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SMART GRID: EVALUATION AND TREND IN BRAZIL

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ABSTRACT

The Smart Grid is considered the most promising conglomerate of technology to be applied for the improvement and optimization of all power production in electrical engineer. Smart Grid's concept is being more and more recognized for its importance for representing a way to meliorate the energetic efficiency of the electric system, reducing consumption, allowing intensive use of energy generation renewable sources. Therefore, the goal of this article is to explore and present Smart Grid's concepts and its global evolution, so as perform an assessment on Smart Grid's tendencies in Brazil. In order to do this, we shown the concepts of Smart Grid, its benefits and impacts in the electric system's value chain, the barriers to its diffusion in Brazil and the paths of investments incentives for deployment of the new technology. Accordingly, we reach the conclusion that the researches point to a long and challenging trajectory for the development and implantation of Smart Grid's technology in Brazil, which is still in an embryonic phase of pilot projects for the knowledge and technology development implantation.

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Keywords: Smart Grid, Energetic Efficiency, Smart Meters.

1. INTRODUCTION

The constant grow of the electric energy consumption in the world has represented a challenge for the energetic sector that needs to supply means to the electric system's expansion, responsible for the generation, transmission and distribution of this energy, in advance to this consumption. However, the construction of electric power generation big ventures is increasingly to restrictions as geographical, technological, economic, regulatory or environmental.

Historically, in Brazil, the investments in big ventures of infrastructure happen in a reactive way, instead of being proactive to the demand's rise. For example, in 2001, after a strong economy expansion and energy consumption period, associated to the underinvestment on the energy generation and transmission system, culminated in the availability of electric supplies shortages, due the excessive water consumption in generation and consequent strangulation of the energy transmission system, resulting in a critical period for the country with energy rationing needs. The electric energy rationing lasted until the beginning of the following year, when the actions to make it energetic efficient and of reinforcement/expansion of the electrical energy generation and transmission generation system. Currently, this risk is no longer in evidence, yet it strongly tagged the history of the Brazilian electric sector.

Based on this scenario, it can be also highlighted the forecast of a global temperature raise, from 4 to 7°C (39,2 to 44,6ºF) till the century's end, as a function of global warming, what is going to represent great challenges to agriculture, water sources maintenance, public health services as well as energy generation. In the analysis of Battaglini et al. (2009), energy is a critical drive to world’s economy growth, however all emerging countries needs a correct energetic plan to obtain a sustainable development. Thereby, strategic decisions of energetic system investments in coming years will determine the future technology generation of electric/energetic sector to the subsequent decades.

The energy savings is a far more efficient way to simultaneously increase security in energy supply and reduce pollutant gaseous emission. According to Garrido (2008) is estimated that, globally, at least 20% of the distributed energy is wasted due the high inefficiency, corresponding to thousands of tons of CO_2 emitted,

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annually, unnecessarily. This energy economy may occur in two ways: consumption reduction and/or through energetic efficiency actions.

Thus, the mentioned authors highlight that the development of one consistent electric energy system, which attends to the economic and environmental objectives, will be much tougher, if not impossible, without any kind of smarter technology to support. Accordingly, arises the Smart Grid, which is a complex system that will require fundamental changes in the business models, public politics, social attitudes as well as engineering.

The future output, according to the quoted authors analysis, is the combination of great potential renewable generation (that are situated far from the big consume centers, for example, wind farms) with the distributed generation (e.g. gas turbines, micro turbines, fuel cells, photovoltaic generation, small wind turbines, biogas, etc.), connected to the electric system through electric smart network "Smart Grid". According to Al-Ali et al. (2011), one of the keys to Smart Grid's success it the integration of renewable sources of energy storage by the load side.

The grids of the future will be different from traditional grids. Zahedi (2011) highlights that the future grids will be a combination of centralized and distributed energy, with more flexibility, what allows the multidirectional flow of energy? In this energy system, the consumers will also be able to produce energy. The grid will be open to all kinds and different sizes of alternative generation sources to be connected. The information technology will make the management of the grid easier and will allow the communication between the system operation, generation and the consumer, and this communication will be based on real time data. Future challenges in this new grid include the integration of renewable sources, demand response, more efficient and reliable power system, reducing peak loads.

Smart Grid (SG) is being responsible for the implementation of a technological revolution in the whole value chain of electric system, which presented a slight evolution in the last century. This modernization will encompass from the power generation, through the transmission sector, distribution and final consumer. The SG will be responsible for optimize and make the existing electric system more efficient, providing gains in quality, security, energy efficiency, reducing the pollutants emission, asset management, among others.

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It is worth noting that is possible to reduce electricity costs by performing load control through the use of equipment's and systems of energy storage along to consumer units. By applying the Smart Grid's concept, it can be expected high efficiency, energy conservation and low emission of carbon (TAKANA, et al., 2012).

Accordingly to Li and Zhou (2011), the Smart Grid is considered the most promising conglomerate of technology, which is gaining generalized popularity in electricity public services, research institutes and telecommunication companies. Broadly the smart grid is referred as the modern grid technology, covering all electric industries of energy, from energy production, transmission and consumption, and implements a convergence between the flow of electric energy, the flow of information and the business flow with basis in information technology, communication technology and informatics. Actually, Smart Grid aims to provide a new model to the electric energy sector that allows adding new technologies or changing what already exists in a simple way. The concept of Smart Grid is being more and more recognized as a way to improve the energetic efficiency and, of generation and consuming electric energy.

The grid transformation of current electric system to the Smart Grid should happen in an incremental way: new automation technology, computing and communication will be introduced to the sectors of the current grid, forming pockets of sub grids with Smart Grid's characteristics, which will coexist in a smooth manner with the legacy grid. Insofar as these pockets increase in number and capacity, the grid as a whole will tent towards a grid within the new view (FALCÃO, 2010).

Thereby, the process may be catalyzed via direct action of the national and governmental electric sector regulating agent that may promote the suitability of the regulatory framework of this sector, aiming to coordinated smart grids in Brazil, as define sources of subsidy to finance this process without burdening the consumer or overload the electric energy distribution concessionaires.

Due the relevance of the Smart Grid theme for implementation of improvements and innovations that are revolutionizing the production chain and electric energy supply all over the world, in terms of processes optimization, energetic efficiency, environmental sustainability increase, this study has as a goal to explore and present the concepts of Smart Grid and its global evolution, as so to

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perform an evaluation of the trend of Smart Grid's diffusion in Brazil, showing the main benefits and challenges that the country might face.

The methodological path that was traced brought (i) this brief introduction about the theme that emphasized the relevance of the matter in evidence, the next topic (ii) will present a more embracing conceptualization about Smart Grid and its consequents impacts in the value chain of the electric system, where the main segments of the electric sector will be assessed. Then (iii) its discussed the regulation of the electric sector regarding Smart Grid use and the incentives to the investment for the implementation of the new technology. In the sequel of work, are presented, respectively, (iv) the main benefits from Smart Grid use, and finally (v) the main barriers to the diffusion of this technology in Brazil.

It is also noteworthy that the final considerations and recommendations to the new researches point to a long and challenging trajectory to the development and implementation of Smart Grid's technology in Brazil, as will be shown, is in a embryonic stage, where pilot projects are being implemented in some cities for tests and knowledge of the involved technology, signalizing the needs of developments of much researches for the customization and viability of the Smart Grid to the Brazilian reality, stressing serious problems of technological, economic, financial and regulatory orders, beyond the challenge of implementing this solution in a grid with continental dimensions.

2. THE UNDERSTANDING OF SMART GRID AND ITS IMPACTS ON THE ELECTRIC SYSTEM VALUE CHAIN

The Smart Grid itself carries a very recent concept and an enterprise, even in developed countries. Hou et al. (2011) reports that the first town that Smart Grid was implemented in United States of America, was Boulder, in Colorado, in 2008.

Smart Grid is constantly mentioned as the solution to electricity industries, however its understanding is not as clear as its terminology, applications and benefits. While some understand that Smart Grid comprises the installation of smart meters in the residential and commercial consuming units, others believe that it's the integration of distributed generation sources to the electric system, as highlighted by Wissner (2011).

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Another very important aspect of the electric system optimization is the empowerment, what means to give power to the final user of the electric energy service (consumer), highlights Falcão (2010) and Gomes et al. (2010). Particularly in telemetry of consumption measurement, this power is directly related to management, decision making and control of its energy consumption control. Nowadays in Brazil, only corporative clients or large-sized institutions, enjoy this benefit.

The smart electric system, through resources tracking and control, will deeply modify the rules of the game in the electric system value chain. Giordano and Fulli (2012) highlight the possibility of measurement with details the consumption of electric energy (till the last device), because it will create a link between each consumer unit and the service provider.

Schettino (2013) emphasizes the composition of the value chain of the power sector basically generators around the country, can be of various kinds of sources (hydroelectric, wind, thermal, solar, etc.), By transmission lines and power distribution and consumers. Figure 1 presents an illustration of the composition of the electrical system.

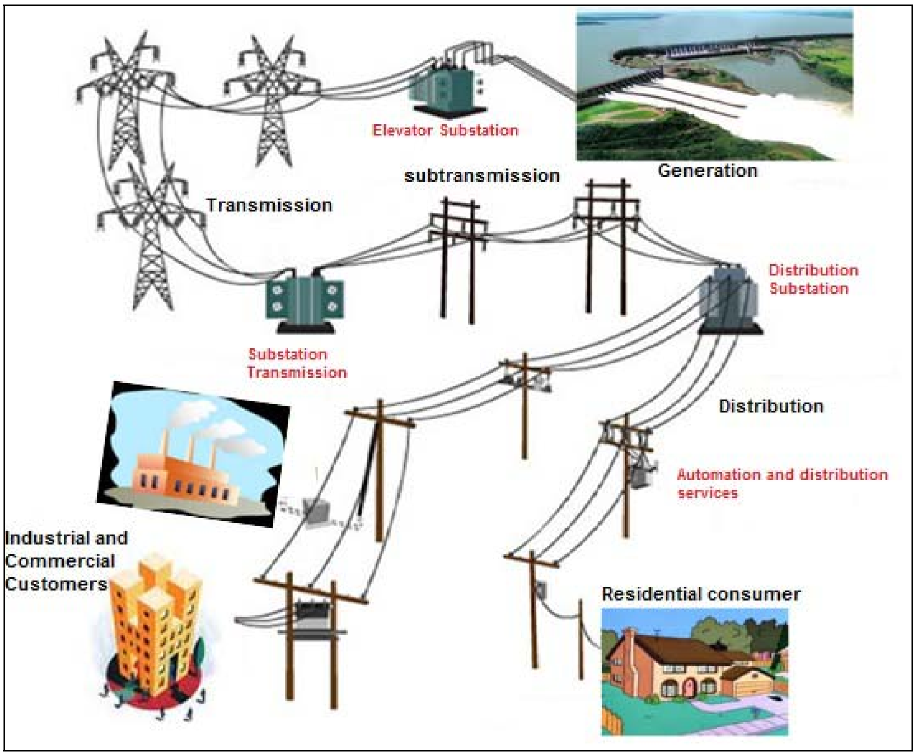

Figure 1 - Composite Power System
Source: Schettino (2013 p.38)

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For this Smart Grid concept to work in a satisfactory way, meeting the criteria of safety, quality, reliability, as well as the environmental assumptions, regulatory and economic, it becomes necessary the adoption of politics of electric network optimization and automation, supported by the technological advances of the digitalization, of information technology and telecommunications, where the Smart Grid will be responsible for integrating and operating all this technologies.

With this, stands that the Smart Grid is a set of intelligent technologies (software and hardware tools) capable of making the electric system more efficient, reducing the needs of overcapacity, through modifications in the process of electric energy distribution, turning it to a two-way street for the generated/consumed energy (BATTAGLINI, et al., 2009).

2.1 The information technology and necessary communication to implement SG

In the next few decades, the Smart Grid will form a critical basis to the new generation's electric system. Applying information technology and telecommunication, as well as computing technologies in the conventional grid, which will transform into a Smart Grid, will greatly enhance the utilization rates of energy assets and the management of the generation/consumption, optimize the resource allocation, and further improve the capacity and quality of the service (LI; ZHOU, 2011).

For enabling the conception of smart grids, Nair and Zhang (2009) state that is fundamental that the integrating equipment's of the electric system communicate and understand each other (speak a same language). The universal communication protocols that should be defined need to attend a few fundamental characteristics, such as: selectivity, sensibility, and velocity and rehabilitation capability.

The structure for the implementation of new technology has significantly changed in the last few years for several reasons. According to Wissner (2011), the basis for the electric system transformation is evaluated by the evolution of the information technology and telecommunication.

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The high penetration of the information technology and telecommunication is a result of the development of the wireless communication network (GPRs, WiMAX, UMTS, satellites). This evolution contributed to the process of telemetry of several activities.

In the Depuru et al. (2011) analysis, there are many ways of implementing the communication between these devices with reliability, however, of all proposed and available possibilities of communication technology, GPRS and PLC technologies are currently the most used because of the ease in maintenance and economic factors.

To Blumsack and Fernandez (2012), the Smart Grid consists in the application of modern communication infrastructure for various segments of the grid. Few technological advances in hardware are needed to make the Smart Grid functional and useful, but the control systems, software, and politics needed to perform fully the vision of Smart Grid are still in development and need great evolutions, figure 2 shows this new smart grid that has a bidirectional flow of information and energy between those involved.

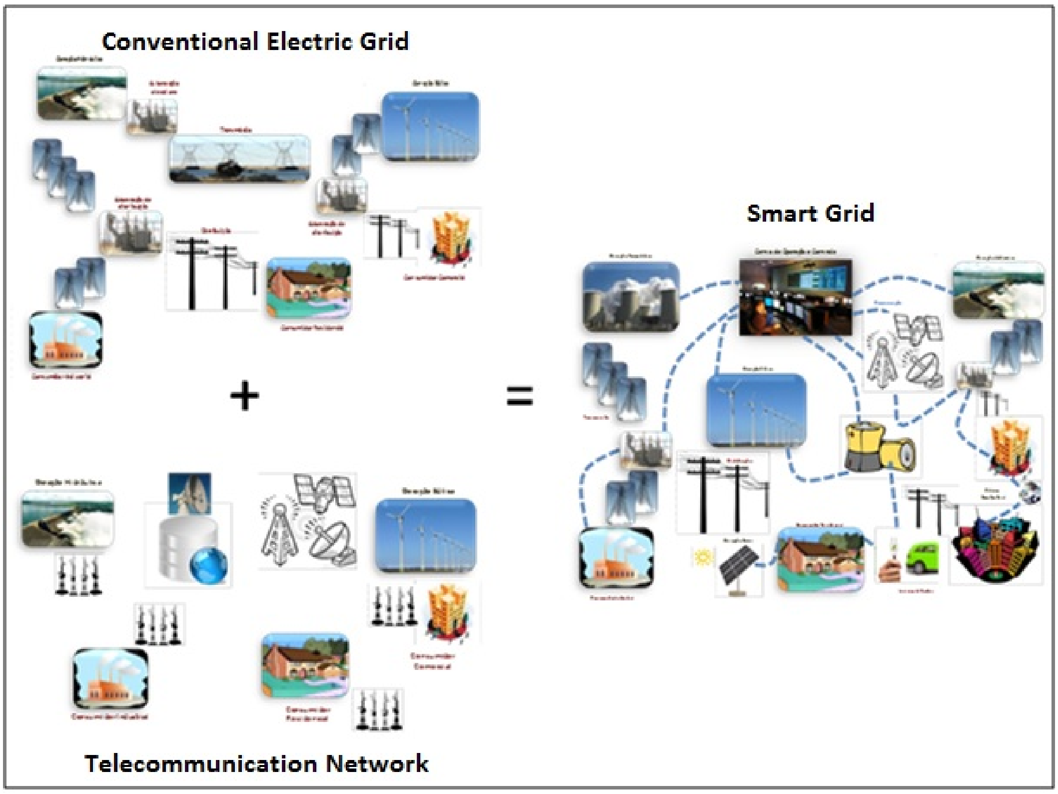

Figure 2 - Composition of Smart Grid (grid + conventional telecommunication network)
Source: Schettino (2013 p.46)

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Despite of the great advances of information technology and telecommunication, that are allowing the development of Smart Grid, it is still lacking the development of patterns and protocols of communication and even the evolution and global diffusion of the most modern technology in this sector, that are extremely important to the effective working of the Smart Grid, and in Brazil that is enhanced by the strangulation of the mobile communication systems.

2.2 Smart Grid in the generation systems

According to Wissner (2011), the main option that Smart Grid offers to the sector of generation is a better integration between the renewable energy sources, such as solar and wind energy. The expectation is that this system allows the integration of systems of generation connected to the distribution grid, in low and medium tension (distributed generation). This will contribute to several countries to reach their goals of raising the quantity of energy generated through renewable sources. In Figure 3 examples of sources of power generation most commonly used are shown.

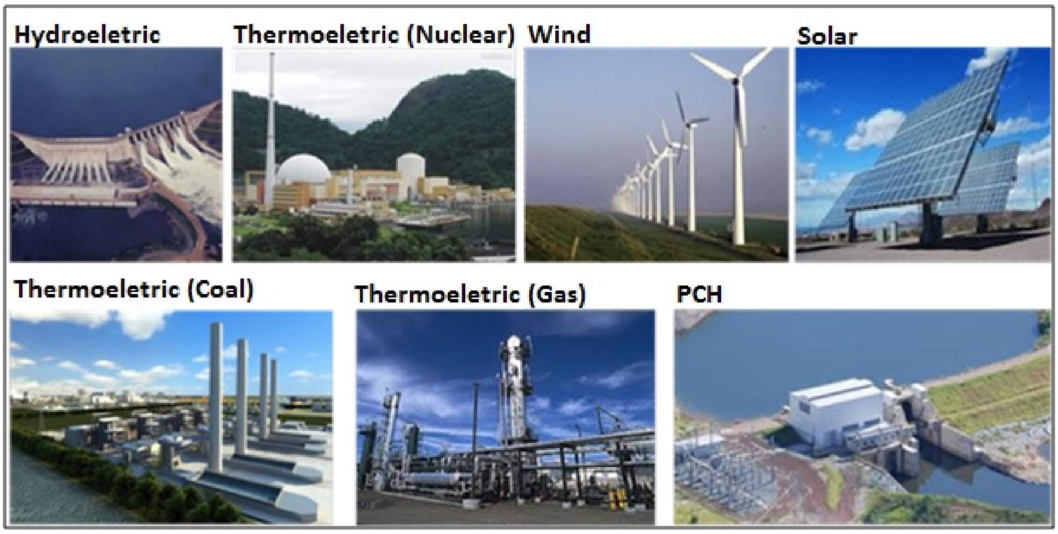

Figure 3 - Examples of sources of electricity generation
Source: Schettino (2013 p.48)

Some benefits of the distributed generation are described by Nair and Zhang (2009):

- Elevation of the supply/load of the electric grid;
- Security of the energetic supply raises, avoiding overcharge in peak times of the system and consequent restrictions of treatment;

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- Reduction of energy loss and postponement of investments in capacity enlargement and consequent reduction in carbon emission.

Still according to the mentioned authors, are related some challenges to the distributed generation and Smart Grid implementation:

- Existing technology outdated;
- Difficulty of adjustment and coordination of electric protection;
- Difficulty to the maintenance of the product quality, with several sources of alternative generation (level of tension, harmonics and frequency);
- High costs associated.

In the Blumsack and Fernandez (2012) analysis, the energetic politics in the United States and other developed nations encouraged the growth in renewable electricity generation. The intermittency of the wind and solar energy generation system puts up challenges to the operators of the electric system that should guarantee that the demand and offer are balanced at all moments. The great challenge for renewable energy generation sources connection is about the seasonality of this generation, not being available to inject energy in the system at any moment.

Regarding the intermittency of the renewable sources generation, Ota et al. (2012) highlight that an existing solution to minimize the needs of complementation of the energy through the use of thermal generation (fossil fuels burning) would be the storage of the surplus of energy generated by the renewable sources in batteries banks. A solution that may be used is the harnessing of the electrical vehicles batteries for the storage of this surplus of energy, that would be injected in the system in the greater load times (peak hours), but in this case it should be planned the disposal of such batteries when finished their useful life.

With the implementation and use of the SG, generators would obtain a clearer image of the demand and a more precise data about the distribution grid, causing ways of improving the production resources due the better demand management, as highlighted by Clastres (2011).

This way, the main gain allowed by the Smart Grid in the generation system is regard exploring the maximum of the utilization of the potential of the installed

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renewable sources generation (and operating) and of the distributed generating, because this sources normally don't allow dispatch (generation) in the most appropriate moment to the consume. Sources of generation as solar and wind power, for example, need to generate and inject in the system the energy generated in the time that the sun and wind are available, respectively.

2.3 Smart Grid in transmission systems

The transmission system is the unifier of the electric energy system, because it's through the transmission system that the main sources of energy are connected to the final users, passing through the distribution system. Failures in the transmission system may trigger systemic disturbances that, in some case result in shutdowns of parts or the whole electric system, causing blackouts.

One of the Smart Grid functions would be to improve the accompaniment and operation of the high tension transmission system, where big blocks of energy are transmitted. There are some economic advantages to this system, even if introduces some energetic deficiencies (resistive losses along the transmission lines), yet it should be respected the capacity limits of the electric energy transmission of this lines.

The technologies of Smart Grid may allow the system operators to control the energy more precisely, through the implementation of Flexible Alternating Current Transmission Systems (FACTS). These devices (FACTS) may allow the optimization of the transmission in almost real time or in response to the system conditions, as highlighted by Blumsack and Fernandez (2012). Thereby, it's possible to explore the maximum of the operational capacity of the energy transmission system, raising the efficiency, security and reliability of the system and, at the same time, allows the postponement of investments in this system expansion.

2.4 Smart Grid in the distribution systems

Historically, the planning and operation of the electric energy system are being performed in a segmented way: the centralized generation and transmission, in general, receive an integrated treatment, while the several subsystems of distribution are studied independently. The vital interest to the operators of the distribution grid, it to know the current charge of the system and provide stability to the system. Several programs of incentive for the price and incentives based on demand are developed

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and designed to model and equalize the demand, being needed the application of information technology and telecommunication and smart meters, for it to start working (WISSNER, 2011).

The distribution systems are those that are being more benefited by the Smart Grid technology. Falcão (2012) highlights that the electronic meters add a series of new functionalities to the old meter electromechanical of consumption (kWh), constituting a smart meter, which opens the possibility of important innovations, such as:

- AMI (Advanced Metering Infrastructure): will allow the automatic reading of the demand and the consumption of individual consumers, connections and disconnections of consumers;
- Automatic detection and isolation of issues, reconfiguration and restoration of the service (energy providing);
- Coordinated control of the tension and flux of reactive.

Falcão (2010) highlights that this approach shall suffer a conceptual chance with Smart Grid's entrance. The bidirectional communication of information and flux of energy between the system and consumer (and also the reverse order, in case of cogeneration), creates a need of an integrated approach of all segments, by more active character each time for the system of distribution and final users. This change of paradigm will affect substantially the methodologies of expansion planning, planning of operation and monitoring the control in real time.

Therefore, fits the electric energy distribution concessionaires to adequate their intern processes to derive all possible gain potential with Smart Grid's utilization, which will lead to the reduction of operational costs that will be reverted in tariff reduction, with direct earnings to the consumers and to the society.

2.5 Needs and consequences of Smart Grid distribution

To Krishnamurti et al. (2012), the first step in Smart Grid's direction is the installation of a smart meter in the residences, allowing the remote reading of the meter, daily or even continuous. Based in these readings, the distributors would be able to implement answering programs to the demand, offering electric energy with differentiated prices in function of the consumption timetable. Actually, demand

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answering programs seek reducing the consumption of electricity during the peak hour of use, relieving the overcharge of the system.

Such meters constitute a natural link and fundamental condition to implement Smart Grid between the consumer and the provider (WISSNER, 2011). The data of the measurement are the basis to the billing of the consumption and in most cases, the moment of the measurement is the only moment of contact between the provider and the consumer. The new meters with digital technology allow communication between the equipment and the operation central of the provider (distributor). The ways of communication used allow the communication in two ways (bidirectional), being: the first from the consumer to the provider, where all data of consumption and other data referring to the quality of the energy are sent; the second from the provider to the consumer, that is the traditional way, which allows some intervention actions over the consumer, as shutdowns and turning on again.

The Smart Meters are fundamental elements to quantify in real time the consumption and generation, the quality of the measured energy, and the instant updates of the prices of electricity. However, the smart meters should not be considered only as a additional component in the existing systems of electric energy, otherwise, its disruptive impact cannot be captured and its business is negatively tendentious, in function of the high initial costs of acquisition. It is possible to see in Figure 4 are examples of conventional meters (electromechanical) and smart meter (SM) and devices for interfacing with the consumer.

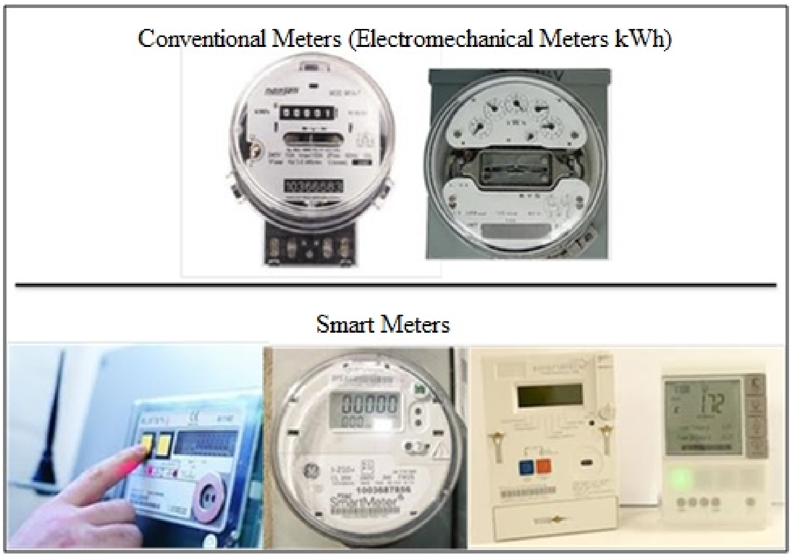

Figure 4 - Examples of Smart Meters
Source: Schettino (2013 p.53)

Thus, the smart meter highlights itself as an element of extreme relevance to the composition of Smart Grid, because is the element of connection that will allow the management practically in real time (on line) of the consumption and production (generation) of electric energy, but previously this management of the production of electric energy was done with basis in estimations of expectations of the consumption.

One consequence of Smart Grid's use with its Smart Meters will be the construction of intelligent houses, because the last link of connection between the consumer and the distributer will be the own electronic equipment's installed in their residence. With the invention of modern technologies it is possible the automation of the equipment's in a residence without the needs of manual intervention for its actuation (WISSNER, 2011).

The prerequisite to the development of intelligent residences is the existence of the interface of communication between the electronic equipment's. This interface of communication should allow the transference of data and the remote operation through a central of control installed in the residence. This control center will be responsible for the management of the utilization and consumption of the equipment's of the residence, as the use of alternative sources of energy (own renewable generation - solar and wind).

A energy management system of an intelligent house is a system capable of allowing the commands of the equipment's of the house and provide the optimization of the energy consumption, with this, reducing the consumption of energy (and consequent value of the energy bill), in function of the management of the charges and the supply of energy in the peak hours, accordingly to Al-Ali et al. (2001).

The smart meters associated to the system of management may be programmed to keep a schedule of the domestic devices operation and control the operation of other devices, such as to control the lights, air conditioner and other devices. Depuru et al. (2011) describe that beyond that, the integration of Smart Meters helps the energy distribution companies in detecting the non-authorized consumption and energy stealing, in view of the improvement in the monitoring of the demands and of the indexes of the energy quality.

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The management of the demand by the consumer, through the management of energy consumption of an intelligent house in the peak hours, using renewable energy sources (own generation) and energy of the concessionaire network, allow real gains in reduction of the energy bill. This economy is possible due the switching between the energy supplying of renewable sources and the concessionaire grid, in order to consume the energy of the concessionaire in hours of cheaper tariff (out of peak hours), while in the hours of more expensive tariff (peak) it utilized the energy generated in the renewable source or stored in the battery, agree Al-Ali et al. (2011) and Wissner (2011).

3. REGULATION OF THE ELECTRICITY SECTOR AND INVESTMENT INCENTIVES - AN OVERVIEW

Lots of European countries (France, Ireland, Holland, Spain and United Kingdom) defined goals to the development of Smart Grid, for example, the smart meters already represent 85% of all devices in Italy, 25% in France and many governments are predicting the implementation in all the country until 2020, as describes Clastres (2011).

An important challenge for the regulatory agencies is to standardize the implementation of distributed generation through renewable sources. An example reported by Wissner (2011) is the Law of Renewable Energy, implemented in Germany in 2000, that forces the operators of the electric systems to connect plants of generation of renewable energy to the electric system. This new challenge established to the operators of the electric system, in function of the environmental protection politics that require considerations about energetic efficiency that are referenced in the national agenda of the "Integrated program of energy and Climate" of Germany.

The appearance of the demand sensible tariff, possible since the implementation of Smart Grid, has important implications to the development of the scenario of the energy in the future, particularly related with the social-environmental parameters and goals of reliability/quality. The displacement of the consumption of energy to periods out of the peak of the system brings positive implications to the electric sector and reduce the emission of gases that causes the greenhouse effect (BLUMSACK; FERNANDEZ, 2012)

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The gains with the Smart Grid will be obtained in all value chain of electricity, whether in the economic, social or environmental areas, but the technology is still in development and implementation. Regulation will be needed to leverage the investments, in a way that the prices of the tariff should offer a sufficient incentive to support the necessary investment. In several countries that the Smart Grid was implemented, there was the incentive or repayable counterpart funding, from the government, of high level of needed investment for the substitution of the conventional meters to Smart Meters, essential to the viability of Smart Grid.

The implementation of Smart Grid's systems should be done with the clear conscience of the benefits and costs associated. It should be discussed not only the implication of the Smart Grid to the development and the analysis of future scenarios of the energy sector, but also evaluated the main social, economic and environmental benefits that Smart Grid may bring.

Johnson (2010) highlights five key factors to the success in the implementation of Smart Grid in the North American energy distribution concessionaire, the Southern California Edson, as being: i) integration of distributed renewable energetic resources and system of storage; ii) control of the grid and optimization of assets; iii) the effectiveness of the workforce; iv) smart metering, and; v) solutions of intelligent energy in the clients.

The Smart Grid system provides several benefits, such as efficient control of the energy of the system, support and intervention together with the operational decisions to minimize the interruptions and energy losses. It also may perform energy cost allocation, failures analysis, control of the demand and analysis of the energy quality; it may indicate the needs of preventive maintenance and improve the functioning of the meters to an exact billing of the consumed energy. Furthermore, the Smart Meters may detect the presence of irregular clients and illegal in the grid, highlights Depuru et al. (2011), the big problem in Brazil, representing 17% of the losses in the electric system.

Accordingly to Clastres (2011), in some case, the main benefit to the consumer is the reduction of the costs obtained by the reduction of the demand or through the transfer of the consume to a period out of peak (of cheaper tariff). The benefit to the distributer is represented by the economy/postponement in the

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production costs and substantial balancing of charges during the periods of high demand (liberation of the capacity), reduction of losses and reduction of operational costs.

Blumsack and Fernadez (2012) report a great North American blackout that occurred in august of 2003 that turned the public attention to the state of the electric network in the United States and Canada. The infrastructure of transmission of energy in the USA had fallen constantly since the decade of 1970. The severity/scope of the blackout convinced even the skeptics that the transmission system was no longer able to attend the demanded services. In first place, the blackout of august 2003 highlighted the fact that, despite the big advances in the sector of coordination and planning, the reliability of the electric system did not improve. Since the 80's, the frequency of great blackouts hasn't decreased, and the greatest blackouts still seem to occur with some regularity in every ten years.

The Smart Grid may even solve specific problems of each country. To Denmark and Sweden, for example, the Smart Grid will contribute to the generalized use of electric vehicles (plug-in). Spain wants to improve the quality of the offer with fewer incidents. Portugal intends to reinforce the integration of renewable energies in its electric system. Italy expects to reduce the frauds and energy thefts. Holland is expecting to save energy and reduce the emission of greenhouse effect gases (CLASTRES, 2011).

Nair and Zhang (2009) highlight that in their studies that New Zealand has the aspiration to reach the index of 90% of its energetic matrix deriving of renewable sources, until 2025. In order to contain Global Warming, the Europe stipulated the goal of having, in 2050, 100% of its energy arising of renewable sources. For this the approach of Smart Grid will combine two alternatives: centralized generation and distributed generation. With those alternatives, that are actually complementary, it will be possible to hit this goal. The Smart Grid contributes simultaneously to the safety of the energetic matrix, climate safety, social safety and national safety; highlight Battaglini et al. (2009).

Finally, France is developing this technology to make it possible to the consumers the control of energy demand, improve the quality of supply and improve the operation of the electric system. To limit the costs of the distributors, each

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country/concessionary has its own vision of what segment of market would win more of the Smart Grid.

In Brazil, alert to the global tendency of Smart Grid's implementation, ANEEL, the Brazilian Energy Regulatory Agency, developed a strategic project of research and development (P&D), which involved several entities such as, various energy distribution concessionaries, that were sponsors of the project, telecommunication companies, manufactures of electronic meters, companies of information technology, energy generators companies, the National Institute of Metrology (INMETRO), agents connected to renewable/alternative energy generation sources, among other agents interested in the theme, to develop researches about Smart Grid.

Terminated the strategic project of research and development of Smart Grid, with contribution of the researched technological content, several energy distributing companies started the pilot project of Smart Grid installation in some cities. It is highlighted that it doesn't exist in Brazil any pilot unit in complete functioning and that all are being developed with a different level of scope and applicability. The pilot units in development, currently, in the country are the municipalities of Paratins, in Amazonas, that is a fluvial island situated in Amazonas river, the island of Fernando de Noronha, in Pernambuco, the city of Aparecida, in São Paulo, the town of Sete Lagoas, in Minas Gerais and finally, in starting phases, it is being developed the pilot project in Buzios, in Rio de Janeiro coast.

The several future benefits of Smart Grid's implementation and use, such as the energetic efficiency, reduction of operation costs of the system, possibility of reduction of the costs of the consumer with the electric energy consumed, improvement of the environmental sustainability, among others, will be consequently obtained in Brazil as Smart Grid is being implemented in the country, however other relevant and specific benefits may also be earned.

As occur in the Interconnected Brazilian National System (SIN), Battaglini et al. (2009) highlight that all over the world, the quick expansion of the wind energy generation registered in the last years raised a lot the loading of the existing system. However, the technical restrictions of the existing system limit the exploration and connection of the new wind farms and other renewable sources.

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Thus, the Brazilian electric system is not adequate to nicely support the future needs of electric energy, as well as it don't attend to the electric security and reliability criteria. According to Blumsack and Fernandez (2012), the existing network has well served the industry of electric energy for over a century, but is no longer configured to attend the multifaceted demands of the society.

This way, in a near future, the total demand of energy should become the double of the current demand. Looking at this situation, many emerging countries do not have resources to the addition of the additional capacity. To fill this gap, the Smart Grid arises to help in the control of electric energy thefts, regularization of clients and optimization of the existing capacity through the better use of the existing assets.

4. MAIN BARRIERS TO SMART GRID'S TECHNOLOGY DIFFUSION IN BRAZIL

The Smart Grid clearly has benefits in terms of macroeconomic potential, associated to the use of renewable energy, as highlighted previously, however, in function of the high level of investments required and the time needed to develop, such investments present some risks associated mainly to the political uncertainties, that need to be better evaluated, as highlighted by Battaglini et al. (2009):

- Magnitude of the investment – the Smart Grid needs a high level of capital application and has associated important gains of scale;
- Indefiniteness and uncertainties as to the sources of sponsoring of the needed investments;
- Technological uncertainties – high tension energy and continuous flow transmission, energy storage technology, electrical vehicles, smart electronic measurement, telecommunication systems, etc.;
- Political uncertainties – changes in the political scenario influence in the regulation of the electric sector and in the governmental guidelines to the technological development of the country.

Accordingly to Blumsack and Fernandez (2012), researchers and politic formulators need better models to evaluate the Smart Grid's system performance and to detail measure the progress of the implementation goals. A attention point that

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Smart Grid will effectively raise is the complexity of the already complex system in which, great scale failure, are susceptible and inevitable. Smart Grid may introduce new types of failures that did not start appearing or studied yet.

In developing countries, Brazil as an example, the architecture of Smart Grid based on the use of smart meters faces with the problem of the cost and availability of communication services to such big volumes of links and high level of complexity of management of the constituted network, highlight Gomes et al. (2010). It is also important to highlight that the big mass of data to be collected, by the center of the operation demand protocols and networks of unavailable communication in a large part of the county.

Another relevant point is that the implementation of the system with the smart meter in distribution involves billions of dollars of investment and maintenance of the network (DEPURU, et al., 2011). Initially, the process of replacement of the existing energy meters for the smart meter is a challenge to the companies, because the lack of adequate infrastructure to synchronize this new technology with the existing ones may interrupt the introduction of the smart meters.

Related to the collected data, Depuru et al. (2011), highlight that the use of the system of smart meters involves an enormous quantity of data transfer between the concessionary company and the client, these data are sensible and confidential, and the access to these should be restricted. With those restrictions about the data, guidelines of security shall be formulated to the gathering, transmission, storage and maintenance of the data of energy consumption.

The quantity of data and information will exponentially rise, and the correlation of those data and information will become much more complex, highlight Li and Zhou (2011). With the explosive grow of the volume of information in public electricity services; the problem of information overcharge will become increasingly severe. In order to efficiently filter all the available information to find the potential and valuable knowledge to the companies of the electric sector, some new approaches should be examined and developed.

Accordingly to Wissner (2011), the final goal of the implementation of information technology and telecommunication in the energy systems is to make most processes automatic and make communication easy and efficient between

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different sectors. But, as it was presented previously, this is one of Smart Grid's greatest challenges in Brazil and the World.

The interoperability and protection of privacy of the data are the problems that need to be solved in the information technology and telecommunication context. All integrant and components of the system should be capable of communicate between each other, and allow the perfect integration, with operational security and integrity/security of the trafficked information. In each part of the chain (generation, transmission, distribution and consumer) there are different obstacles to be beaten.

Hashmi et al. (2011) highlight that Smart Grid's implementation is composed by much more than any technology associated the benefits of making it a reality go way beyond the electric energy system. In fact, this transition will not be easy nor quick. In Brazil, reach the potential of Smart Grid will require a new level of cooperation between the members of the industries, society, and mainly, the regulatory organs that have immediate influence about the direction and time that the process must follow. The Smart Grid is an evolution to an optimized and sustainable energy system, smarter, efficient and reliable and will bring a positive influence about the climate changes.

Even though many devices are integrated with the smart meter system, they will be able to be used in their maximum extension only when all equipment's and devices in the distribution and measurement network are integrated to the communication network. The integration of the devices becomes even more complicated with a growing number of clients. It also may be considered that the implementation of the communication network in some localities may be though due geographical and technological issues.

Starting from an international experience of Smart Grid's implementation, a indirect risk to Brazil, related to the use of smart meters, is related to the possibility of the consumer privacy violation due the possibility of the disclosure of the data of detailed billing that could reveal when the consumers are at home and how the use their devices. Another point that may create resistance by the Brazilian consumers side is the fact of the larger precision of the smart meters, it may result in a raise in the value of the consumer bill, without changing the pattern of consume, as highlights Krishnamurti et al. (2012). This question should serve as a attention point to the

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installation of Smart Grid in Brazil, as it represents a previous research theme to the development of the project.

A variety of social, cultural, economic and regulation factors has been some of the decisive factors to the success of the implementation of Smart Grid in several countries and probably, it will be in Brazil. Krishnamurti et al. (2012) highlight that the first step to advance to Smart Grid's implementation goes through the implementation of programs of answering and acceptance of the consumers to the installation of smart meters in their residences. Fact that also needs to be examined in Brazil, to ensure the success of the projects that will be performed to Smart Grid's implementation.

5. FINAL CONSIDERATIONS

The benefits of Smart Grid's implementation and use are evident to all agents involved in the production chain and consumption of electric energy to the society in general. In the segment of electric energy generation it will be possible to couple, use in an efficient way the renewable sources of energy and distributed generation, as well as allow a larger energetic use available through the cogeneration of energy of all and any consumer unit. And, in this way, it will be possible to optimize the dispatch of energy generation of all available sources aiming the lowest global cost of generation and an improvement of the environmental sustainability with the reduction emission of the greenhouse effect gases, in function of the fossil fuels burning for electrical energy.

In the segment of transmission and distribution of electric energy exists a lot of benefits such as the optimization of the use of the transport capacity (conduction) of energy and its consequent improvement of the assets management, that in Brazilian case, the operation of these systems will be broadly benefited with Smart Grid, because it will exist the possibility of monitoring in real time of the electric parameter of quality of the service and the product, as the minimization of the areas affected by interruptions of energy supplying.

It still should be highlighted the benefits of the consumers that will be obtained through the use of smart meters and variable tariff that will allow the management of its demand and consume and displacement of the consume to the times of lower cost, that will cause a reduction of the charged value in the bill of energy and

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reduction of the demand (charge) in the peak hours of the system. This reduction of the demand in the peak hours of the system reduces the needs of investments to the reinforcement of all productive chain of electric energy and consequent tariff raise.

In the area of innovation and technology, Smart Grid will allow the development of intelligent houses that allow the management, automatic operation and remote of the electric and electronic equipment's installed in the residence, as the use of cogeneration (generation of photovoltaic, wind energy, micro turbines, etc.) and electrical vehicles (plug-in) connected to this residence.

The use of Smart Grid is quickly expanding all over the world and its diffusion in Brazil is inevitable, yet some barriers to its implementation must be overcome such as the improvement and reduction of costs of the smart meters and development of the telecommunication network, because to the adequate functioning of Smart Grid it is necessary an excellent communication network due the enormous flow of measurement data that will need to be received and treated without losses of information and in time to all making of decisions.

A critical factor of success for Smart Grid's implementation is to disrupt the cultural resistance of the residential consumers as for the substitution of the conventional meters for the smart meters, that are directly connected to the information systems of the concessionaries and won't need that the consume reading and demand to be performed in the presence of a reader.

In Krishnamurti et al. (2012) vision, there are reasons to worry about the comprehension of the consumers about the smart meters and lack of orientation about how to deal with the proactive politics that help to explain and attend the consumers' expectations, developing simultaneously the communication that create realist expectations about the benefits and risks, addressing explicitly the mistakes commonly found in the mental models of the consumers forced to trust in the current available information to them.

To Smart Grid's diffusion in Brazil, it is still necessary to establish a regulatory mark to the electric sector that regulates essential questions to the functioning of the productive chain of the national electric system with Smart Grid. The regulation of the electric sector should allow the rate design (higher tariff during peak hours and lower rate out times of peak) of residential consumer, and allow that other classes of

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consumers, independently of its level of consumption, become cogenerates and sell their surplus of produced energy to the concessionary, in a dynamic way. It is also fundamental that the regulation establish criteria of tariff coverage and financial subsidy to make the needed investments to the substitution of the park of conventional meters to smart meters (approximately 70 million meters), that represent a very high cost, without encumbering too much the concessionary or the consumer and cause economic unbalance between the agents.

As showed in this article, the implantation of Smart Grid includes several challenges such as technological, operational, regulatory and cultural, which need to be identified and beaten in Brazilian level, because the obtained experience by other countries may not be replicated in their plenitude for Brazil due the regional, cultural, regulatory, infrastructure and technology differences. This way exists a vast field to be developed researches in Smart Grid's area in Brazil, taking in consideration the restrict existence of literature and studies regarding this in the country and even the world, by treating of a contemporary matter with several areas of knowledge involved.

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