced to secure the grid [19]. The percentage has been increasing since 2004 where it was as low as 5% [19]. In order to reduce losses, a wide area monitoring network needs to be established. As far as the transmission infrastructure, more lines are being deployed

 ISBN: 978-1-61208-635-4

each year to accompany the demand. At the distribution level, the metering infrastructure still relies on conventional (electro-magnetic) meters. It is clear that an AMI needs to be implemented. Given the 58-15 law, for instance, enabling low voltage integration of RE will require a metering infrastructure that will enable the utilities to bill the customers accordingly and to implement a particular pricing scheme. In addition, if Morocco expects to apply measures for peak shaving, it will be important to involve the customers which can only be achieved through an AMI. Introducing energy management systems and dynamic pricing could significantly improve energy efficiency and maximize the use of locally generated RE. The country will need to implement social awareness initiatives to promote the use of distributed generation. The importance of SG needs to be promoted as well and the different demand response programs need to be explained to the public in order to show the benefits customers can benefit from after installing an AMI. Security is also a challenge in implementing a SG. The country needs to procure the most secure network for its customers in order for them to trust the utilities and share their private data.

## V. COMPARISON OF MOROCCAN SG SITUATION WITH OTHER COUNTRIES

In this section, we compare the current situation of Morocco to various countries using the main components of the SG as the metric for comparision. The main components of the SG are:

TABLE II. SMART GRID COMPARISON TABLE

| | | **Morocco** | **India** | **Turkey** | **US** | **China** |
|---|---|---|---|---|---|---|
| **A** | Electric Power Consumption per Capita (2014) | 901.13 KWh per capita | 805.60 KWh per capita | 2,854.60 KWh per capita | 12,986.74 KWh per capita | 3,927.04 KWh per capita |
| | Regulations and perspectives | National energy strategy (2009) | SG roadmap for India (2013) | Strategic plan 2015-2019 | The US SG initiative (2007) | Strategic plan for a robust grid (2009) |
| | Total installed capacity | 8,300 MW (2016) | 329,000 MW (2017) | 80,000 MW (2016) | 1,190,500 MW (2017) | 1,645,750 MW (2017) |
| | Wide-Area Monitoring | SCADA | Phase Measurement Units | SCADA / GIS | Strong Area monitoring | Development of SG on HV and smart dispatch and control technologies |
| **B** | Transmission losses | 14.7% | 19% | 15% | 6% | 6% |
| | Business Model of the electric industry | 56.9% of generation from IPPs 42.1% of distribution is private | 5% of distribution is private [32] | 65% of generation from IPPs All distribution is privatized [33] | 41% of generation from IPPs [34] | Generation dominated by 5 state-owned utilities and distribution by 3 state-owned operators [35] |
| **C** | % of energy from RE | 14.0% | 31.3% | 35% | 17.0% | 24.8% |
| **D** | Smart meter | --- | Development of smart meters | Automated Metering Reading | Automated Metering Infrastructure | Smart meter procurements ongoing [35] |
| **E** | Electrical vehicle | --- | Shift to electrical vehicles expected by 2030 [21] | --- | Development of plug-in hybrid technologies | Target of 1 Million electric cars by 2020 [27] |
| **F** | Customer-based technologies | --- | Development of Demand Response programs | --- | Development of customer based technologies | Demand Side Management programs |

A- Wide Area Monitoring
B- Information and Communication Technology
C- Renewable and Distributed Generation Integration
D- Advanced Metering Infrastructure
E- Electrical Vehicle Charging Infrastructure
F- Customer-side Systems

As detailed in Table 2, Morocco needs to follow the footsteps of other countries that are on the right track to deploying a SG. It is clear from Table 2 that the US is the only country that is consedering all the components, China and India come after. With the integration of RE into the energy mix in Morocco, it is only natural that the country will transition to a grid that is smarter and more robust.

## VI. CONCLUSION

SG is the future definition of electric grid around the world. Countries are making huge efforts in order to reach the necessary intelligence needed to optimize the use of its electricity. This paper presented the main components needed to acquire a robust electric grid, along with its challenges. Different countries around the world set short and long term plans that would help reach a certain intelligence needed for their electrical grid. The energy transition that Morocco is undergoing will only help hasten the development of a SG. The country is on the right track when it comes to passing the right laws that accompany the transition to a smart grid. Morocco is facing some real challenges to attain a certain level of intelligence, but following steps of developed countries can help getting its SG.

## ACKNOWLEDGMENT

This paper’s publication was supported by two projects. “Fes-Meknes Energy performance”; financed by the Region of Fes-Meknes and “Development of Smart Metering and an Energy Management System in Morocco”; financed by the National Center of Scientific and Technical Research (CNRST). The authors would like to thank both the Region and the Center for their help.

## REFERENCES

[1] High Commission for Planning, "Prospective Morocco 2030: Morocco's Energy Outlook Issues and Challenges," High Commission for Planning, Rabat, 2009.

[2] I. E. Agency, "Technology Roadmap: Smart Grids," International Energy Agency, Paris, 2011.

[3] S. Luthra, S. Kumar, R. Kharb, M. F. Ansari, and S. L. Shimmi, "Adoption of smart grid technologies: An analysis of interactions among barriers," *Elsevier*, vol. 33, no. Renewable and Sustainable Energy Reviews, pp. 554-565, 2014.

[4] M. F. Nejad, A. M. Saberian, H. Hizam, M. A. M. Radzi, and M. Z. A. Ab Kadir, "Application of Smart Power Grid in Developing Countries," in *IEEE 7th International Power Engineering and Optimization Conference*, Langkawi, Malaysia, 2013.

[5] I. Colak et al., "Smart grid opportunities and applications in Turkey," *Elsevier,* vol. 33, no. Renewable and Sustainable Energy Reviews, pp. 344-352, 2014.

[6] T. Atasoy et al., "Challenges & Opportunities towards Smart Grid in Turkey; Distribution System Operator Perspective," in *IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe)*, pp. 1-6, Istanbul, 2014.

[7] M. G. Simoes et al., "A Comparison of Smart Grid Technologies and Progresses in Europe and the U.S.," *IEEE Transactions on Industry Applications,* vol. 48, no. 4, pp. 1154-1162, July/August 2012.

[8] U. S. D. o. Energy, "2014 Smart Grid System Report: Report to Congress August 2014," United States Department of Energy, Washigton, DC, 2014.

[9] J. Lu, D. Xie, and Q. Ai, "Research on Smart Grid in China," in *IEEE T&D Asia*, pp. 1-4, 2009.

[10] Z. Ming, A. Sikaer, and H. Kelei, "The Future Development of Smart Grid in China," in *8th International Conference of Intelligent Computation Technology and Automation*, 2015.

[11] Z. Ruihua, D. Yumei, and L. Yuhong, "New Challenges to Power System Planning and Operation of Smart Grid Development in China," in *International Conference on Power System Technology*, pp. 1-8, 2010.

[12] Directorate of Observation and Programming, "Energy Statistics," Ministry of Energy, Mining, Water and Environment, Rabat, 2014.

[13] Ministry of Energy, Mining, Water and Environment, "Mr. Amara: "Morocco is developing energy projects with real investment opportunities valued at more than $ 37 billion"," 2015.

[14] Ministry of Energy, Mining, Water and Environment, "Texte Réglementaires: Electricité et Energies Renouvelables," Moroccan Kingdom.

[15] The Shift Project, "Data Portal: Browse Energy and Climate Data," The Shift Project, [Online]. Available: tsp-data-portal.org.

[16] Z. M. Fadlullah and N. Kato, Evolution of Smart Grids, New York: Springer International Publishing, 2015.

[17] I. L'hadi, "Liberalization of the Moroccan Electricity Market: A General Equilibrium Analysis," Ifrane, 2016.

[18] Indian Ministry of Power - Central Electricity Authority, "All Installed Capacity of India," 30 September 2017. [Online]. Available: http://cea.nic.in/reports/monthly/installedcapacity/2017/installed_capacity-09.pdf. [Retrieved April, 2018].

[19] World Bank Group, "The World Bank," IEA Statistics, 2014. [Online]. Available: http://data.worldbank.org/indicator/. [Retrieved April, 2018].

[20] Ministry of Power - Central Electricity Authority, "Annual Report 2014-15," Government of India, New Delhi, 2015.

[21] Ministry of Power , "Smart Grid Roadmap for India: Vision, Targets and Outcomes," Government of India, New Delhi, 2013.

[22] Republic of Turkey Ministry of Energy and Natural Resources, "Electricity," Ministry of Energy and Natural Resources, 2017. [Online]. Available: http://www.enerji.gov.tr/en-US/Pages/Electricity. [Retrieved April, 2018].

[23] Republic of Turkey Ministry of Energy and Natural Resources, "2015-2019 Strategic Plan," Ministry of Energy and Natural Resources, Ankara, 2015.

[24] P. Zummo, "America's Electricity Generation Capacity 2017 Update," American Public Power Association, February 2017.

[25] Z. XU, Y. Xue, and K. P. Wong, "Recent Advancements on Smart Grids in China," *Electric Power Components and Systems*, vol. 42, no. 3-4, pp. 251-261, 27 April 2014.

[26] Statista Inc., "Installed capacity of electric power generation in China in 2016, by source (in GW)," Statista, 2017. [Online]. Available: https://www.statista.com/statistics/302191/china-power-generation-installed-capacity-by-source/. [Retrieved April, 2018].

[27] " Energy Transition in the Power Sector in China: State of Affairs in 2016. Review on the Devlopments in 2016 and an Outlook. Analysis on behalf of Agora Energiewende and Chaine National Renewable Energy Centre," June 2017.

[28] ONEE, "Activity Report 2016," ONEE: Electricity Branch, 2017.

[29] ONEE, "Activity Report 2015," ONEE: Electricity Branch, 2016.

[30] S. Sahbani, H. Mahmoudi, A. Hasnaoui, and M. Kchikach, "Development prospect of smart grid in Morocco," *Procedia Computer Science*, vol. 83, pp. 1313-1320, 2016.

[31] Direction des Energies Renouvelables & de l'Efficacité Energétique, "Smart Grid: Un levier essentiel pour accompagner la montée en puissance des énergies renouvelables," Ministère de l'Energie, des Mines & du Développement Durable, Benguerir, 2017.

[32] International Trade Administration, "2016 Top Markets Report Smart Grid Country Case Study: India," U.S. Department of Commerce, 2016.

[33] International Trader Administration, "2016 Top Markets Report Smart Grid Country Case Study: Turkey," U.S. Department of Commerce, 2016.

[34] EIA, "Power Plant Operations Report," EIA, 2016.

[35] International Trade Administration, "2016 Top Markets Report Smart Grid Country Case Study: China," U.S. Department of Commerce, 2016.