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Smart Grids for the City of Praia: Benefits and Challenges

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Abstract

The current state of the electrical sector in Praia (Cape Verde capital city), characterized by high levels of technical and commercial losses and high cost of electricity that is caused by the lack of resources of fossil origin and aggravated by an inadequate investment policy, is forcing a deep restructuring of the entire sector. In order to have a more efficient, robust and fair electric system and to take advantage of existing local natural resources, it seems inevitable to bet on innovative, intelligent and secure technology that allows tight integration of renewable energy –mainly wind and photovoltaic energy. In this regard, the present article discusses the economic, social and environmental impacts of a Smart Grid for Praia city. Based on a proposed SG architecture that integrates the existing endogenous resources and technologies, it was possible to identify the main advantages and challenges that the implementation of SG technologies would have for the city.

Keywords

Smart Grid; Electric system; Integration of renewable energy

1. Introduction

A smart grid (SG) comprises a set of controllers, computers, equipment, automation and new technologies that work in an interconnected manner, similar to the Internet but applied to electricity grid management, to enhance the response to the growing challenges facing the electricity sector (*"What is a smart Grid?"*, 2015; *"Smart Grid Communications R&D Roadmap", 2015*). The SG is an evolution of the conventional electricity grid that offers communication, monitoring, analysis and control capabilities to maximize efficiency in all stages of the electrical system's (ES's) operation ("Centro de Gestão e Estudos Estratégicos Ciência", 2012).

The SG concept has undergone several updates over time and in accordance with the actual needs of each region. The European Union, through the European Platform for Electric Networks of the Future (ETP), defines a SG as an electrical network that integrates innovative services and products through intelligent monitoring technology, control and communication, and whose aim is to facilitate the connection and operation of generators of all sizes as well as technologies. A SG helps consumers optimize the system's operation and provides consumers with more information and options for choosing an energy supplier. It can significantly reduce the environmental impact of the electricity supply system and maintain or improve the safety, quality and reliability of the supply system. A SG also can maintain or improve the efficiency of existing services and foster the development of an integrated European market (“*European technology platform SmartGrids”, 2006).* The SG can also help to improve the integration of renewable energy sources by combining energy demand information with weather forecasts, which can help the system operators to better plan their integration to keep the system balanced. When there is low irradiation or a wind shortage, the SG also enables consumers to produce their own energy and provides the possibility of selling the surplus energy generated to the AC grid (European Commission, 2018).

A SG could contribute to global, efficient and sustainable access to electricity. This last point is a major challenge in developing countries, such as Cape Verde (Welsch, Bazilian, Howells, Divan, Elzinga, Strbac, Yumkella, 2013). Cape Verde (Fig. 1) is an archipelago country located in the Atlantic Ocean, about 450 km from the West African coast, consisting of 10 islands and about 500,000 inhabitants; it is devoid of natural resources and has a coastline length of about 2,000 km, a surface of 4,033 sq. km and an exclusive economic zone (EEZ) totaling 734,256 sq. km. More than half (57%) of the approximately half a million inhabitants live on the island of Santiago, which is the largest one and where the capital city of Praia is located (“Câmara de Comércio Indústria e Turismo”, n.d.). Thanks to the country’s investment in education, the improvement of its human development index and the growing tourism industry have increased rapidly, and the country is working hard to turn the islands into a trading and transport platform. It needs a well-structured ES that guarantees continuity and quality of service to boost other sectors of the economy and thus ensure its sustainable growth. However, it needs to find solutions to help to address the major weaknesses of the current traditional ES, mainly with respect to the intermittent power availability, high technical and commercial losses and poor management of resources.

Figure 1. Cape Verde map

The aim of this paper is to explain, by characterizing the city of Praia, the prospects and challenges of transforming its traditional ES into a SG. This includes understanding the potential impact of the SG on the various stakeholders of the national electricity sector and how the SG might solve or mitigate their difficulties, especially with respect to the level of regulation made possible by this new technology.

The present analysis is based on understanding the impact of implementing SG technology in several levels of national life, including the economic, social and environmental levels, especially with regard to the integration of renewable energy sources and the reduction of electrical losses. The analysis is based on a proposed Smart Grid architecture for the city, supported by existing features and technologies.

2. Smart Grid Structure

Although there is no single model of SG, and despite the various possible settings, almost all SGs have similar requirements: the integration of scattered energy sources and storage; the entire energy supply system being based on smart systems and on information and communication technologies (ICTs); efficient and sustainable ES; improving and changing the existing structures for an entirely new system; having decentralized network operating technology; integrating producers and consumers; the clever use of equipment; and using the best features of ICTs in management and power distribution systems (Uslar, Rohjans, Bleiker, Gonzalez, Specht, Suding & Weidelt, 2010).

The operation of a SG is coupled with a wide range of applications, software, hardware and other technologies to help utilities identify and quickly correct imbalances caused by demand. Through the process of "self-healing," utilities are capable of detecting and correcting imbalances to improve the quality of services, increase reliability and reduce costs (Zareen, Mustafa, Al Gizi, & Alsaedi, 2012). There are several ways to represent the layout and operation of a SG. The National Institute for Standards and Technology (NIST) together with the Smart Grid Interoperability Panel (SGIP) created a model (Fig. 2) that includes the seven primary areas comprising a SG: generation, transmission, distribution, customer, market, operators and service providers. The model clearly shows that there are several options from which to choose regarding the characteristics, uses, behavior, interfaces, requirements and concepts of a SG (International Business Machines Corporation, 2011).

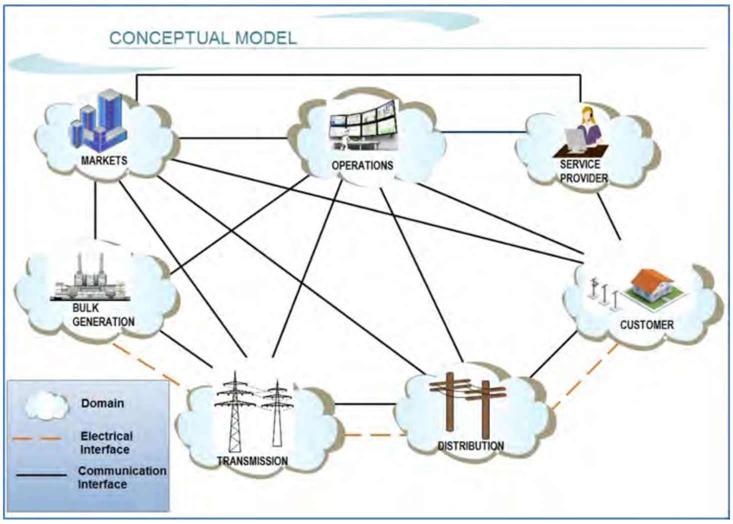

Figure 2. Smart Grid Reference Architecture by NIST, adapted from (IBM, 2011).

2.1. Smart Grid Technologies and Applications

The various areas of SG technologies range from energy generation to the consumers. For each sector within the system, a suitable technology is applied, according to its area of expertise. The main applications of SG technologies are linked to the network monitoring and control system (EMS); Advanced Measurement System (AMI), Distributed Renewable Energy Integration (DER); Demand Response (DR) through smart meters and residential management systems (HEMS). Many of these technologies are already considered mature, both in their development stage and in terms of their applicability, while others still require further development and demonstration. As shown in Fig. 3, a fully optimized ES would present technologies in all areas to allow monitoring and control, enable integration of ICT, facilitate integration of distributed generation, simplify the management of transmission and distribution networks, enable the integration of smart meters, provide the integration of intelligent vehicles and make it possible for industrial and residential customers to have an energy data management system (International Energy agency, 2011).

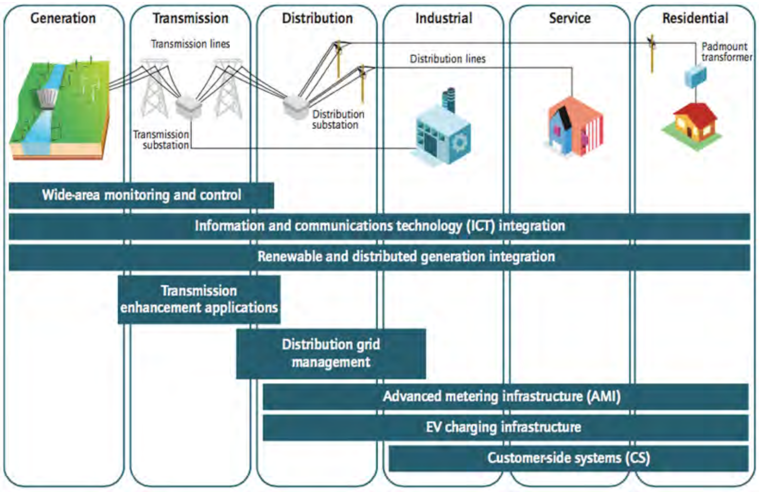

Figure 3. Smart grid technology areas, adapted from (International Energy Agency, 2011).

2.2. Smart Grid Communication Technologies

Another aspect to take into account are communication technologies, which play a key role in the operation of the SG, is to manage enormous amounts of data from different technologies and applications, monitor them and analyze them in detail to send a real-time response (Gungor, Sahin, Kocak, Ergut, Buccella, Cecati & Hancke, 2013). In this sense, it is necessary to define a communication structure that guarantees confidence, sophistication and speed and that allows interconnection and exchange of information between the various components of the network, such as generators, substations, transformation stations, systems storage and consumers, both in real time and benefiting all system actors.

Communications for intelligent networks are standardized protocols and allow interconnection with the main control unit through a secure communication network structure composed of these three hierarchical layers: Local Area Network (LAN), Home Area Network (HAN) and Wide-Area Network (WAN). Each layer is defined according to the coverage range and the transmission rate, so at a lower level are the customer's private networks, Home Area Network (HAN) / Building Area Network (BAN) / Industrial Area Network), at an intermediate level are the Neighborhood Area Networks (NAN) or Field Area Network (FAN) and in a larger area are the Wide Area Networks (WAN), according to Table 1 (Kuzlu, Pipattanasomporn & Rahman, 2014). For each of these networks there are several technologies that support them according to the intended application, scope or transmission capacity. Technologies can be wired or wireless, and wireless technologies such as 3G, WiMAX, ZigBee or Wi-Fi have the advantage of operating with cheaper infrastructure and allowing connections in hard-to-reach areas, but are more vulnerable to external interference in transmission. On the other hand, wired technologies like fiber optics, PLC, Digital Subscriber Line (DSL) and Coaxial Cable, have no interference problems and do not need external power sources such as battery to operate, but the cost of their implementation is higher (International Energy Agency, 2011; Kuzlu, 2013).This time, the great challenge is to define the communication requirements and the best communication infrastructure that best fits the reality in which it is framed, in order to guarantee a safe, accessible and reliable service.

Table 1. Smart grid communication technologies (Gungor et al. 2013)

Technology	Spectrum	Data Rate	Coverage Range	Applications	Limitations
GSM	900–1880 MHz	Up to 14.4 kbps	1–10 km	AMI, Demand Response, HAN	Low data rates

Continued on next page

Table 1 continued

GPRS	900–1880 MHz	Up to 170 kbss	1–10 km	AMI, Demand Response, HAN	Low data rates
3G	1.92–1.98 GHz 2.11–2.17GHz	384 kbps-2Mbps	1–10 km	AMI, Demand Response, HAN	Costly spectrum fees
WiMAX	2.5 GHz, 3.5GHz, 5.8 GHz	Up to 75 Mbps	10–50 km (LOS) 1–5 km (NLOS)	AMI, Demand Response	Not widespread
PLC	1–30 MHz	2–3 Mbps	1–3 km	AMI, Fraud Detection	Harsh, noisy channel environment
ZigBee	2.4 GHz, 915 MHz	250 kbps	30–50 m	AMI, HAN	Low data rates, short range

3. Review of Smart Grid Implementations

The purposes of SG technology investments worldwide are varied, but countries generally invest as a way to reduce CO2 emissions to improve the network's effectiveness, as a signal of commitment, to improve services and to search for an emerging technology market ("Centro de Gestão e Estudos Estratégicos Ciência", 2012). The differences lay mainly in the chosen approach and technological means, which may vary by country or region.

First, several cases of implementation are discussed below, with a separate subsection dedicated to the case of African countries. Thus, the necessary information is made available to address the Cape Verde case, which is shown and discussed in section 4.

3.1. Cases of Implementation

In Europe, the smart meter and other SG initiatives have largely been driven by policies to meet environmental and climate goals. On the other hand, in the United States, the main drivers for the development of SG come from economic issues related to job creation, the quality of public services and adding value and increasing the system's overall efficiency. Regarding communication technologies associated with the SG, the United States prefers technologies based on communication wireless mesh, mainly because of the flexibility of regulations on the use of wireless communications, while Europe opts for power line carrier (PLC) technology, which is a system of communication that uses existing power lines to send and receive information (US Energy Information Administration, 2011).

The focus on smart grid technologies in the Asian countries is already quite significant, driven by the main economic powers of the region, such as China, India, Japan and South Korea. China is promoting the development of SGs because of the high increase in demand for energy and the need to integrate renewable energy sources. In India, the high costs associated with technical and commercial losses due to the inefficient ES have led to investments in smart meters and flexibility in electricity generation (SMB Smart Grid Strategic Group 2017; Zpryme Smart Grid Insights, 2012).

However, in the countries of Southeast Asia the energy market is growing very fast. It has been rated as the world's fastest growing market for Smart grid technologies. To this end, countries such as Singapore, Malaysia and Vietnam have contributed, mainly due to the holistic approach that makes the sector able to identify potential new sources of income that give them sustainability for the next decades ("*What is a smart Grid?*", 2015). The countries of Latin America and the Caribbean have come up with the solution to help them reduce widespread electricity theft, increase the reliability of their electrical system, and improve operational efficiencies across the industry (“*Smart Grid Communications R&D Roadmap”, 2015)*. In this sense countries like Mexico, Colombia, Ecuador, Chile and Argentina are investing seriously in the planning and modernization of their electrical networks. Brazil stands out as the largest investor in Latin America in smart grid technologies.

Brazil, whose electrical production comes mainly (about 84%) from hydroelectric power plants, has no dependence on fossil resources and has one of the cleanest power matrixes in the world. Instead, SG arise from the inefficiency of the ES. The first measure in order to reduce losses and high power thefts in the country was the implementation of smart meters (Ferreira, 2010).

Australia understands that its bet on SG technology is a guarantee for the sector’s future, since the SG has the potential to improve the quality of life, economy and environment of Australians. They intend to create an ES based on technical and operational principles but also on respect for environmental principles, as an opportunity to become part of a new market that will revolutionize how electricity is produced, distributed and consumed (Smart Grid Australia, n.d).

3.2. The Case of African Countries

Electricity consumption has increased and will continue to increase, as shown in a study conducted by the International Energy Agency (IEA) (International Energy Agency, 2011) which estimates an increase in electricity consumption of over 150% by 2050, starting in 2010 (Fig. 4). The recommendation for emerging economies is to use SGs to respond more efficiently to rapid growth in global electricity demand.

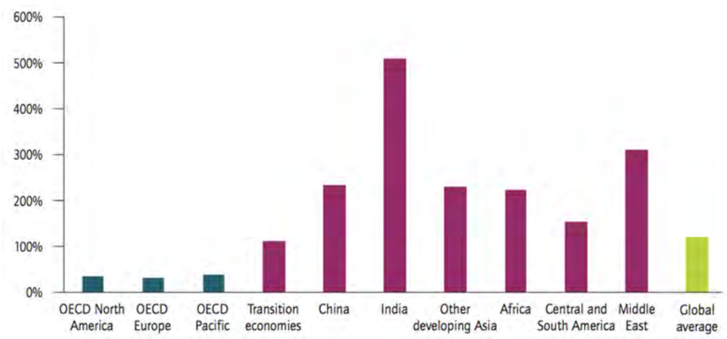

Figure 4. Projected electricity consumption growth, 2007–2050 (international Energy Agency, 2011).

Africa has only recently begun to take the first steps toward SG technologies, compared to the various initiatives and investments made in the United States, Europe and China.

Africa is rich in opportunities to not just explore renewable energy generation technologies but also to operate new strategies and technologies adapted to the region’s specific characteristics and needs. The continent has shown its innovative capacity in terms of computing and communications, as well as with mobile money. Africa has the potential to become one of the most fertile regions in terms of SG-related innovation.

Africa has huge potential in terms of solar photovoltaic, geothermal, wind and hydropower resources. Sub-Saharan Africa alone contributed almost 30% of oil and global gas discoveries made over the last five years (International Energy Agency, 2014), a fact that has aroused the attention of large companies such as Siemens, Schneider, GE and Alstom. Nevertheless, the greatest energy challenge in the continent is the availability of electricity, especially in rural areas. Some African countries see in SG technology, associated with their resources, a way to resolve or alleviate energy problems. Countries like Ghana, Rwanda, Angola, Tunisia, Nigeria, Egypt and South Africa have identified and are implementing specific projects to move toward a fairer and more intelligent electrical network (Anderson, 2012).

Ghana has faced several problems related to the aging and overloading of its electrical networks, since the pace of investment has not matched the 3.2% growth of annual demand. Consequently, this has caused losses in excess of 30%, a lack of reliability and power quality, bottleneck issues in transmission and distribution and environmental concerns requiring the integration of renewable energy sources and distributed generation. Thus, Ghana has naturally started thinking about SG as the solution to these issues. Zaglago, Craig, & Shah (2013) analyzed the main barriers that Ghana could face in case it adopts SG technology.

Despite Nigeria being rich in fossil resources such as oil and gas as well as rich in renewable natural resources, just over half the population has access to electricity, a fact that is due to the existence of few and inefficient power stations, a lack of production from renewable sources, the physical deterioration of transmission lines, energy theft and outdated energy meters (Vincent & Yusuf, 2014). By adopting SG technology, Nigeria could take advantage of renewable energy sources such as wind, sun, biomass and hydroelectricity, first to meet its immediate energy needs and then to look for sustainable, prosperous development and clean energy sources (Aroge & Meisen, 2014).

The South African National Energy Development Institute (SANEDI) had an initiative to create the South African Smart Grid Initiative (SASGI), with the goal of promoting a specialized market and developing a strategic vision for SG as well as creating a platform for knowledge sharing (Parallelus, n.d.). The aims of implementing a SG in South Africa include a sustainable reduction of peak electricity demand by 20%, with 2012 as base year; having 100% network availability to serve all critical loads at the national level; reducing technical and non-technical losses by 40% for the entire national system; reaching 8 GW of installed network capacity from renewable sources; and increasing customer satisfaction by up to 80% by improving the quality of service and consumer confidence (Bipath, 2014).

Egypt has excellent wind and sun conditions for electricity production, but due to the rapid increase in demand and the aging of its electrical networks—as the result of delays in infrastructure investment—the Egyptian ES is inefficient. Here, the bet on SGs will help in managing the integration of photovoltaic, wind and hydro power plants, while reducing the environmental impact of the ES and supporting the network's management, particularly its expansion and the integration of smart meters (Abou-Ghazala & El-Shennawy, 2012). Regarding the financing of the SG's implementation, some large multinational companies are already investing in the Egyptian electric sector. IBM and Siemens have referred to the Egyptian choice of SG technology as the foundation of a more stable and reliable ES, which will contribute to reducing the switching frequency and allowing continuous monitoring of the national grid. The first steps are already being taken. The Egyptian government has put into practice a program that aims to acquire about 20 million smart meters in the coming years. This program has the intention of improving the management and operation of the electric network, but mainly, reduce the theft of electricity and reduce the operational costs of the concessionaires ("*What is a smart Grid", 2015).*

4. Implement SG in the City of Praia

4.1. Description of the ES of Santiago Island

Due to its geographical location, Cape Verde is grouped with the Sahel countries and therefore has an arid/semi-arid, warm and dry climate, with rainfall shortages and an average temperature of 25 °C, which gives it high potential for harnessing wind and solar power. A study in 2007 showing that the archipelago has exceptional features in some locations, with average winds over 8 m / s. Regarding solar exposure, much of the territory has a global radiation of 1800 kWh / m2 / year and 2000 kWh / m2 / year on slopes and ground with natural exposure. Over half of the land has the potential for over 3750 hours of sunshine per year. Other resources also identified in this study include pure pumping plants, municipal solid waste, geothermal resources and marine resources, but they have little expression in the national energy matrix due to their scarcity and/or the complexity of their operation (Boletim Oficial, 2012). However, electricity production mainly comes from imports of petroleum products, which results in costly financial resources invested into their acquisition, which is a heavy weight on the wider economy that consumes a high percentage of the country's scarce resources (Fonseca, 2010).

Santiago's ES is mainly managed by the public/private company Electra SARL, whose majority shareholder is the state of Cape Verde, and which operates in nine of the 10 islands. In 2016, the 88 MW of installed power generation capacity in the island came from thermal power plants based on diesel and fuel, which accounted for about 86% of production. The remaining 14% came from renewable energy sources: 10% from wind power and 4% from solar photovoltaic arrays. The total energy consumed in 2016 was 225,658 MWh, more than double of what was consumed in 2006. This progression helps us realize the scale of the island's economic growth, reflected in the increasing demand for electricity (Direcção Geral de Energia, 2013).

Until now, the great challenge met by the country has been the high price of electricity. The current production cost of more than €0.3 per kWh is considered to be one of the most expensive in the world—up to three times higher than the price of electricity in the European Union (Costa, n.d.). The exorbitant price of electricity is the result of several factors: (1) the lack of natural resources like oil, gas or coal or precious metals that can serve as bargaining chips, which forces the country to import these products; (2) the insular character of the country, which forces it to have autonomous production systems, with the inherent burden of fuel transport and the difficulty of integrating them into a single energy production and distribution project; and (3) the major technical and commercial losses that affect the networks—particularly energy theft— which accounts for more than 30% of the produced electricity (Fig. 5) (Direcção Geral de Energia, 2015).

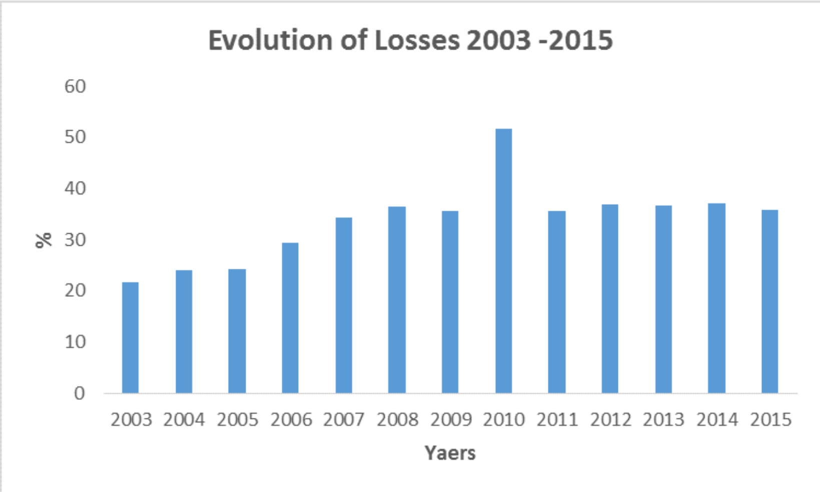

Figure 5. Evolution of Santiago Island electrical losses.

4.2. New Approach Proposed for the City's ES

The ES of Praia city has gone through several transformations, and many investments have been made, but they have not had the desired impact, mainly because the base of the energy matrix remains dependent on fossil fuel and because of the difficulties inherent to its insular condition. These factors, coupled with the poor management of the existing ES, have caused many of the problems to remain and worsen over the years.

In this sense, a new structure is proposed for the SE of the city based on the SG technologies, taking maximum advantage of the already existing infrastructures and technologies. This new Smart Grid structure consists of three layers (Fig. 6): the first layer and the electrical structure and all its components; the second layer is the Communication System, which includes the infrastructure / hardware part and the software part; the third layer is the layer of applications and solutions that the new structure provides. This is intended to ensure bidirectional communication to and from all levels of the electrical system based on a range of sensors, actuators, accelerometers and remote terminal units (RTU), which should be integrated into the network, allowing it to be made available to the operations and monitoring center all information concerning the operation of the electricity network.

The proposed WAN network covers a wide geographic area encompassing the LANs of the exchanges and the substation networks, also known as the backhaul network. This network would enhance the existing SCADA /

EMS / DMS dispatch system, mainly in the management of ER production integration in the power grid. The proposed communication technology to support the network would be a hybrid system using fiber optics and 3G technology from the telecommunication operators for the transmission of data between the production centers and the substations (Qualcomm, 2012).

On the other hand, to ensure communication in the distribution network, from substation distributors to consumers, the creation of several NAN or FAN networks based on GSM and GPRS communication technologies or 3G technology is proposed. Each NAN network would result from the aggregation of several Smart Meters around an aggregator / data collector so as to form a neighborhood network. In turn, each data collector would connect to the WAN backhaul network, allowing full communication from SM and other control devices, from consumers to the automatic counting system in PT, to the central server located in the center control in the power plants (Qualcomm, 2012; Bouhafs, Mackay & Merabti, 2014). This communication structure would provide all the electrical system with intelligence, helping to monitor, manage, measure and intervene in real time in all sectors, from production to consumer consumers through EMS and AMI technologies. As communication technologies that serve as a serious support to ADSL and 3G, given its capacity of transmission and coverage.

At the consumer level, several HAN, BAN and IAN networks are proposed for residential, commercial and industrial consumers respectively. These networks would allow the interconnection of the SM with the intelligent devices of residences or buildings, residential automation systems, energy storage systems, microproductions and electric vehicles, separately or together (Mohassel, Fung, Mohammadi & Raahemifar, 2014). The HAN network would ensure the communication between the counting systems of each individual consumer, mainly the residential ones, and the concessionaire, being able to be used several technologies like ZigBee, WiFi, ZWave, GSM, or Ethernet (Kuzlu et al. 2013).

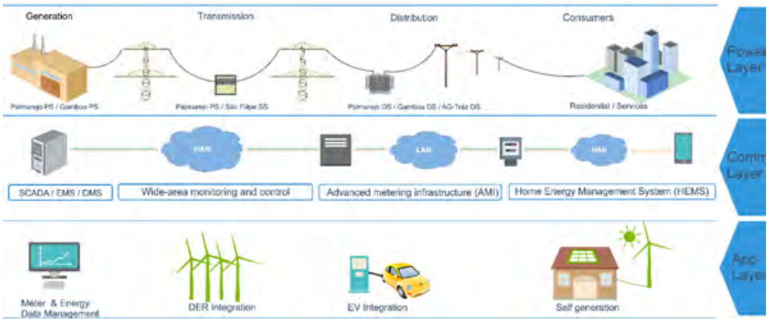

Figure 6. Layout of Smart Grid system proposed for Praia city.

4.3. Benefits of Smart Grid

An ES restructuring based on SG technologies could make the city's electricity grid most modern and sustainable, with benefits for all concerned actors in the sector, from producers to consumers, through the government and regulators. The intended social benefits arising from SG technology not only include modern and energy-efficient residential and commercial buildings but even extend to agriculture and animal husbandry, public transport, healthcare, communications, the provision of information and knowledge and the exchange of goods and services (Crabtree, Kocs & Aláan, 2014). This transition seems inevitable for these and other reasons; therefore, the concerns about the benefits of the intended SG for Cape Verde should focus on the core requirements for building ES sustainability.

4.3.1. Network Operation

At the level of the operation of the network, which has to do with, reliability, efficiency, warranty and safety concerning economic aspects and environmental impact, and without forgetting regulation issues. These benefits, in general, must reflect on all the actors that interact with the system (Oliveira, 2015). The main advantage of SG for the sustainable operation of the city's electricity network is the ability to ”self-heal”. This means that the system would have the ability to detect and isolate problematic elements in the network and do its restoration or treatment without human intervention. As a consequence it would reduce the negative impacts of network operation, shorten the dealer's restoration time, as well as optimize the quality of service. SG would make it possible to solve the main issues related to trust, efficiency and safety in the functioning of the city's SE.

The implementation of SG technologies will help to solve the sector's reliability problem by reducing the frequency and duration of power failures as well as the number of disorders that occur due to the poor power quality. Minimizing blackout occurrences through intelligent management of resources would make possible a wider and better availability of energy, bringing confidence for both utility and consumers, including industry and tourism (Hamilton, Miller & Renz, 2010; Bossart & Bean, 2011). These technologies are an important role for the stabilization of the network, mainly with the integration of intermittent renewal energies and the interlinking of the electric carriage system.

As a way to improve SE efficiency, the new SG would monitor and control the entire production, transmission and distribution process, making the most of the available DER, especially renewables, in addition to automating the dispatch system and network stability. These functionalities would have a direct impact on reducing dependence on fossil fuels, as well as making it possible to meet the growing demands of demand without adding new infrastructures. The evolution toward a SG has also reduced costs of electricity production, distribution and consumption, through its ability to anticipate and correct system disorders, reducing technical losses and peak demand and acting preventively to prevent occurrences of interruptions and damaged equipment (Crabtree et al. 2014; Sessa & Ricci, 2014; El-Hawary, 2016). AMI technology and smart metering would enable a substantial reduction of non-technical losses and would help optimize consumer energy consumption.

Another very important benefit in the operation of the network is the question of guarantee and security. For the electricity sector, confidence means having the power that consumer need, in the required quantity and quality, without damaging the provider. People have already died from electrocution when trying to steal power, there are constant power cuts due to short-circuits in distribution networks that could be avoided with tracking and monitoring services, and uptime guarantees are often challenged by the negligence of the concessionaires. A SG ensures better security of the network by using online sensors with intelligent information and communication technologies, connected to an advanced network control center. One of the main features of such a center is continuous monitoring of the whole ES, allowing the operator to detect any out-of-order or unsafe situations that could jeopardize the reliability of its operations. This increases the network's robustness, while reducing the likelihood and consequences of possible attacks, cyber-attacks or natural disasters (Hamilton, Miller & Renz, 2010).

4.3.2. Economy

The implementation of a SG would create new opportunities and markets where and when required, thus interconnecting the system whenever possible, opening the road for alternative electricity production sources, bringing new opportunities for micro-generation and enabling customers to produce electricity for their own consumption and sell their surpluses to the system, while significantly reducing the price paid by consumers and creating new jobs (Crabtree et al. 2014; Sessa & Ricci, 2014; El-Hawary, 2016). With the introduction of Smart Grid technologies and measures to reduce losses, a reduction of up to 65% of the current value of losses could be achieved, from 37% to 13%, both for technical losses and mainly for non-technical lossesIn monetary terms this reduction of electric losses would correspond to an annual saving of 2.5 Million Euros. At the level of operations and maintenance the new SE would provide a substantial reduction in relation to the transport costs of transport and technicians. Automatic metering and billing systems would allow you to increase your utility billing rate together with your customers. Taking into account the need to create new services, to implement new technologies and to expand existing infrastructures, would lead to the emergence of a new market in the electricity sector. All the improvements and efficiencies provided by SG technologies have a direct impact on the final price of electricity. The maximum final use rate (MTU) is determined for each year of the regulation period based on the CNRC: non-fuel costs related to the production and purchase, transportation, distribution and sale of electricity, and in CRC: costs related to using the following formula (1):

$$TMU = CNRC + CRC \quad (1)$$

Where

$$CNRC = \sum_{t=1}^{n} \frac{CNRC_{i,t-1}(1 + IN - X_{i,t})Q_{it}}{(1+r)^t} \quad (2)$$

$$CRC = \frac{\sum(\alpha_i \times Pc_{i,tb}) \times \sigma \times (1 - \%ER)}{(1 - \%CI - \%P)} \quad (3)$$

$CNRC_{i,t-1}$ - refers to the regulated tariff for activity i in period t-1;
IN - corresponds to inflation adjustment;
$X_{i,t}$ - refers to the efficiency factor;
$Q_{i,t}$ - is the quantity sold in period t;
r - refers to the weighted average cost of capital;
α_i - percentage share of fuel type (i) in electricity production;
$P_{ci,tb}$ - refers to the reference price excluding VAT of the fuel type (i) used to determine the base rate, (ECV / kg);
σ - specific fossil fuel consumption of thermal production (kg / kWh);
%ER - corresponds to the percentage value of participation of renewable energies in relation to total energy;
%CI - refers to the percentage value of internal consumption in relation to total energy;
%P - refers to the percentage value of losses in relation to the total energy.

4.3.3. Environment

SG technology would allow a slowing of climate change and provide a new way to reduce the environmental impact of the ES, since the CO2 emissions generated by the production, transport and distribution of electricity mainly depend on the amount of fossil fuel resources consumed as well as the technology used (El-Hawary, 2016). The reduction of energy waste by end consumers is often the source of faster, cheaper and cleaner energy, but distributed generation of renewable energy can provide substantial environmental gains, because in addition to generating an electricity market for off-grid consumers, it allows self-consumption for those who are already connected to the network. Both options of power resources could be encouraged through adequate policies and SG technologies, allowing a two-way flow of information and electricity between utilities and consumers, thus realizing the full potential of energy efficiency and distributed renewable energy generation (Brown, 2014).

The automated monitoring provided by the SG would help to mitigate the negative effects of the ES, as it can intervene by switching resources and production sources whenever necessary. Taking into account Cape Verde's policies and its need to have as much renewable energy as possible in its energy matrix, SG technology would add significant value to this effort. It is estimated that with the expenses avoided with the thermal diesel production the SE of the city could avoid more than 20% of the emission of CO2.

4.3.4. Stakeholders

All of the industry stakeholders would benefit from the implementation of a SG. Consumer SG technology enables real-time communication with energy providers, allowing these utilities to choose according to their individual preferences, based on prices or environmental concerns (El-Hawary, 2016). They would be able to manage their consumption through smart metering and control equipment as well as have the opportunity to participate in small-scale production of electricity on their own through micro-production. The possibility of reducing cuts and blackouts would bring confidence to consumers, which will be reflected in honesty to the dealership. Improved management of resources and security provided by the SG would help electrical power to be provided in a way that is wide and with less cost (Dada, 2014). The consumers could even benefit from the reduction of losses among business, more reliable service and reduced transportation costs through electric vehicles and, as a consequence, have significantly decreased in electricity bills (Bossart & Bean, 2011). The concessionaires would have recognized gains from a SG, especially in reducing both technical and commercial losses, improving the measurement and billing system to make it more precise and automated, improving the management of interruptions, helping with the maintaining and planning process, and helping to manage the integration of renewable energy; hence, the SG would allow improvements among all of the concessionaires' operations (Bossart & Bean, 2011). Society in general will benefit from the SG through reduced imports of crude oil for both transportation and electrification, improved safety and efficiency of the electricity supply and reduced environmental impact of the sector. Also, the city of Praia would make better use of the available renewable resources; improve security; allow for better use of existing assets; provide a new, more open and competitive market; create new jobs; and generate wealth. The implementation of a SG would dramatically reduce costs and power outages, help to keep the prices of goods and services lower than they would otherwise be and improve the quality of energy (Hamilton et al. 2010; Bossart & Bean, 2011).

5. Challenges to Implementing SG

In the previous section, we addressed the benefits of implementing a SG, but SG technology is not easy to implement, especially for a country with the economic reality of Cape Verde. Therefore, it is crucial to determine the main challenges facing the implementation of a SG in the city of Praia, to find their respective solutions. These solutions should be contextualized by taking social, regulatory, technical and financial perspectives into account (European Commission, 2018; Bossart & Bean, 2011). In this sense, it is crucial to analyze some aspects, such as the actual performance of the SG phase compared to the conventional system, collect data from locations at the appropriate frequency, determine the social and financial challenges, recognize regional differences among the consumers and service providers and use appropriate methods of calculation (Bossart & Bean, 2011).

5.1. Security and Privacy

The main concerns that are internally connected to the electrical sector have to do with electricity theft, which is often beyond the costs for utilities and cause human victims through electrocution. One of the main challenges to overcome in implementing a SG is the level of security. One of the aspects that can influence safety is the state of aging of equipment that is often not compatible with the requirements of the SG. In such cases it may be necessary to replace the equipment even if it has not reached its useful life cycle, as a consequence, it would increase the costs of the system. Privacy is the first concern that arises when it comes to transmitting digital data. This concern focuses on cyber-insecurity and potential misuse of private data. The city has successfully implemented an electronic system of governance through its ICT cluster policy and has built a technology park that houses a high-standard data center with processing equipment and state data storage capabilities, companies, banks and others, both national and international, because of the country's ambition to constitute an international services platform in terms of new ICTs. This increase in the use of ICT could be directed to operating the ES through consumer data collection and optimization of the system, but it could also have a perverse impact on the system. Therefore, to integrate the SG, it is essential to ensure the confidentiality of commitment and the security of the providers of these services regarding customer data (*"Energy technology perspectives",* 2012).

5.2. Stakeholder Participation

The increase in operating capacity provided by a SG would require changes in the operational processes of dealerships, especially in their relations with customers (“*Energy technology perspectives”,* 2012).. In a SG, implementations often overlook a critical component—consumer awareness, especially on issues such as conservation of electricity, micro-generation, hybrid vehicles, smart meters, appliances and intelligent buildings (Agência de Regulação Económica, 1998) Energy is a basic human need like food, shelter and mobility, and it is part of every aspect of our personal, professional and civic lives, which means that consumers do not see the means to achieve their goals (Crabtree, 2014). This creates concerns, the need for a detailed analysis and clear communication of expected opportunities and risks. In the city of Praia, despite its considerable literacy rate and use of new technologies, which have become part of the day-to-day lives of Cape Verdeans, the country would have to invest in re-education of consumers regarding the SG system. Not only should consumers receive clarification—all stakeholders should be fully informed about the benefits of these technologies. Customers, regulators and investors need to understand and be convinced of the benefits of the SG. Also, dealerships should be ready for the significant and perhaps radical changes that would follow, and the government needs to do a lot of work through awareness campaigns to show the importance and opportunities of SG technologies. Society in general and politicians need to be made aware of the capabilities of SGs. Academic institutions could help through conferences, workshops and seminars to promote and encourage the implementation of SG technologies (Dada, 2014).

5.3. Policies and Regulations

Energy regulation in the city has been troubled, because in most cases, while laws regulating the sector’s functioning exist, their implementation does not occur. The Regulatory Agency of Economic Activities (AER) acts only in setting the price of fuel and electricity, while consumer laws are the responsibility of local authorities and the government (Agência de Regulação Económica, 1998) so a good relationship between these entities is required. The costs and benefits of SG technology cannot easily be accommodated by the existing legal and regulatory frameworks. These issues must be addressed before project deployments can proceed (“*Energy technology perspectives”,* 2012). The level of the legislation would require new laws to facilitate investment into a SG related to the price of land, customs fees, taxes and licenses, which should be kept to a minimum. Yet, these challenges could be surmountable because the city of Praia could adopt the best practices and laws of countries that have already implemented the system and adapt them to the national reality. The time of government action in terms of legislation is crucial to maximize the benefits of CO2 emissions and the respective carbon market. The approval of projects and new investments requires an exhaustive and intensive analysis, in which the benefits of the new technologies have to be well promoted, so that the government or public companies can invest.

5.4. Financial Costs

For the city of Praia, the main challenge in implementing the SG would be the financial issues. The project would take a voluminous initial investment, even if implemented in a phased manner as it should be, which would include the cost of education and training of technicians, those associated with the building of communications infrastructure, the costs of operation and maintenance, and the costs involved in procuring technology items, especially smart meters and other technical solutions, among many other costs involved in the implementation of SG technology. Private companies would not have enough financial capacity to make this investment without the government creating programs to encourage research and development. Several ways to circumvent these difficulties have been proposed. For example, the proposal to Bangladesh in (Ali, Mansur, Shams, Ferdous & Hoque, 2011) is that the SG project could first be held jointly by the country and foreign investors interested in a general expansion of the network, if the project is successful. These investors would have to meet some requirements and pass a rigorous evaluation process. In the same vein, (Dada, 2014) argues that for Nigeria, involving private investors and facilitating access to finance could help solve the financial problems, but banks and other financial institutions could also contribute through long loans with low rates for investments, and the government and industries could provide funding for the research and development of prototypes before implementing a SG across the country. Private company-oriented policies, such as the promotion of third-party financing and long-term strategies, seem to be a good way to circumvent the financial issue in Ghana, given the financial inability of public companies (Zaglago et al. 2013). From these proposals, it can be understood that the issue of public funding and the involvement of the private sector are strategic, as is openness to foreign investors with capital and know-how, which together could solve the issue of SG funding.

6. Conclusion

One can ascertain from this study that the ES problems of the city of Praia are due to a disintegrated energy policy that has lagged behind the evolution of demand as well as the lack of a modern, automated ES with monitoring and control capabilities. The sustainable electricity sector advocated here should base itself on operating principles such as the integration of renewable energy at large and small scales, the need to generate employment and have quality power in good quantities, respect for the environment, profit generation for utilities and ultimately providing electricity to users at a fair price.

The need for a transition to a more modern and appropriate grid naturally implies a bet on SG technology. However, several factors have to be considered for its implementation. In addition to the technical and financial issues, a smooth flow of communication between all stakeholders should be guaranteed, and the functions of each should be well defined. Also, all stakeholders must play their roles judiciously, based on rules and regulations that are enforced strictly by the competent supervisory bodies, thus ensuring the sector's integrability and integrity.

Due to its economic condition and the current technical condition of its ES, the city has much to gain by upgrading to a new system that integrates a SG. However, considering the current economic reality and technological level of the country, this development would have to be made in a gradual and phased manner to have time to educate and train its technicians, engineers and specialists. In this way, the system will gain sustainability, especially with regard to standardization, regulation, supervision, planning, operation and maintenance. The financial investment should be the result of commitments from the government as well as from the private sector, while involving foreign investors and creating incentives to attract them.

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