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A review on smart grids and experiences in Brazil

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ABSTRACT

The paper presents a literature review on smart grid concepts, considering generation, transmission and distribution of electricity besides smart consumption, including smart home, Demand-Side Response Programs, and Active Demand-Side Management. An analysis of the smart grid development in Brazil is performed, presenting the policy and regulation efforts beyond investments. This analysis takes account a pattern for smart grid development, and one may observe that Brazil is going towards a smart grid full implementation; however it could take decades and requires adjusts from govern, regulatory agency, utilities and consumers, and more investments. Moreover, some of the major smart grid projects in Brazil are presented, and their characteristics are compared considering the technologies used, location and electric utility goals. Depending on the electric utilities objectives, one may observe similarities and differences between concepts adopted and location of the Brazilian smart grid pilot projects. The first objective is the validation and replicability of the pilot project implemented; once, the project location is a sample of the utility's energy market or it is a particular area of interest, like an off-grid powered island with high environmental restrictions, for instance. The second objective is creating a model of sustainable smart grid with national visibility, once the project location is a touristic place. The conception of smart grid is aligned with sustainability, and it is a tendency in Brazil a massive entry of smart grid technologies in the next years.

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1. Introduction

A traditional power system consists of centralized generation of electricity, which is transmitted and distributed to the customers following a unidirectional way [1].

The main primary sources used to generate electricity in the world are non-renewable: coal (41%) and natural gas (21.9%) [2]. Electricity generation by non-renewable sources has several problems as limitation of energy resources, which affects countries energy security and environmental impacts due to increase of greenhouse gas emissions.

Thus, countries have to diversify their energy matrix with renewable energy sources. However, they should prepare the system to accommodate distributed and intermittent generation along with the bidirectional way of electric energy.

Regarding to demand, projections in [3] point increase up to 16% of electric energy demand until 2050 to Organization for Economic Co-operation and Development (OECD) countries and 300% to non-OECD countries, considering 2011 as base. While the OECD countries have already reached the development, the non-OECD countries are searching for their economic development, thus they have to increase their electric energy consumption. Therefore, disparities at projections are due to the current high demand rates on developed countries in contrast with the developing countries' rates.

Moreover, projections in [4] indicate a market of electric and hybrid cars of 106.4 million until 2050, representing 10% of the world electric energy consumption. Thus, it is necessary to adapt the power system to accommodate new technologies and new load profiles.

Considering this scenario, smart grids are a trend in the world power grids. They can be considered as a modern power system able to improve grids efficiency, reliability and security; reduce on peak demand; offer environmental benefits; locate and repair faults easily; accommodate renewable resources; among others [5]. These features are achieved by automated controls, modern communication infrastructure and sensing, monitoring and energy management technologies [6].

A smart grid can be defined as a generation, transmission and distribution system equipped with a two-way communication system controlled by the grid operator.

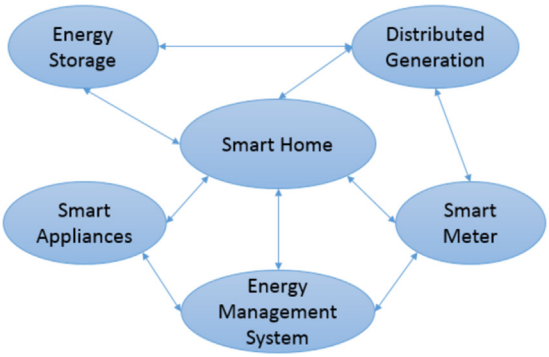

Fig. 1. Conceptual model of a smart home.

The main smart grid characteristics are [6–8]:

- Participation of the electricity consumers: distributed generation, chance to change their consumer behavior based on real-time consumption and electricity tariffs as so on.
- Quality power supply according to the grid needs.
- Adequacy of electricity generation and storage.
- Integration of electricity self-producers.
- Energy efficiency practices.
- Operation resilient to disturbances, natural disasters and attacks.
- Creation of new products and services.
- Integration of renewable resources.

These characteristics contribute to the smart grid premises: reliability, security, efficiency, saving and sustainability [9].

Smart grids have some barriers that confront the forward progress as high initial costs, need of stakeholder engagement, cyber-security vulnerability, risk of consumer privacy violation, and risk of technological obsolescence [5].

However, smart grids are important to integrate several forms of renewable distributed generation, diversifying the energy matrix, reducing transmission losses, and improving the power system reliability, security and efficiency [6,8]. Furthermore, smart grids result in socio-economic benefits to the society at large [5].

The remainder of this paper is organized as follows: Section 2 details the smart grid components, considering smart home, consumption, distribution, transmission, and generation. Section 3 presents the development of smart grid and the major pilot projects in Brazil. Section 4 presents a discussion about the current development of smart grids in the country and a comparison among the pilot projects. Conclusions are in Section 5.

2. Smart grid components

The following items present several components of the smart grids general conception.

2.1. Smart home

The key element of a smart grid is the interaction between the grid operator, electric utility and consumers, which occurs directly in a smart home. As stated in [10], a smart home aims to increase home automation, improve energy management, and reduce greenhouse gas emissions.

A smart home can have household appliances controlled by electric utility signals and automated controls to optimize electricity consumption, reducing the consumption when the grid is overloaded or changing some household appliance schedules. Fig. 1 shows a conceptual model of a smart home.

2.1.1. Smart meter

The smart meter is digital and bidirectional, being an interface between the consumer and the electric utility.

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