Contemporary Engineering Sciences, Vol. 10, 2017, no. 20, 987 - 999
HIKARI Ltd, www.m-hikari.com
https://doi.org/10.12988/ces.2017.79113

Energy Policies in Smart Grids

Víctor Gómez

Universidad Distrital Francisco José de Caldas, Bogotá, Colombia

Cesar Hernández

Universidad Distrital Francisco José de Caldas, Bogotá, Colombia

Fredy Martínez

Universidad Distrital Francisco José de Caldas, Bogotá, Colombia

Abstract

Mankind's demand for the continuous evolution of energy supply systems is ever-increasing since lower environmental impacts are sought after by replacing conventional energy sources. The goal of this project is to review the numerous researches related to global energy policies including new trends in power generation and management, where smart grids are commonly used. The research is segmented in terms of the different energy solutions adopted in several countries from Europe, Asia and America. Thus, the main scenario focuses on knowing about the energy solutions where intelligent networks and smart metering systems are well-articulated. Subsequently, the main exchange policies are identified and a comparative scenario is presented with respect to the Colombian electric sector. A review of the energy policies from different countries was made considering both supporters and detractors of the Kyoto protocol. As an initial result, an overview is presented on the main improvement actions that are currently being developed worldwide and the current state of the Colombian energy sector. This enables the authors to know firsthand the energy policies that Colombia requires in order to guarantee a more sustainable energy basket. Nowadays, the developed countries are championed in the energy policies related to the rational use of electrical energy and the use of clean energy sources. Hence, the present investigation reveals the strategies led by several nations and use them as guidelines in managing the Colombian energy sector and strengthening it through the use of intelligent networks.

Keywords: distributed energy resources, energy policies, smart grid

1 Introduction

Intelligent networks also known as Smart Grids (SG) emerged as a response to the need to modernize the electrical network, make it greener and improve the energy supply system. Since intelligent networks are more independent and can improve the effectiveness and efficiency in energy management, the public service companies can use the existing infrastructure and minimize the need to build more energy plants. Intelligent networks enable renewable energy resources to connect securely to the network in order to complement the energy source with the energy coming from distributed generation and the storage of clients.

The purpose of this article is to present a general vision of the worldwide energy policies over SG showing how technologies have reshaped the modern electrical network. The policies, pilot projects and implementations are analyzed in different countries to define how technology has flourished. However, the present work also has the intention of identifying the research activities, tendencies, issues and challenges. When people learn about SG they can understand their value and it will be easier to adopt the compromises necessary for changes. This can be explained by the fact that knowing more on the success and matters related to SG leads to a stronger participation to improve its capabilities and diminishing its inconveniences.

The article is structured as follows: in section 2, the worldwide energy policies on intelligent networks are presented; in section 3, the Colombian energy policy on intelligent networks is described; in section 4, the challenges of intelligent networks are shown; finally, in section 5, a set of conclusions is stated.

2 Worldwide Energy Policies

The SG policies all over the world show the growing trend to offer a reliable framework to facilitate the development and implementation of SGs.

United States

The energy policy of the United States government aims at offering a secure energy supply, maintaining low energy costs and protecting the environment through the reduction of the consumption via efficient management and the development of new non-conventional energy sources [1]. United States has invested in renewable energy resources and started modernizing its energy infrastructure. The country is not a member of the Kyoto protocol (the nation signed but rejected to ratify its position later on) it does aim to reduce carbon emissions. The Report of the Global Federation of 2012 states that the USA has a non-binding purpose of reaching close to 17% below the levels from 2005 for the year of 2020 under the Copenhagen

Agreement. Additionally, in 2010, 663 American electrical companies had installed more than 20 million devices with embedded intelligent measurement infrastructure and the national penetration rate of intelligent measurement devices was at 14% per year [2].

With the consolidation of SG Consumer Collaborative, a non-profit organization that facilities the cooperation between consumers, defenders, public service companies and technology suppliers, the sustainable benefits of the SG can be adequately managed.

The USA Energy Department created the Office of Electric Reliability to modernize the electrical network and the resilience of the energetic infrastructure. The office has produced "GRID 2030" which articulates a national vision for the electricity of that country.

South Korea
Driven by the national security and economic growth, it developed an energy policy related to sustainable development. Wanting to improve the country's self-sufficiency and diversifying the energy supply offer, South Korea has approved laws that promote low carbon emissions and green energy initiatives. The nation has set the goal of reducing voluntary emissions by 30% for the year 2020 and plans to install intelligent measuring devices in half of the Korean households for 2016 as well as replacing all the old measuring devices by 2020 [3]. The organic law of low carbon growth and green evolution of 2010 makes for 2% of the country's GDP for businesses and ecological projects as well as the reduction of greenhouse gas emissions.

Under the policies previously implemented by the government since 2012, 2% of the total generation came from renewable energies for bigger generators with an estimated growth rate of 10% for 2022 [4]. While South Korea pretends to improve it energetic self-sufficiency, it exports green technology and offers assistance for development in exchange of energy resources. South Korea's Promotion Law of the SG offers a framework for sustainable projects of the SG for its development, deploy and commercialization.

This country is a leader in technology and its demonstration project is the Jeju SG. The level of coordination between the government and the industry to achieve Korea's ecological innovation goal is remarkable adding the presence of the Korean association of SG as an intermediary and contributing to the development of the system, its standardization and all the valuable research.

Europe
The European Union (EU) is an economical, scientific and political organization composed by: Belgium, France, Italy, Luxembourg, Holland, Germany, Denmark, Greece, Ireland, Spain, Portugal, Austria, Estonia, Hungary, Latvia, Lithuania, Malta,

Poland, Slovakia, Slovenia, Bulgaria, Rumania and Croatia [5]. It works through institutions and agreements between governments. The EU pretends to obtain 20% of its energy from renewable sources by 2020 and reducing greenhouses gas emissions as well as depending less on imported energy [6]. In 2007, the European Council adopted the 20/20/20 goal: reducing greenhouse gas emissions by 20%, increasing renewable energies by 20% and improving energy efficiency by 20% in year 2020.

The regulation over electricity demands the EU members to apply the intelligent measurement in 80% of the homes by 2020. However, this evaluation is subjected to a positive cost-benefit analysis. The electrical sectors of the member countries greatly vary so the deployment and its costs must be treated individually. The European Commission also established the European initiative of the electrical network, a research program and the development of nine years for SG technologies and market innovations [7].

Australia

Australia has the purpose of integrating 20% of renewable energy by 2020. As Australia a federal parliamentarian democracy with states and territories, the policies (although coordinated nationwide) are under the jurisdiction of the state. The Council of Governments of Australia establishes the framework for its energy policy. It promised to deploy intelligent measurement devices after the energy crisis in 2006 and 2007 even if it is costly. New South Wales and the State of Victoria led the deployment of intelligent measurement devices. The interest of Australia to implement new technologies of energy supply is manifested through SG Australia, a non-partisan organization that leads the modernization of the electrical system and helps the government in the electrical sector initiatives, one of them being SG Smart City.

Australia is also working on improving the incentives for investment on SG and the development of measures to regulate the demand and time of use fees. The main priority is to manage the demand, the energy safety and the energetic efficiency.

Canada

Even though Canada abandoned the Kyoto protocol, it is a part of the Copenhagen Agreement. The country aims at reducing greenhouses gas emissions to 17% below the levels of 2005 by the year 2020. However, it is not mandatory. The federal government finances ecological initiatives such as the Fond for Clean Energy and the ecoEnergy Innovation Initiative. This nation has adopted green energy and some provinces have taxes over carbon. Currently, there are pilot projects for SG in the provinces of Quebec, Ontario and other cities. The public services companies are also carrying out network modernization projects. SG Canada is an association of different parties and academic sectors that was created to promote the conscience on SG and allowing the research and development of new energy technologies and recommending policies that support the development of SG [3].

The Canadian government supports the development of SG through these entities: Natural Resources Canada, the Ministry which supervises the energy sector and the National Board of Energy. The latter is an independent federal agency which regulates the international and interprovincial aspects of the industries of oil, gas and electricity services. However, the Taskforce for National Technology and intelligent network standards was created to coordinate all aspects of development related to the SG. The provincial governments also participate in the support of the SG developments [5].

One of the main initiatives of the Canadian state has been to build the first SG laboratory in Ryerson University along with the Schneider Electric company; this laboratory will be based on the Urban Energy Center with the purpose of offering a workspace for the collaboration in research, development and testing for students, researchers and professionals of the industry.

Japan

The Strategic Energy Plan of Japan focuses on the energetic security, the protection of the environment, the efficient supply, the economic growth and the rebuild of the energy industrial structure. Among its ambitious goals for 2030, some are: elevate its energetic independence to 70%, increase the supply of zero emission sources to 70%, reducing the CO2 emissions by half in the residential sector, keeping and improving the energetic efficiency in the industrial sector. The intention is to strongly participate in the worldwide markets of products and systems related with the energy sector [8].

The Japanese government has adopted smart measuring after the nuclear disaster at Fukushima as a contribution to the management of demand. The government announced the installation of 27 million smart measurement devices for household clients in 2014. The services that use such devices will function in July 2015 to allow remote measurement and offer the users detailed data regarding the use of energy [9].

The Ministry of Economy, Commerce and Industry, responsible for the establishment of energy policies promotes the construction of SG and its deployment overseas to support the efforts that are currently in progress. Japan has promoted the eco-city model which is a next generation energetic and social system that uses low carbon technology. The city of Kansai, for example focuses on electrical vehicles (EV) and photovoltaic systems (PV) both for domestic use. Yokohama integrates photovoltaic installations and electrical vehicles along with energy management systems that work in real time for households and buildings. Toyota City also integrates electric vehicles and demand response centers [3].

China

The basic contents of the energy policies of China give priority to conservation driving support from national resources and promoting diversified development, protecting the environment, advertising scientific and technological innovation, deepening the reconstitution, widening international cooperation and improving the population's means of subsistence [10].

The development of intelligent networks in China is incorporated in the energetic priorities of the country. One of them consists on improving the energetic efficiency, increasing the combination of renewable energies and reducing the carbon intensity. The Chinese government has put national development agencies in charge of supervising the investment plans for SG: the National Energy Agency (NEA) has to control the price of electricity and review and approve the SG projects, the State Electricity Regulation Commission (SERC) has to supervise the daily operation of the electrical generation companies, the Chinese Electricity Council (CIC) has to help in the formulation of energy policies and the Ministry of Science and Technology is in charge of research and development where SG is on their priorities in the 12th quinquennial plan of scientific and technological development [11]. China has paid great attention to the development and emergence of intelligent networks over their entire territory.

Brazil

Brazil will widen long term credit to finance renewable energy and energetic efficiency for the private sector with $750 million worth of resources from the Inter-American Development Bank (IDB) [12] [13].

The clean energy and low level carbon projects are long term and require the extensive use of initial capital while the costs of maintenance and operation are relatively low. The program offers deadlines and interest rates that satisfy the necessary flows for this type of investment supporting the finance and attraction of investment in renewable energies.

The resources will be dedicated to projects focused on raising the participation of alternative renewable energies such as wind energy, solar energy and biomass in the Brazilian energy matrix and also on widening use of energetically efficient technologies in the sectors with great potential to increase the efficient use of alternative renewable energy [12] [13].

Brazil has a renewable energy matrix where more than 60% of the generated energy comes from hydroelectric sources. Although hydroelectricity is a renewable resource, the system tends to be increasingly exposed to the effects of climate change and periods of drought [12] [13].

3 Energy Policy in Colombia

The Colombian electrical sector is majorly dominated by the generation of hydraulic energy with a participation of 64% and the thermic generation with a participation of 33%. However, Colombia is one of the South American countries with the most potential to explore the implementation of renewable energies. Therefore, the state entities such as the Ministry of Mines and Energy (Minminas) and the Mining-Energy Planning Unit (UPME) have incentivized the construction of the judicial apparatus to support the growth of the electrical sector in the implementation of non-conventional energy sources. The result is evidenced in law 1715 (where the integration of non-conventional renewable energies into the national energy system is regulated) and in the National Energy Plan 2010 – 2030 whose main goal is to promote the use of renewable energy sources in Non-Interconnected Zones.

The Colombian energy policies have been oriented to guarantee that the electric flow is managed under the principles of quality, continuity and reliability. As a result, the World Economic Forum has indicated through its numerous competitiveness analyses (through the Global Energy Architecture 2013) that Colombia takes the 6th place in the 105 countries evaluated in terms of: economic growth, energetic safety development, incentives for transformation policies, environmental sustainability and access to energy.

However, it is noteworthy to mention that there is still a lot to be done in order to materialize the projection of the Colombian electric sector. Even if the Law 1715 marked the path for renewable energies in microgrids (MG), the customers are not covered and the huge area of Colombia without electricity represents an important challenge and a crucial factor that must be considered as the ideal scenario to develop management strategies for energy generation and its rational use.

Current needs of the Colombian electric system

The exponential increase of the electric energy demand in rural residential users in Colombia has led to important discussion points in comparison to the quality and reliability standards in the electric supply chain. Hence, the consumers require a reliable, flexible, accessible and inexpensive system for the development of rural activities mainly in activities related to agriculture. As a consequence, and under this scenario, renewable energy sources added to technological developments in generation, transmission and distribution have contributed to the emergence of micro-networks, subjacent to intelligent networks in order to guarantee a better articulation in the consumption and self-provision capacity. This is particularly crucial in areas where the access level to energy resources is limited or almost non-existent even with the presence of rural areas that do not belong to the national interconnection system.

For the Colombian case, the customer interactions in energy management have been historically oriented to the regulation of their own consumption and to the use of energy-saving technologies such as fluorescent lighting or LED (light-emitting diode). The previous practices, although compliant with criteria for the efficient and responsible use of electric energy, are not included within the compendium of the wide functionalities in the implementation of autonomous experienced, precise and highly-reliable systems that offer a backup and a more active role for users subscribed to the energy service [14].

Therefore, the main challenges of intelligent networks in non-interconnected areas of the Colombian territory are focused on: offering fast responses to changing conditions in the electric network, possessing systems of self-supply, analyzing the valley and peak events in the energetic demand, promote reliability in the interconnection nodes and last but not least, guaranteeing the articulation with renewable energy sources. Taking all of this into consideration, a protagonist role will be given where the rural user will be able to improve its agricultural production standards in terms of the access level to energy sources for the improvement of schemes, processes and techniques, among others.

4 Microgrids and Projects

In many countries, smart MGs are being implemented as well as pilot projects and similar work. There has also been as exchange in knowledge and experiences that has set the path for better planning and execution of SG projects. In countries such as Australia, Canada, Great Britain, United States, South Korea, Ireland and Japan, the SG already is a vital part of the government strategy to achieve energetic safety and the low carbon emissions. The report from the Global Federation of Intelligent Networks of 2012 [3] has pointed the following: The project of intelligent networks communities in Australia is testing the detection of failures within the network, the isolation and restoration, the monitoring of quality for the electric power and the automation of the distribution with a commercial distribution management system. Canada has a dynamic classification that can optimize the transmission transfer capacity as well as the wide area of the control system that improves the voltage stability and the initiative of intelligent measurement in Ontario that managed to reduce the peaks by 5 to 8% in the users' load profiles.

London's low carbon program integrated a series of low carbon emission technologies such as photovoltaic, intelligent measurements, electric vehicles, charging stations and heat pumps installations in the distribution network. Hence, the first ever cryogenic (liquid at low temperature) energy storage solution has been integrated into the national network which led to it being called Pilot for cryogenic energy storage.

In United States, the demonstration Project of intelligent networks in the north East pacific shows a pilot Project that covers five states (Montana, Washington, Idaho, Oregon and Wyoming) and includes 22 public services to show the continuous coordination of SG actives. Additionally, Houston implements a totally integrated measuring system, a website for the customer and an automatic interruption notification. Additionally, Smart Texas implements the deployment of intelligent measuring devices and automation in the distribution.

Korea has the well-known SG Demonstration Complex which incorporates wind and photovoltaic solar technologies, electric vehicles, IMA, energy storage, distributed automation, network monitoring and telemetric. The Smart Transport Program implements an electric vehicle infrastructure that depends on wireless communication. The operational system of renewable energy source is a demonstration of the MG that incorporates generation technologies (including high-volume wind energy). The Smart Place which participates with the consumer introduces electricity fees in real time, renewable energies sources, smart house appliances and storage solutions with screens embedded at home.

In Ireland, the Commission of Energy Regulation has implemented a trial of smart measurement devices in over 9000 household and companies. A project called Ecar Ireland is a pilot for EV infrastructure where the electric vehicle drivers pay the electricity supplier and not the charging station.

In Japan, Kit Carson Electric Cooperative builds a network of smart measuring devices which are about 30% more economic that the current measuring devices that are available in the market. The previous actions are all helped by Fujitsu's wireless technological solution. A project in Aomori proved the performance of a supply-demand control system in the management of the impact of renewable energies in a commercial electric network. Other projects and significant pilots in Japan are:

- ✓ A prototype Project for total energy solutions where photovoltaic systems and lithium batteries are used to create and store energy
- ✓ A distribution-stabilizing solution that verified that the photovoltaic energy voltage regulation was efficient and offered fast control of the voltage in intermittent generation intervals
- ✓ The smart city project from Yokohama that offers a massive introduction of photovoltaic installations and studies their impact while giving protagonism to rechargeable batteries in the stability of electric systems.

The European project for Integration of Renewable Energies in the European Electricity network (IGREENGrid) will be used as large scale deployment of IMA discussed in detail in terms of its function [15]. The project deploys more than 200.000 smart measurement devices in the Madrid area. The necessary field data to prepare the regulation that must promote the innovation of distribution systems for intelligent networks is identified for pilot projects of the Italian SG [16].

Since these SG projects are still in progress and the data from the field cannot be discarded, numeric solutions were developed in a reference network. Hence, the main implementations of SG projects in Portugal are shown in [17]. The entire development process is presented with the real implementation of developed concepts. Portugal began adopting management and control systems both in a pilot trial scenario and in a laboratory.

Other researches in this category are:

- ✓ Practical implementation of SGS in the urban area of Milan
- ✓ Mathematical model for the optimal operation of the Smart Polygeneration MG from the University of Geneva
- ✓ Paving the road for SGS through large scale infrastructures in advanced measurement, SG in field applications on the Italian scenery, opportunities and applications of SG in Turkey.
- ✓ Criteria for deployment of SG in Brazil through the Delphi method application.
- ✓ Experimental and recollection methods of data for a deployment of SG at large scale
- ✓ Italian SG pilot projects: Selection and evaluation of the data test banks for the regulation of the smart intelligent distribution
- ✓ The deployment of smart networks with efficient normative instruments [18][19].

5 Challenges in Smart Grids

In spite of the obvious success of the development of SGs, their technologies and systems, the issues and challenges are many and the final success stage is very far from grasp. The following topics and challenges are also potential areas of research:

- ✓ V2G Technologies: Battery decay and new storage technologies [20]
- ✓ Barriers for implementation: cost and benefit, knowledge, institutional inertia [21]
- ✓ Costs, consumer participation, data protection, privacy [22]
- ✓ Safety issues and challengers within the SG [23]
- ✓ Routing design [24]
- ✓ Interoperability and conformity with regulations [25]
- ✓ Physical security, cybernetic safety and AMI vulnerabilities [26]
- ✓ Simulators and co-simulators of SG (capable of only simulating simple scenarios, time synchronicity and data exchange [27]
- ✓ Compatibility issues with Smart devices, technological regulations for data registering and communication requirements [28]
- ✓ Distributed generation and automation in distribution systems [29]
- ✓ Design of ciphering schemes for strong data [30].

6 Conclusions

The concept of SG has evolved from a vision to a goal that is slowly coming to fruition. As technology grows, the devices and systems are capable of handling the construction of smarter network. Concrete energy policies facilitate the initiatives regarding SG in all countries. The practices of SGs in different regions barely indicate that there is a competition; instead there is a disorganized community of similar applications and learned lessons.

The basic idea of SG is not enough to embark in this complex system even when the experiences and technologies that are available for reference, the search for the ideal network is an investment in terms of time, money and research that needs continuous testing. With great efforts put ahead for research in SG, it is more useful to help achieve energetic sustainability and conservation as well as environmental preservation. The exact future state of SG is hard to predict but recent innovations show a dynamic fusion of the electric sector's agents.

References

[1] C. E. Behrens, *Energy Policy: 113th congress Issues*, Congr. Res. Serv., 2013.

[2] G. S. G. Federation, *Global Smart Grid Federation Report*, Glob. Smart Grid Fed., 2012.

[3] J. Hiscock and D. Beauvais, *Smart Grid in Canada 2012-2013*, report, 2013.

[4] I. Statistics, *Analysis, US Energy Information Administration*, 2012, Anu. Energy Outlook, 2015.

[5] M. L. Tuballa and M. L. Abundo, A review of the development of Smart Grid technologies, *Renew. Sustain. Energy Rev.*, **59** (2016), 710–725. https://doi.org/10.1016/j.rser.2016.01.011

[6] P. Menanteau, D. Finon and M.-L. Lamy, Prices versus quantities: choosing policies for promoting the development of renewable energy, *Energy Policy*, **31** (2003), no. 8, 799–812. https://doi.org/10.1016/s0301-4215(02)00133-7

[7] L. R. Brown, M. Renner, C. Flavin and L. Starke, *Vital Signs 1998: The Environmental Trends that are Shaping our Future*, WW Norton & Company, 1998.

[8] J. S. Duffield and B. Woodall, Japan's new basic energy plan, *Energy Policy*, **39** (2011), no. 6, 3741–3749. https://doi.org/10.1016/j.enpol.2011.04.002

[9] P. Clarisse, *Smart Cities in Japan, An Assess. Potential EU-Japan Coop. Bus. Dev.*, Tokyo, 2014.

[10] A. Shiu and P.-L. Lam, Electricity consumption and economic growth in China, *Energy Policy*, **32** (2004), no. 1, 47–54. https://doi.org/10.1016/s0301-4215(02)00250-1

[11] Y. Yu, J. Yang and B. Chen, The smart grids in China—A review, *Energies*, **5** (2012), no. 5, 1321–1338. https://doi.org/10.3390/en5051321

[12] A. E. Burda, B. P. M. Baltazar and C. J. I. Bernardo, Evolution of renewable energy in Brazil, *2011 International Conference on Clean Electrical Power (ICCEP)*, (2011), 316–319. https://doi.org/10.1109/iccep.2011.6036306

[13] B.-B. I. de Desarrollo, Brasil impulsará inversión privada en energía limpia con recursos de US$750 millones al BID, *Desarrollo, BID - Banco Interamericano de*, 2016.

[14] C. Hernandez, V. Gomez and A. Peña, *Calidad del Servicio en la Energía Eléctrica Residencial*, Bogotá: Editorial UD, 2013.

[15] G. López, J. I. Moreno, H. Amarís and F. Salazar, Paving the road toward smart grids through large-scale advanced metering infrastructures, *Electr. Power Syst. Res.*, **120** (2015), 194–205. https://doi.org/10.1016/j.epsr.2014.05.006

[16] M. Coppo, P. Pelacchi, F. Pilo, G. Pisano, G. G. Soma, and R. Turri, The Italian smart grid pilot projects: Selection and assessment of the test beds for the regulation of smart electricity distribution, *Electr. Power Syst. Res.*, **120** (2015), 136–149. https://doi.org/10.1016/j.epsr.2014.06.018

[17] C. Gouveia, D. Rua, F. J. Soares, C. Moreira, P. G. Matos, and J. A. P. Lopes, Development and implementation of Portuguese smart distribution system, *Electr. Power Syst. Res.*, **120** (2015), 150–162. https://doi.org/10.1016/j.epsr.2014.06.004

[18] M. Delfanti, E. Fasciolo, V. Olivieri, and M. Pozzi, "A2A project: A practical implementation of smart grids in the urban area of Milan, *Electr. Power Syst. Res.*, **120** (2015), 2–19. https://doi.org/10.1016/j.epsr.2014.11.019

[19] V. Marques, N. Bento, and P. M. Costa, "The 'Smart Paradox': Stimulate the deployment of smart grids with effective regulatory instruments, *Energy*, **69** (2014), 96–103. https://doi.org/10.1016/j.energy.2014.01.007

[20] F. Mwasilu, J. J. Justo, E.-K. Kim, T. D. Do and J.-W. Jung, Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration, *Renew. Sustain. Energy Rev.*, **34** (2014), 501–516. https://doi.org/10.1016/j.rser.2014.03.031

[21] S. Muench, S. Thuss and E. Guenther, What hampers energy system transformations? The case of smart grids, *Energy Policy*, **73** (2014), 80–92. https://doi.org/10.1016/j.enpol.2014.05.051

[22] J. Crispim, J. Braz, R. Castro, and J. Esteves, Smart Grids in the EU with smart regulation: Experiences from the UK, Italy and Portugal, *Util. Policy*, **31** (2014),

85–93. https://doi.org/10.1016/j.jup.2014.09.006

[23] D. B. Rawat and C. Bajracharya, Cyber security for smart grid systems: Status, challenges and perspectives, *SoutheastCon 2015*, (2015), 1–6. https://doi.org/10.1109/secon.2015.7132891

[24] N. Saputro, K. Akkaya, and S. Uludag, A survey of routing protocols for smart grid communications, *Comput. Networks*, **56** (2012), no. 11, 2742–2771. https://doi.org/10.1016/j.comnet.2012.03.027

[25] A. Gaviano, K. Weber and C. Dirmeier, Challenges and integration of PV and wind energy facilities from a smart grid point of view, *Energy Procedia*, **25** (2012), 118–125 https://doi.org/10.1016/j.egypro.2012.07.016

[26] S. M. Amin, Smart grid: Overview, issues and opportunities. advances and challenges in sensing, modeling, simulation, optimization and control, *Eur. J. Control*, **17** (2011), no. 5–6, 547–567. https://doi.org/10.3166/ejc.17.547-567

[27] W. Li and X. Zhang, Simulation of the smart grid communications: Challenges, techniques, and future trends, *Comput. Electr. Eng.*, **40** (2014), no. 1, 270–288. https://doi.org/10.1016/j.compeleceng.2013.11.022

[28] K. M. Muttaqi, A. E. Nezhad, J. Aghaei and V. Ganapathy, Control issues of distribution system automation in smart grids, *Renew. Sustain. Energy Rev.*, **37** (2014), 386–396. https://doi.org/10.1016/j.rser.2014.05.020

[29] K. M. Muttaqi, J. Aghaei, V. Ganapathy and A. E. Nezhad, Technical challenges for electric power industries with implementation of distribution system automation in smart grids, *Renew. Sustain. Energy Rev.*, **46** (2015), 129–142. https://doi.org/10.1016/j.rser.2015.02.013

[30] W. Wang and Z. Lu, Cyber security in the Smart Grid: Survey and challenges, *Comput. Networks*, **57** (2013), no. 5, 1344–1371. https://doi.org/10.1016/j.comnet.2012.12.017

Received: October 3, 2017; Published: November 6, 2017