v. 2, n. 5, 2022

Journal of
Agricultural
Sciences
Research

AN INSIGHT INTO THE USE OF SMART GRIDS IN PUBLIC BRAZILIAN UNIVERSITIES

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Abstract: This paper proposes a brief discussion about the smart grids in Brazilian public universities. The smart grid and its implications are gaining more attention worldwide due to the increasing research in sustainable energies and distributed generation. This topic leads to analysis and speculations about the practicality of this technology in urban areas, thus bringing the futuristic concept of smart cities to life. There are numerous advanced researches, whose origins are papers submitted by public universities, which encounter resistance from the society in terms of implementation. This resistance builds a gap between theory and practice. Therefore, the present paper tries to shed light on this subject by giving an insight into some aspects of smart grid integration.
Keywords: Smart grids, Brazilian universities, distributed generation, sustainable energies.

INTRODUCTION

There are two important major reasons for discussing the subject of smart grids in Brazilian universities. The first revolves around the current expansion of the Brazilian Electric Power System (EPS) in geographic and technological terms and the horizontalization of its agents (generation, transmission, distribution, and consumers). The public universities are one of the few places in Brazil where the research and development (R&D) sector receives the proper attention. This fact is confirmed by faculties such as the University of São Paulo (considered the 18th most sustainable university by the UI GreenMetric World University Ranking [1]) when dealing with advanced technological topics at the undergraduate and graduate level. Consequently, the implementation of smart grid technology could be a way of integrating the great theoretical framework of the public university with the industrial and private sectors.

Smart grids can be described as modern electrical power systems, which improve grid efficiency, reliability, and safety, reducing peak energy demand, providing environmental benefits, locating and repairing system faults more easily, and allocating renewable energy resources [2]. The allocation of renewable energy resources is highlighted later in this paper. The smart grid uses broadband communication, sensors (smart meters), and computers to connect the energy distributor to the final consumer, bringing these two agents together and reducing transparency in terms of electricity consumption. Conclusively, the consumer gains more control over the energy flow received by the generating unit, thus facilitating its sustainable usage. National successful examples of smart grid implementations can be seen in [2] and in [3].

The São Carlos School of Engineering (University of São Paulo), therefore, can be a case study for the use of smart grids in partnership with electric energy concessionaires, such as Elektro and the Paulista Power and Light Company. With the implementation of smart grids at the University of São Paulo, distributed generation and renewable energy resources may be explored more objectively. A suggestion of distributed generation to be integrated into the smart grid is electric bicycles and photovoltaic panels, functioning as electric micro-generators, allocated throughout the university area.

Another important application of the smart grid comes from the possibility of online data processing, manipulation, and systems control by the internet of things. The internet of things it is a cornerstone for the development of intelligent techniques which includes smart agriculture.

The following sections present the basic structure of the smart grid along with some applications of this technology, a case study involving part of the University of São Paulo, and the conclusion of this work.

SMART GRIDS AND INTEGRATING SYSTEMS

The U.S Electric Power Research Institute proposed the smart grid in 2001. Such a system has been propelled by the promotion of green economies in developing countries to satisfy the rapid increase in electric demand while alleviating environmental degradation caused by fossil fuel-based power generation. Also, the current electric grid has been experiencing rapid technological growth due to the penetration of renewable energy resources and the different market players and end-users. The vertical structure of the energy agents is becoming horizontal, where the end-users are becoming closer to the input product (electrical energy). According to [4] the smart grid, in urban life, will be equipped with communication support schemes and real-time measurement techniques to enhance and forecasting as well as to protect against internal and external threats, preserving. Therefore, the smart grid will be capable of:

1) Handling uncertainties in schedules and power transfers across regions
2) Accommodating renewables
3) Optimizing the transfer capability of the transmission and distribution networks and meeting the demand for increased quality and reliable supply
4) Managing and resolving unpredictable events and uncertainties in operations and planning more aggressively

This paper focuses on the renewable energy resources topic, even though the other aspects of smart grids have predominant roles in the distributed generation, efficiency, security, and reliability of an electrical power system.

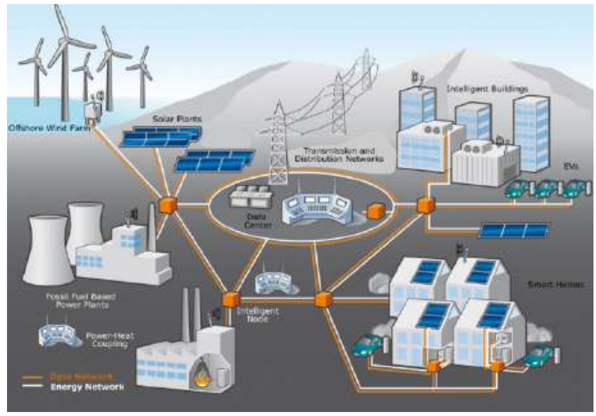

Figure 1. This figure shows an illustrative representation of the smart grid. A data center interconnects different energy technologies [5].

Figure 1 shows the versatility of electric technologies in terms of grid coupling. This multi-module aspect of the smart grid enables the insertion or removal of different components in a given time. Therefore, technologies such as distributed generations (electric bicycles), systems control (smart lighting), and extensive process and decision making (internet of things), can be incorporated into the grid in a modular way.

However, like many emerging new technologies, there are many problems involving practical use of the smart grid. Basic examples of smart grid problems are the stability and performance of the energy flow [4]; the entire grid has to be in almost perfect synchrony frequency while maintaining reasonable energy quality indexes. It is easy to see that the increase of components connected to the grid also increases the complexity and the issues with energy profile, creating a cascade effect. The level of processing with big data analytics also presents challenges [6].

By giving a zoom into Figure 1, another structure unfolds. This structure is composed of power generators, substations, a control center, Phase Measurement Units (PMU), Advanced Metering Infrastructures (AMI), Electric Vehicles (EV), and the consumers [7]. Figure 2 represents a more dissected topology of the smart grid, enabling inferences and questionings about the possibility of energy network operation, new integrating systems, different players, economic aspects of the energy market, et cetera.

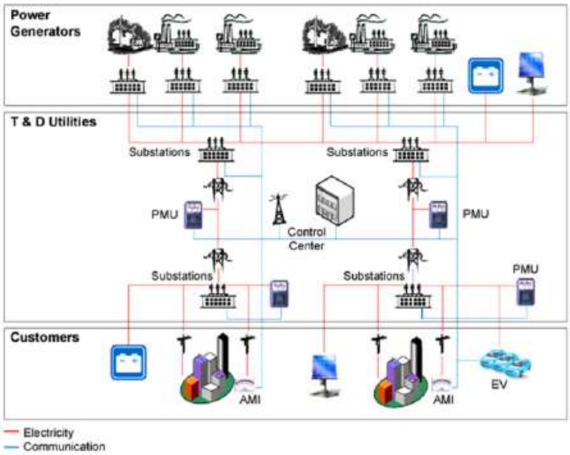

Figure 2. Schematic of a smart grid highlighting the basic structural components [5].

EXAMPLES OF SMART GRIDS USAGE IN REAL PROBLEMS

The gradual application of smart grids in isolated areas is justified by the physical and economic constraints (some of these constraints are presented in this paper). However, the natural generalizations of the smart grids called "future smart cities" are now more than just projections, academic research, and speculations. Urban areas consume up to 80% of global electricity generation. By 2050, more than 70% of the population will live in cities (responsible for most greenhouse gas emissions).

The Smart City concept combines, in a single urban model, environmental protection, energy efficiency, and economic and social progress [8]. Based on the single urban model, with the smart grids integrated, the universities can follow up that same model, finally putting theory and practice in the same framework. Nowadays, several smart grids pilots including energy demand response programs are providing a variety of smart grid applications and approaches all over the world. Most smart grid-related activities are concentrated on smart meters and AMI, with regulations promoting net metering, data privacy issues, opt-out policies, and distributed generation.

An industrial application of smart-grids is related to Amy's Kitchen in California (U.S) with a processing plant producing packaged vegetarian meal. In 2008, this facility participated in an automated demand response program based on the information exchange model established to communicate price and reliability information to large commercial and industrial facilities [9].

China, in 2011, has made great efforts in constructing a smart grid as a substitution of traditional energy-intensive power grid. In the China's 12th Five-Year Plan in particular, it was stated that emphasis should be placed on the development of renewable energy and smart grids [10], although the final realization of the complete system still has a long way to go.

Finally, Brazil which is a country of continental dimensions with a predominant renewable and centralized electric generation, implemented real projects of smart cities in Búzios, Barueri, Vargem Grande Paulista, Sete Lagoas, Paritins, Aparecida, Curitiba and Fernando de Noronha [2]. These projects, promoted by energy concessionaires covered energy management, generation, storage, electric mobility (scooters, electric bikes), public lighting, smart buildings, telecommunications, grid automation, broadband internet and a consumer awareness program [2]. Also, the Elektro Energy Company implemented a project called Energy from the Future consisting on the installation of the first intelligent meter in Atibaia [3].

CASE STUDY OF A PULIC BRAZILIAN UNIVERSITY

Until recently, the dominant paradigm in the electrification consisted of universal service and its centralization, but since then is experiencing a radical leap in terms of better energy resources managements, environmental protection and quality of service. Consequently, experimental projects emerging from research centers and universities are a mere consequence [11].

The Brazilian public universities have cutting-edge research, with papers published worldwide. However, there is a gap between the universities theoretical background and the practical applications in urban life. One of the causes of this problem is the lack of government incentives for research and development; another cause is the industrial resistance to change. Nevertheless, this country still has several successful projects implemented over the years, like the smart cities discussed in this paper.

The current case study of smart grids in a Brazilian university uses data from the São Carlos School of Engineering (University of São Paulo), Campus 2, acquired from [12] and [13]. It is just considered conjecturable analysis and inferences in this section, as well as ideal electrical conditions for the insertion of components into the grid. Although the case study is an illustrative model, the benefits of the applications of the smart grids are real. The examples of the national usage of smart grids in Brazil, discussed previously in the paper, show reasonable feasibility of the integrated system.

The Campus 2 of the São Carlos School of Engineering possesses the following characteristics, based on the year of 2018:

- Area = 1,3 km^2
- kWh/month = 8260 MWh
- Total cost/month = 4016139 R$
- Carbon dioxide emission/month [14] = 5,85 tons

Figure 3. Didactic block (in yellow) of the University of São Paulo. Campus 2 of São Carlos's city taken from the google maps [15].

Figure 3 shows the google maps view of the Campus. To estimate some impacts of distributed generation and smart metering on the grid, the projects of energy economy by photovoltaic panels and electric bikes are discussed below.

According to the National Public Radio [16], an electric bike can generate up to 24 kWh of energy and the photovoltaic panel, implemented in the São Carlos School of Engineering [17], can generate 44 kWh, each per month. The question here is to create a simple model that can describe the energy savings from these two components. The equation (1) is presented:

$$E=F(Q,A), \tag{1}$$

where E is the energy saving, F is a functional, Q is the quantity of electric bikes and photovoltaic panels and A is the area occupied by the distributed generators. Equation (1) is not trivial, because there are other factors to take into consideration that can change over time, however, this equation can serve as a starting point to a more general analysis. The next step would be to minimize

Q and A while maximizing E. Also, the carbon footprint energy equivalence can be represented by equation 2:

$$CO_2=F(E), \quad (2)$$

where CO_2 represents de carbon dioxide emission that will be avoid by the energy saving. Equation (3) of the monetary saving C is:

$$C=F(E), \quad (3)$$

From the data presented before and projecting a minimum starting point of 5% of energy saving with the electric bikes, photovoltaic panels, smart monitoring and control, the energy saving and the carbon dioxide emission reduction are:

- 413 MWh/month
- 293 tons/month
- 198240 R$/month

The calculated values try to capture the magnitude of electric energy, money cost, and environmental impact from a didactic point of view based on numerical approximations and ideal assumptions.

The general objective is to give an insight into the extensions of the problems concerning nature and society while showing the possible benefits of smart grid technology. In the end, the development of the smart grid technology in the Brazilian public universities combined with the proximity of these entities in the form of partnership with the industry and corporations can accelerate the process of innovation and improvement of urban life.

A final example consists of the reciprocity between the São Carlos School of Engineering and the Brazilian Agricultural Research Corporation, where the university's theoretical background and cutting-edge research solve real problems such as data acquisition and processing in the field by mobile robots.

CONCLUSION

Although the case study is based on the data from 2018, the basic components of the smart grid, like smart meters and data processing centers, are still lacking in the São Carlos School of Engineering. Therefore, the insight promoted by the discussion of the benefits and the practicality of such projects is still valid.

The renewable energy usage, management, and intelligent control of the grid have a considerable weight in modern society due to the increased energy demand and the need for more sustainable solutions. The universities can be a bridge between cutting-edge technology and societal revolution.

Finally, this work serves, also, as a bibliographical reference for future research and development in numerous fields of science.

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