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Smart Grid Implementation in Mozambique: Where to Start?

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Abstract: The article presents a survey on the development of Smart Grids in the world. Its purpose is to present an overview of the possibilities and initial challenges to be overcome for its implementation in Mozambique. For the development of this article, a bibliographical survey of the world panorama of technology was made. As a result of this literary survey, it was understood that the concept of smart grids became more clear from 2005 and is developing. Some countries, mainly developed, have already joined the technology and they are with the pilot projects and realized. The motivations for its implementation vary from country to country. Increasing profits in the electricity sector, reducing energy technical losses, improving the environment and enhancing renewable energy are the main motivations. This technology brings benefits associated with technological innovation, new product development and new market opportunities. At the moment, it's understood that, Mozambique is not in time to implement this technology effectively. Not only because many countries are still with pilot projects, but also, the financial costs for their implementationarehigh. However, although there are presumed difficulties for its implementation, it's considered convenient to start with the discussions about smart grids in higher education and research institutions, fund mobilization and implementation of testing laboratories. Additionally, it is important to study the possibility of phased implementation of this technology in new condominiums or residential neighborhoods and to gain experience in countries that have already started to implement it.

Key words: smart grids, electric power and technology

1. Introduction

It's the technology time, and it's a bit unwise for electric powerdistribution companies to rely on consumers to be notified of an interruption of power at their clients' houses,it means that they don't have full control of power networks. Because of these apprehensions, the Smart Grid concept emerged as a technology that allows the efficient use of electrical energy and thus is an important tool to overcome many challenges in the electricity sector [2]. The deployment of smart grids has advanced in other parts of the world. Some countries are in the experimental stage and others with projects already materialized. Interest in technology is evident and as a result one can be seen the existence of many studies and large financial investments. As references, we have Italy, the United States and Japan that are already at an advanced stage of deployment [1].

The term smart grid was first used in 2005 in an article written by S. Massoud Amin and Bruce F. Wollenberg, published in the IEEE P & E magazine, entitled "Toward A Smart Grid" [1]. There are several definitions, but all of them are summarized in the use of digital elements and communications in the networks that carry the electric power. These elements make it possible to send data and information to the control centers, where they are treated, assisting in the operation and control of the system as a whole [2].

The first concept we underline is that smart grids are electricity transmission and distribution networks that move in two directions (from consumers to the

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distributor as well as from the distributors to consumers) [3] as shown in Fig. 1.

The second smart grid concept that deserves our attention says that it's about: "An electrical network with a high integration of information technology, telecommunications, sensing/measurement and automation, in order to considerably increase its capacity to attend sceneries with intermittent and distributed power sources, high reliability requirements, low impact on the environment and compatible with new energy markets" [4].

From Fig. 2, it's possible to see that one of the great functionalities of smart grids is adaptability of various types of electricity generation, flexibleness of bidirectional communication between the control and management units and the points of actuation and measurement.

As mentioned earlier, there are countries that are seriously investing in smart grids because of the many benefits they provide to the electricity sector.

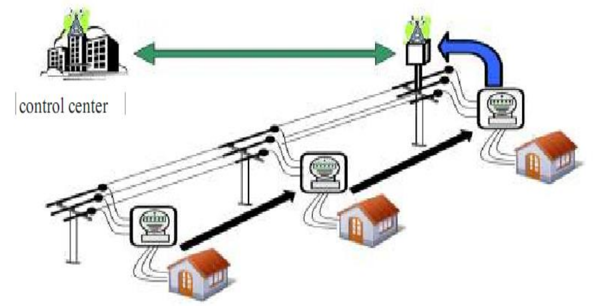

Fig. 1 Example of bidirectional communication in smart grid [1].

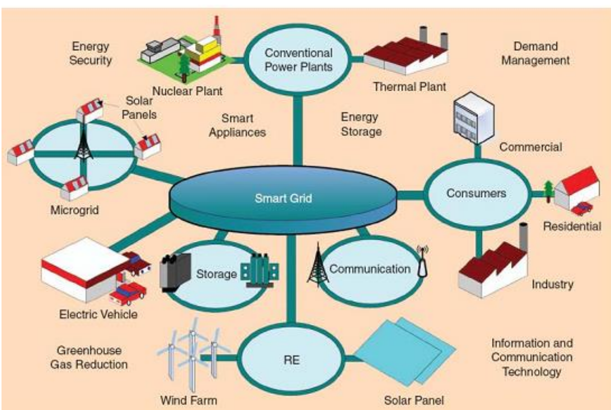

Fig. 2 Conceptual overview of a smart grid [5].

The objectives for the implementation depend on each country and the budgets for its implementation; also depend on the financial strength of each country. However, the article gives an idea about the first steps that Mozambique can take to implement this type of electricity networks. It's structured as follows: Material and methods, the results of the literary consultation and the main conclusions.

2. Material and Methods

During the elaboration of this approach, there were no studies in the literature that have the same objective or lineage as: finding the first steps to follow for implementing smart grids in Mozambique. By virtue of this situation, it's understood that the study is exploratory as well as descriptive. It's descriptive because there is already many contents published in literatures referring to the concept of smart grid and as well as the challenges for its deployment, technologies involved and benefits. The study explored these literatures in order to find an idea that allowed finding a position that in some way helped to show some possibilities for the implantation of smart grids in Mozambique. The research adopts a qualitative methodological approach because it's based on the interpretation of the literature.

It's important to note that, in the data analysis, the inductive reasoning was used, since from the data found in the literature it was possible to comply with the objective established in the study.

The bibliographic survey was the technique and method of data collection used. The texts were selected according to the proposed objective and the scientific works were used (articles, thesis and dissertations), web pages and books. The main sources of informationused were found in international open access and periodic digital libraries, with emphasis on Brazilians. In addition, information on Internet resources was useful, such as ISGAN (*International Smart Grid Action*), ERA (*Energy Retail Association*), ARRA (American Recovery and Reinvestment Act) and SASGI (South Africa Smart Grid) web pages.

As for the method of data analysis, the first activity consisted in selecting the literature according to the place of publication (country, publisher or the type of event where they were presented) in order to be based on reliable information. Next, was donethe careful reading of the texts where a critical analysis of the contents, and selected according to the purpose of the article. Finally, the results of the chosen literature were interpreted.

3. Results and Discussion

The smart grids concept emerged in 2005 and now it awakes interest of many countries in the world. As a result of this acceptance, it was observed that the researches related to this topic are several and in all languages. These researchs report the existing projects and the stage of their implementation. It was notorious that the USA leads the implementation of smart grid projects. In Africa, South Africa stands out and is one of the members of the ISGAN international working group. It is true that this technology is being discussed by several researchers and companies in the electricity sector, but we are saying that the investigations around this, are still necessary. Finding a workable and practical technique for transforming today's networks is one of the issues that still needs to be clarified.

Almost all literatures speak of technologies involved in smart grids, challenges, functions and budgets. These data helped to get an idea about the technology, even without moving to countries with projects implemented. Next, the main results found in the literature are presented.

3.1 Technologies Involved

From the literatures, it was possible to know that the *smart grid* integrates a set of technologies related to generation, transmission, distribution, storage and consumption of electricity. Several technologies associated to the theme are actively being implemented and their respective developments and application are considered mature. Nevertheless, it has become clear that some technologies are still very recent. They require several stages of development, analysis, and demonstration to be fully incorporated. Industries have a challenge of massively producing the required technologies such as digital meters and smart connectors.

The installation of sensors in the electric power lines, the establishment of a reliable communication system intwo-waywith wide coverage with the various devices and automation of the assets were the main technologies mentioned.

The sensors are equipped with chips capable of detecting information about network operation and performance, such as voltage and current. From these measurements, the sensors process the information to determine what is significant. For example, if the sensor installation point is low voltage, it is possible to take action and send data to the distribution center [3].

Smart connectors and digital meters are standout technologies. Smart connectors are specific hardware capable of recognizing the electrical energy network is in trouble and automatically taking action [3]. They are able to isolate the point of energy drop through the opening of keys and with that, to analyze if something that generated this energy drop was permanent or transient damage was interesting. If the damage is transient, the smart connector is able to automatically turn the system back on, or even redirect the power from other areas to the affected area with the power failure.

This feature has convinced many companies in the electricity sector that they want to keep the electricity network efficient. This feature would be very important for Mozambique, where the restoration of power supply after an interruption takes days. Some examples of intelligent automatic connectors are shown in Figs. 3 and 4.

Other features integrated into *smart grids* are of the telecommunications [1]. The communications systems are key components of the network infrastructure. Telecommunications are responsible for transmitting huge amounts of data [3]. These data can originate in the various consumers or test points in the network, and from these data, a distribution control center can do in-depth analysis through real-time mathematical methods [7]. Some authors state that there are many doubts among electricity distribution/transmission companies to define the communications requirements and find the best communication infrastructure to handle the input and output data. However, it's important that experts dispel doubt that transmission services are reliable [3].

The data transmission over the network via cable is used the PLC (Power Line Communications) system and while for wireless transmission are possible GSM (Global System for Mobile Communications),

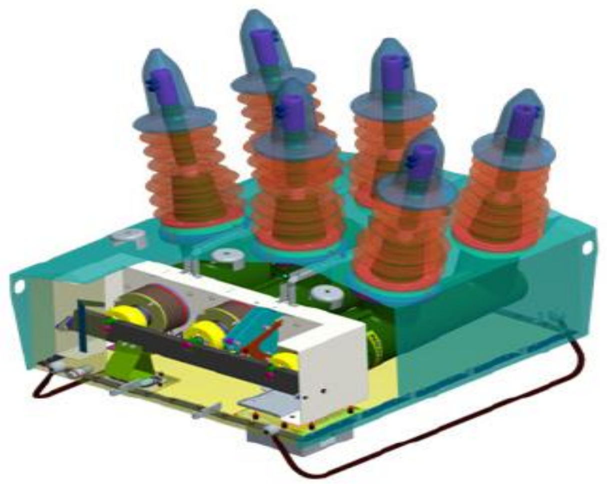

Fig. 3 Most modern smart connector [6].

Fig. 4 Old connectors [3].

GPRS (General Packet Radio Service), UMTS (Universal Mobile Telecommunications Service), SMS (Short Message Service), WIMAX (Worldwide Interoperability for Microwave Access), LTE (Long Term Evolution).

Another indispensable element in smart grid is the Smart Meter or digital intelligent meter, bi-directional equipment capable of connecting to the internet and has the function of measuring the data (Fig. 5). With accountants, residential or industrial customers can interact with smart grids by making decisions about their conscious use of electric power [3]. The customer can observe the schedules that have reduced charging so that it's possible to reduce their expenses. At the same time, companies and industries will be able to determine the best cost/benefit schedules to increase production [1].

3.2 Challenges, Role and Benefits

3.2.1 Functions

Self-repair: The use of real-time information to anticipate, detect and respond to network problems through intelligent connectors. Smart grids can mitigate or even avoid interruptions or decreases in quality of service [9];

Consumer motivation and involvement: A smart grid incorporates technologies that enable consumers to control the equipment in their homes and enable them to achieve more efficient energy management while reducing electricity bill costs. Communication between the network and the consumer allows for a

Fig. 5 Smart meter/meter [8].

cooperative relationship, enabling real-time charging or reducing consumption during periods of peak electricity demand [9];

Resistance to attacks or disasters: Real-time information from the network enables operators to manage the electrical flows in order to redirect them through alternative routes that guarantee service in the affected areas [9];

Accommodating all power generation and Storage Options: The efficient interconnection of multiple distributed power sources allows residential, commercial, and industrial consumers to produce excess electricity that can be delivered to the grid. This factor improves the reliability and quality of energy, lowers electricity prices and increases consumer choice [9].

Greater efficiency: The smart grid minimizes network operation and maintenance costs. Optimized energy fluids reduce energy waste and maximize the use of low-cost energy resources. The harmonization of local distribution with interregional energy fluids in the transmission network reduces congestion and bottlenecks in the network [9].

3.2.2 The Challenges

For the implementation of smart grids it is necessary to overcome regulatory, economic and financial challenges. It is also necessary to produce specific regulations related to tariffs, which must be revised considering changes in values throughout the day, according to variations in demand; regulations for new appliances, intelligent buildings and distributed generation (solar, biomass, wind, etc.).

From the literatures, it was possible to perceive that it is still necessary to define the sources of resources for the realization of the necessary investments; clarify the specific financial treatment for equipment and be replaced to enable the new technology, as well as change the remuneration model of electricity distributors, which could offer other services to their consumers (communications, internet, TV, remote monitoring, etc). In summary and systematically, the challenges to be overcome for the implementation of smart grids are presented in Table 1.

Table 1 Challenges in smart grids [10].

Challenges	**Consumer-centered approach**	**Liberalization of the market**	**Modulation of demand**	**Securitizationofsupplies**	**Renewal of networks and their operation**
Description	Insertion of new services, revision of tariffs, bidirectionality in the interaction of consumers ...	Induction of competition and flexibility in tariffs, new products and services ...	Alignment between demand and supply of energy	Increase of the generation source through renewable sources.	Automation of the current network so that it is efficient and feasible.

3.2.3 Benefits of Smart Grid

The benefits of smart grids are many and they solve problems from distributors to consumers. It is true that the benefits are divided into sectors but the end is the same, maintain and increase the economy of a certain country. Fig. 6 shows the benefits in a more specific way.

With the data presented in figure 6, it is possible to see why the developed countries in particular are interested in this technology. Smart Grids is considered as the solution to almost all the problems of companies in the electrical sector. Companies are interested in maintaining an efficient network, reducing network losses, establishing mechanisms for remote network control, improving tariffs and aggregating electricity from all generation sources.

Literatures say that in smart grids, it is possible to improve the environment by reducing greenhouse gases, especially those related to carbon dioxide.

3.3 International Scenery

As has been said, the technology is being adhered to and it's known that in June 2010 in Washington, at a meeting of Ministers of Energy and Environment, an International Smart Grid Action Network (ISGAN) was created in ambit of the International Energy Agency (IEA) [11].

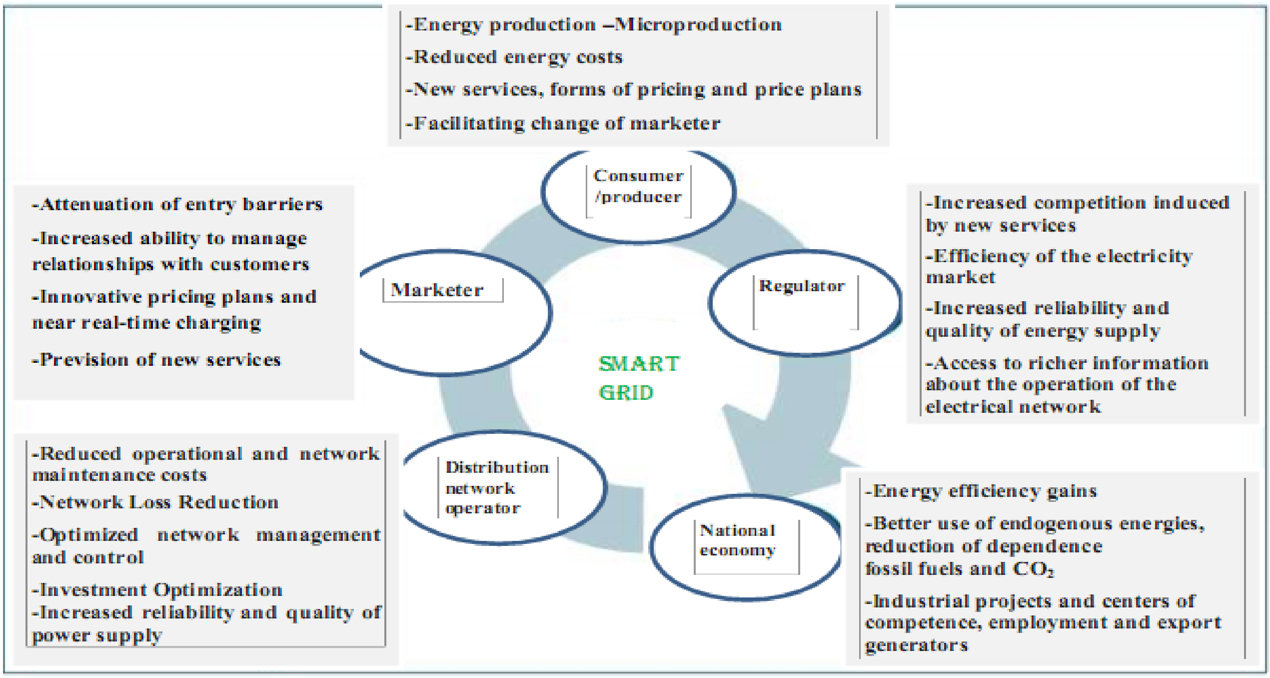

Fig. 6 Benefits of smart grids [10].

Until 2012, the following countries were included: Australia, Germany, Austria, Belgium, Canada, South Korea, Spain, Finland, France, Holland, India, England, Ireland, Italy, Mexico, Norway, Russia, Sweden and Switzerland. In addition, were also invited to join ISGAN: South Africa, Brazil, China, Denmark, Japan, and Turkey [11].

The group aims to establish mechanisms for collaboration, exchange of experiences and dissemination of smart grids activities among countries in the development of intelligent electric power networks, [11]. The web page of this group is available at http://www.iea-isgan.org/.

Energy Retail Association from UK has not lagged behind and has maintained a map[1] that catalogs more than 250 projects related to Smart Grids.

As much as the characteristics of power supply systems differ from one country to another, the motivations, implementation procedures, timelines and priorities defined for the deployment of smart grids are also different.

ARRA-2009 (American Recovery and Reinvestment Act) was the first to deploy smart grids in the United States of America. It aimed to boost the US economy and established financial incentives for the deployment of smart grids in the country [11].

In addition to the economic factor, the literature explains that the US had other motivations for the smart grid deployment, namely: Increased security of electricity supply (less vulnerability to terrorist attacks, hacker attacks, and failures due to the obsolescence of assets and natural disasters) and apprehension for the environment preservation. With smart grids, the US seeks to improve the productivity of the sector by expanding the supply of electricity without proportionally increasing existing physical equipment.

In Europe, the main motivation is environmental, with a special focus on the large-scale integration of

[1] https://www.metering.com/energy-retail-association-publishes-international-smart-metering-map-11502.

renewable sources of electricity in the form of distributed generation. The author oversees that in Brazil and in other developing countries, the main motivator for the implementation of smart grids is the reduction of commercial losses, or else, theft of energy and fraud in meters [11].

A common motivation for the implementation of smart grids is the emergence of cars with electric traction, as it's expected that the use of this type of vehicle by people become popular. However, electric power distributors are worried about the increase of electric charge in large cities due to the increase in the use of electric traction cars, or else, the increase in the electric energy consumption due to the demand associated with the recharge of the electrical traction car's batteries [11].

In the last decade, smart grids investments around the world beganto be made. Many countries and large companies from various areas (such as Siemens, IBM, Oracle and Cisco) have been investing heavily in pilot projects, whose objective is to improve and investigate the feasibility of this type of system [1].

In Europe, almost all countries already have some initiative related to smart grids. Both Italy and Malta have nationwide projects. Other countries, such as Germany, Portugal and the United Kingdom, are already testing the technology on a smaller scale to assess their resource saving potential [11].

In the United States, the evolution of smart grid deployment is also not homogenous. Some states are much more engaged than others due to different strategies, needs and resources [11]. More than five million smart meters have been installed throughout the country, especially in the states of Florida, Texas, California, Idaho, Arizona, Oklahoma, Michigan and Nevada. Important initiatives are also in Australia, Japan, India and China. Related to Latin America, Brazil is the country that has invested most in this type of technology, followed by Mexico.

The main projects in the world are found in:

Australia: In order to gather information on the costs and benefits of the smart grid, assisting in future decision making by government, energy providers and consumers, and by national technology providers [13].

China: With the aim of reducing energy consumption, increasing grid efficiency and managing electricity generation from renewable technologies [13].

South Korea: Consists of the integration of a REI with six thousand residences, Aeolic parks and four distribution lines [13].

India: In order to increase the levels of energy efficiency and the quota of renewable energy in the national grid [13].

Japan: Incorporation of renewable energy, smart metering and services, as well as electric vehicles [13].

European Union (EU): governments of the 27 European Union (EU) countries have developed actions to encourage smart grids to renew and expand national electricity generation, transmission and distribution systems [13]. The same reference indicates that the "European Eletricity Grid Initiative" (EEGI), the initiative is in the context of "EU's 20-20-20", which in turn was launched by the EU containing the directives for reductions of 20% GHG gases, increase of 20% in energy generation from renewable sources and 20% increase in energy efficiency up to 2020. Germany, Spain, France, Italy and the United Kingdom are the leading countries in investments in demonstration projects and deployments made in smart grids.

Brazil: according to Barros et al. (2013), Brazil is the country of Latin America that is ahead in REIs Implantation projects. Projects were in progress and all aimed at the reducing losses from theft of energy [14].

South Africa: Pilot-projects of REIs are ongoing in several townships in South Africa. These initiatives are related to the establishment of the SASGI (South African Smart Grid) project of the South African Institute for Energy Development (SANEDI). SASGI was created with the aim of assisting initiatives aimed at providing insight on smart grids for South Africa and providing input and policy guidance [14].

In 2013, at the request of the British High Commission under its Prosperity Fund and the Western Cape Department of Economic Development and Tourism (DEDAT), Green Cape carried out a project to investigate various aspects of smart grids from the perspective of the Western Cape communes. The project continued in 2014/15 through funding provided by the DEDAT Green Economy program [15]. The ultimate goal of the project is to apply the knowledge and experience gained through case studies to the training and implementation of smart grids at the provincial and municipal levels. Subsection 2.5 presents the main investments of smart grid in the World.

Now, from the literature consulted, it can be understood that the investments allocated for the implementation of REIs are quite high. As an example, Table 2 shows the main investments made so far and some in progress.

Table 2 shows that by the year 2010, the USA, Japan and China made the largest investments in smart grids development, totaling more than US $ 16 billion. It is also clear that for the next two decades the EU, Japan and the USA are expected to be the countries with the largest sums invested in deploying national smart grids. These countries will be accompanied by the national investments of developing countries, such as China, India and Brazil, with considerable projects and deployments for the modernization of their respective electricity networks.

3.4 The Main Investments

Table 2 Main Investments and estimates for the coming years [13].

Country	Investments in dollars (2010)	Estimates of Investments in dollars (coming years)
Australia	360 million	240 billion until 2030
China	7.3 billion	100 billion until 2016)
South Korea	824 million	24 to 30 billion until 2030
USA	7.09 billion	1.5 trillion until 2030
India	Not available	26.2 billion until 2015
Japan	849 million	1.7 trillion until 2030
European Union	1.76 billion	1.88 trillion until 2030

4. Conclusions

The results obtained and discussed in this research allow us to conclude that although smart grids have recently appeared, many researches and projects are already underway. This is an indicator that academics and the energy sector recognize the benefits that smart grids offer. It is true that the implementation of this network involves costs, but it cannot be an excuse for developing countries, like Mozambique, to be on the margins of this technology. It is clear that in Mozambique the financial difficulties are evident, but there is room to take the first steps. In this way, we suggest that the academies start to insert the smart grids in their programs in the courses of engineering (electronics, electrical, computing and communications or telecommunications) and informatics to create more space for discussion. Industries can create test labs and study ways to manufacture the devices involved, such as smart connectors and digital meters. For companies in the electricity sector, it is understood that it is time to mobilize resources and establish partnerships with countries that have advanced in this technology, such as the United States, Italy and Japan. The statements indicate that to implement smart grids it is necessary to have a lot of money, that is a fact, but Mozambican professionals can be sent to the countries mentioned for an in-depth study. From that, there may be possibilities to implement in a phased manner. Perhaps, in a first phase, it is possible to install digital meters and smart connectors in expansion zones or new condominiums. Today we talk a lot about renewable energies and, taking photovoltaic panels as a reference, it turns out that their implementation also involves many costs. These start in the construction and maintenance of the panel factories, construction of the converters and in addition to the acquisition of the raw material for the manufacture of the panels. In addition, it appears that the state and companies are already mobilizing resources for this area. Today, the topic of renewable energies is discussed in almost the entire Mozambican territory, although the results are still far from desired. Recognize that this is a very important step, but it must be emphasized that some types of renewable energy can be more advantageous if they work in parallel with electrical energy systems, which can be achieved with the use of smart grid technology. In Maputo, for example, we have hospitals and universities that, in some seasons, can use solar panels for lighting. In our opinion, this action could reduce the financial costs for the Mozambican State. According to the literature, this is more practical in smart grids. It is important that Mozambican companies or industries have the notion that, in the future, the smart grid will be a good solution to the problems facing the electricity sector. Of these, we can highlight the low levels of reliability, sustainability, resilience and stability of the system more efficiently. The last suggestion goes to research institutions and, in our humble opinion, it is opportune for them to start encouraging similar research in their congresses or conferences.

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