Overview of Socio-Economic Issues for Smart Grids Development

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Abstract: The electrical world system is experiencing many challenges, including the increasing presence of renewable energy sources characterized by high variability, the call for actions to mitigate climate change, the need to restructure the infrastructure already aged and then the development of smart grids. Smart grid projects have been launched in various countries around the world. The transition to the smart grid is affecting primarily the European Union and the United States, but also emerging markets such as China and India are strongly investing in the smart grids. In this paper we analyze the socio-economic aspects that are among the key variables towards the feasibility of smart grid projects. Construction of new infrastructures generally rises acceptance problems. Social acceptance of consumers is important for the adoption of new technologies. We advocate that multidisciplinary cooperation is needed to develop scientific research on smart grids.

1 INTRODUCTION

We are in the midst of a historical paradigm shift in the energy market linked to the synergy between energy and Information and Communication Technology, i.e., the smart grids. “A smart grid is an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure an economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety” (European Commission Task Force for Smart Grids, 2010).

The traditional operation of the electric grid was based on a top-down hierarchical approach, whereby electricity flows from few large generation plants to the large community of millions of final consumers (firms and households). This was the old world of large efficient fossil and nuclear plants, which needed a centralized dispatching control in order to ensure the transmission network security. Nowadays, the surge of renewable energy sources (RES) and other small scale efficient generation units has revolutionized the concept of the electric grid operation. Management and control needs to be performed at all levels of the electric system in a simultaneous fashion. It is sufficient to consider that a sudden increase in a photovoltaic unit generation, which is embedded in the low voltage distribution network, produced a feedback of lower load signal to the primary high voltage transmission network. All this needs to design a new grid architecture, such as sophisticated information technology, new cyber security, new opportunities for investment and consumption management. For instance, a new proposal is the development of a distributed system platform as a smart interface between production and costumer need, in the New York system (New York State Department of Public Service, 2014).

A change of the electricity grid model and an evolution of the current system highly needs several factors, such as the liberalization of energy markets and the necessity for sustainable development, which can be achieved through energy efficiency, CO_2 emissions reductions, the reduction of the massive use of fossil fuels and the increase of RES production.

The aim of this paper is to analyze the socio-economic aspects of smart grids, from the viewpoint of social acceptance: consumers’ acceptability, privacy, costs, cyber security and regulatory aspects. They have a significant impact on the development of smart grids technologies. Indeed, electricity consumers play a key role in smart grids development: they are called for a transformation of their role of consumers from passive to active, aware of their consumption and able to handle it according

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to the availability of energy. The analysis of socio-economic aspects of smart grids in important for understanding how to induce consumers to enter into a contract and implement virtuous and useful behavior to optimize the operation of the electricity grid.

The development of scientific research on smart grids requires a broad multidisciplinary and interdisciplinary cooperation, involving different actors, both public and private, ranging from universities and research organizations, to electricity producers and operators of electrical grids, agencies and companies on new communication technologies, to the consumer organizations.

For the realization of smart grids, it is necessary that all stakeholders are equally involved, thus incorporating RES industry, small producers who are also consumers, trade and territorial associations.

We first discuss smart grids in terms of opportunities for climate change mitigation. Next, we provide an overview of the socio-economic aspects for smart grids development. Finally, we present architecture policies of the major countries that are investing in smart grids.

2 SMART GRIDS FOR CLIMATE CHANGE

Currently we see the impact in everyday life and in the economic balance of everything that is related to the perceived quality of life, the environment, the development of the person and of the economic system and the necessary infrastructure to produce and deliver energy. Everything related and connected in a large system that is the planet we live in. The real news of the last few decades is the choice to reduce the use of fossil fuels and increase more and more the RES production. This is a new way of thinking the supply and distribution of electrical energy, particularly in terms of CO_2 emissions reductions. The international community has become aware of the serious and concrete problem of polluting emissions, then implementing several international environmental agreements. As the source of more than two thirds of global polluting emissions, the energy sector is crucial to tackling climate change. RES are one of the most important drivers for climate change mitigation, as well as other measures such as energy efficiency, carbon capture and storage.

In the “New Policy Scenario” issued by IEA, which explores the evolution of energy markets on the basis of the continuation of existing policies and those implemented until mid-2014, the RES growth will be approximately 3 times higher than that occurred in the period 1990-2012. Although fossil fuels will still dominate the energy mix, in 2040 RES could provide about 23% of the electricity consumed in the world against the current 3.3% (IEA, 2014a) (Figure 1).

In the "smart" development model, RES are no longer necessarily linked to a few producers but increasingly become a production and consumption option available to large sections of the population. Electricity production increasingly widespread and irregular requires the development of flexible and smart grids, able to handle peak and distribute the most of the energy produced. Then, smart grids could become a key element to increase the use of RES.

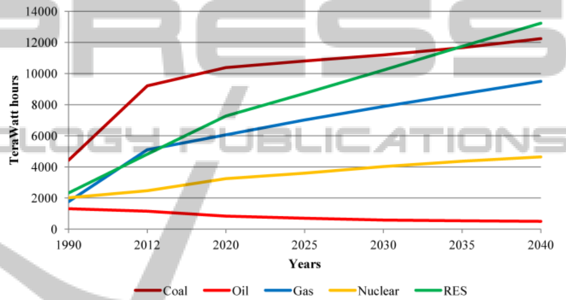

Figure 1: Electricity generation (TWh) (IEA, 2014a).

3 SOCIO-ECONOMIC ISSUES

The smart grid technologies use innovative products and services combined with advanced technologies for monitoring, control and communication, in order to integrate distributed generation from RES. They provide customers with tools to optimize their consumption and improve the functioning of the global system, promote a charging infrastructure for electric mobility, reduce significantly the environmental impact and increase the degree of reliability. These are at the same time the incentive factors for the development of smart grids worldwide (Figure 2).

Indeed, benefits of smart grids are related both to the environment and to the final consumers. They allow reliability and quality in the supply of electricity, effectiveness in the distribution of energy flows and flexibility in managing peak demand, environmental protection, support the deployment of RES and electric mobility, contributing to the reduction of CO_2 emissions, greater awareness for the final consumers of their own consumption style.

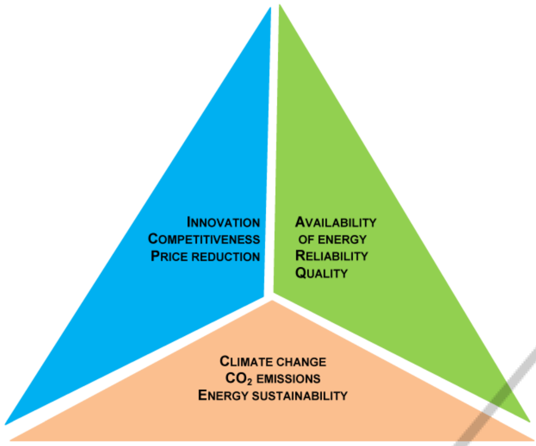

Figure 2: Smart grids incentive factors.

For instance, it is experiencing the diffusion of small plants related to RES production, scattered across regions and often placed on the distribution networks in medium and low voltage. In these cases there is a high electricity consumption in the site. This phenomenon has led to the occurrence of a paradigm of production and consumption contextual of electricity: electricity consumers are evolving in "prosumers" because they not only consume, but also produce and store electricity (Grijalva and Tariq, 2011; Kanchev et al., 2011). The prosumer is a hybrid figure which, according to market signals and systems management, through smart decision, automatically and in real-time, he decides if it is more convenient to self-consume the energy produced or to enter the grid and sell it.

Notwithstanding benefits related to smart grids technologies, it is unclear whether final consumers are willing to accept smart grids technologies, that is changing their energy behavior. Smart grids require a complete rethinking of how to introduce new technologies. This is not an easy process, because it involves more than just providing solutions to technical issues. Development of smart grids as a new infrastructure affects significantly the entire value chain and then bring about shifts in consumer behavior, culture, and practice, i.e., a whole range of new socio-economic aspects, including the crucial issue of new ways of actively contributing to climate change mitigation. Successful introduction of smart grids require support of final consumers and households (Verbong et al., 2013).

There are socio-economic barriers that are not deeply analyzed by the social sciences, or that are at a very early stage of study, but that could significantly influence smart grids deployment: consumers' acceptability, privacy, costs, cyber security and regulatory aspects. These are the main determinants of acceptance. In the energy sector, social acceptance of new technologies has been discussed mainly with respect to nuclear energy and RES technologies (Semadeni et al., 2004; Kaldellis, 2005). Oppositions to new infrastructures are generally related to the Not-In-My-Back-Yard (NIMBY) syndrome, as in the case of wind power. For instance, it is widespread there is quite strong overall public support for wind power but when the projects become concrete, people suffer from the NIMBY syndrome (Wolsink, 2000).

Some studies on smart grids acceptability are carried out through public opinion surveys. These studies allow to understand how electricity consumers perceive the possible development of smart grids and how their behavior changes accordinlgy. Most of the opinion surveys report that consumers have a positive attitude with respect to smart grids as a solution to energy problems, but they are sensitive to possible tariff increases. Given the complex issue of smart grids, involving home energy management up to the physical installation of new technologies in home, final consumers may resist smart grids. Complexity makes people uncertain about the consequence of a choice, so it might be that fear that there are risks related to smart grids brings final consumers doing nothing, i.e., do not participate in smart grids (Anderson, 2003; Broman Toft et al., 2014).

An ongoing problem with respect to social acceptation of smart grids is the consumer privacy issue. The main consequence of smart grids' introduction is the possibility of large accumulation of data from smart devices. Data availability in the hands of energy utilities will show the largest increase since electrification (Rusitschka et al., 2010). The smart grids are able to detect not only the energy consumption of consumers but also to recognize its use. These are sensitive users data, which should definitely be protected but at the same time they are very interesting for the purposes of energy savings. Data control on the amount of energy consumed can lead to monitoring the behavior of a consumer with every imaginable consequence: it is possible to know how long the consumer sleep, when and for how many hours he use appliances, when and for how much time watching TV, etc. For instance, the main privacy concerns related to smart meters in a dwelling context where people expect their activities to be private. Consumers' sensitive data might be used for illegal uses, commercial uses, uses by law enforcement agencies, uses by other parties for legal purposes, use by family members and other co-inhabitants (McKenna et al., 2012). The privacy risks exist as well by translating the same phenomenon in the context of a firm. In fact, considering the activities carried out by a firm, even through the monitoring of data on electricity consumption, it is possible to know the operational procedures of that specific firm. All this, however, is related to the security measures to transmit information relating to the individual users directly to the energy supplier (Rial and Dazenis, 2011).

High initial costs for smart grids' development can constitute a socio-economic aspect that can act as a deterrent to social acceptance of smart grids. As young technologies, smart grids require significant investment and a distribution of costs in the short term, while there will be some long-term benefits for the various stakeholders of the sector. The quantitative assessment of costs to implement the smart grids is mainly provided by institutional entities. Some literature highlight the importance of policy makers in designing effective dynamic tariff programs involving the largest number of consumers. Indeed, dynamic pricing rate designs may represent a solution offered by smart grid technologies to reduce the bill paid by consumers. For instance, consumers can change their pattern of electricity usage by lowering consumption during the most critical hours. Some literature highlights the existence of many benefits that are not monetize in quantitative terms, such as reduced electricity outage times, the greater use of RES (Faruqui et al., 2010; Schwister and Fiedler, 2014).

The social/psychological risk of cyber security threats is the key risk that consumers experience and it is a real barrier to the deployment of smart grids. The security issue is related to the digital technology typical of smart grids and mainly to the related possibility of cyber-attacks. The targets of cyber attacks are: compromising and control devices control the grid, often as a first step for deeper and complex attacks, enter data traffic contradictory, edit or delete them in order to force bad decisions in response systems, obtain private information on user data, sabotage the system of communication and data processing to delay or send it into a tailspin. Anyway, there are countermeasures to be implemented for information security, such as actions to build communication secrecy, through secret keys sharing or designing a highly resilient communication architecture for smart grids (Ericsson, 2010; Park et al., 2014).

Regulation has a key role for developing smart grids. Given the climate of uncertainty that leads to postponing investments, the economic theory investigates regulatory measures that give incentives to enable investments (Clastres, 2011). Indeed, regulation affects market structure, the behavior of the different actors, in particular through the choices of return on investment, but also through administrative decisions.

Then, from an economic point of view, the development of the smart grids is mainly inserted in view of public policies to be implemented for their deployment. To the final consumers should be transmitted both the important benefits from the socio-economic point of view and the "environmental" values related to smart grids for climate change mitigation. Moreover, smart grids contribute to rural development, lowering health costs linked to air pollution and allowing energy independence; this reinforce the need for smart grids also in developing countries (Fadaeenejad et al., 2014).

4 INSTITUTIONAL ARCHITECTURE

The adoption of smart grid technologies varies across countries and depends on many factors including governmental policies, regulatory incentives, and technology experience levels within utilities. It is important to understand how government policies are moving for encouraging smart grids development. The development of smart grid projects is also a policy and financial problem. According to the New Policy Scenario, global investments forecasted amount to \$16.4 trillion between 2014 and 2035, of which about 58% is used for the construction of new power plants and the remaining for transmission and distribution infrastructures (IEA, 2014b). Investments in power plants are mainly aimed at non-hydro RES, mostly wind and solar photovoltaic, because their capacity is projected to increase over time, in spite of fossil fuels. Investments in transmission and distribution infrastructures clearly involve also smart grids. At the regional level, China is supposed to be the largest investor in the power sector, followed by the European Union (EU), the United States (USA), India and Southeast Asia (Figure 3).

Smart grid projects has been launched in various countries around the world. The transition to the smart grid is affecting primarily the EU and USA, but also emerging markets such as China, India and Brazil are investing strongly in the smart grid. It

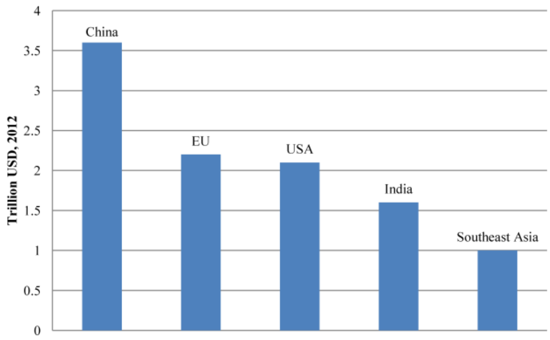

Figure 3: Cumulative global power sector investments in selected regions (trillion dollars, 2012) in 2014-2035 (IEA, 2014b).

follows a brief description of the main national smart grids initiatives.

With reference to the EU, most of the ongoing projects (and over 70% of investments) are relating to smart meters. In the period 2008-2013 investment in smart grids have been consistent and approximately € 200 million per year; they mainly come from private capital (49%), EU institutions (22%), national governments (18%) and regulatory agencies (9%), with the remaining 2% funding unclassified. According to the Third Energy Package (a legislation package on internal electricity and gas markets fully applicable since March 2011), there is the target of rolling out 80% market penetration for electricity by 2020. The European Commission forecast the installation of 200 million smart meters for electricity (that are 72% of EU consumers) for an investment of around € 45 billion by 2020 (European Commission, 2014). The geographical distribution of projects in the EU is quite unbalanced. Almost 90% of the projects are implemented in the old EU-15, while a few marginal projects are present in countries entered for the last members of the EU 28. This inequality may create in the future, not only difficulties of cooperation between the different EU countries, but also fracture within the EU between more and less technologically advanced countries, with consequences that would endanger both the achievement of the EU objectives of sustainable development in the energy sector and the EU cohesion.

Net investments to implement smart grids in USA are estimated to range between USD 338 billion and USD 476 billion over 20 years (United States Department of Energy, 2014). Their main objectives are the development of smart grid technologies in the transmission and distribution systems and the provision of more information to consumers so that they can better manage their electricity consumption and therefore costs. Over the last years, the production of electricity from RES has risen in USA, especially with reference to solar photovoltaic, with California heading the RES market. Even the small wind, biomass and geothermal are going through a phase of development. The growth of RES requires greater integration of these into the electrical system. In addition, the utilities want to exploit the US smart grid to reduce the effects of grid outages due to storms and fires. In 2013, some utilities located in Georgia, New York and Colorado announced their intention to produce 840 MW of solar energy by 2016 (GSGF, 2014).

Although smart grid projects have been developed mainly in the US and the EU, many other countries around the world are beginning to explore smart grids deployments and in some cases the projects have already taken hold. BRICS’s countries (Brazil, Russia, India, China, and South Africa) account for 24% of global smart grids market in 2012. In particular, China drives the growth of smart grids among BRICS’s countries: the development of smart grid is high in the Chinese agenda because it is important to keep pace with the rapid economic growth. Smart grids are seen also as a way to reduce carbon emissions through energy efficiency of power generation (The Smart Grid Observer, 2013).

Both the developed and the emerging countries are moving to the deployment of smart grids. There is awareness worldwide by governments that to the population increase corresponds growth in electricity demand, but the compelling need remains to reduce electricity consumption for climate change mitigation.

5 CONCLUSIONS

In this paper we have analyzed the socio-economic aspects for the feasibility of smart grids development. We have identified five crucial aspects: consumers’ acceptability, privacy, costs, cyber security and regulatory aspects. We deem that these are the crucial issues that need to be understood and solved, in order to ensure a realistic smart grid technology deployment in the long run. The inclusion of consumers in the energy market will be, primarily, through the diffusion of consumption’s monitoring and choice of flexibly time of use rates. Informed choices of consumers will generate a boost to optimize electricity consumption. Our socio-economic analysis highlighted the need to complement technical issues with a comprehensive search for all the solutions that can be made available to customers/users, in a framework of convenience for them and for the operators. Thus, the responsibility of policy makers is to adopt a multidisciplinary approach in order to transform the electricity system in proactive and crucial component of climate mitigation and adaptation strategy. Such transformation goes through smart grids. The inclusion of conscious consumers in the process is of fundamental importance.

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