Smart Grids and their Applicability for the Development of the Electricity Sector for Colombia in the year 2050

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Abstract. Smart Grids are a technology that can be used to implement a sustainable energy scheme of a country. Therefore, this paper proposes the development of a prospective analysis of Smart Grids as a tool to ensure energetic security in Colombia in 2050. Using LEAP software, a base scenario for Colombian energy demand has developed according to current policies, with a time horizon from 2012 to 2050. The energy analysis is based on three scenarios, taking into account the impact of cogeneration in the residential and industrial sector using renewable energy and the power quality indicators. The results show that the implementation of Smart Grids generate energy savings and increasing the coverage of the national electricity system, ensuring energetic security of the country by 2050.

1. Introduction

Smart grid are the next step in the development of a country electrical grid, because it allows the implementation of electricity cogeneration systems and the inclusion of renewable energies contributing to the diversification of energetic matrix\cite{1},\cite{2},\cite{3}. In the case of Colombia generates 70\% of electricity by hydroelectricity. This shows a big dependence of hydric resources, which will be affected for a change in the precipitation levels due to the global warming\cite{4}. Above situation will carry an energy default, which must be satisfied with new clean energy sources that contribute to reduce the greenhouse gases emissions and ensure the energetic security of the Colombian Citizens. Therefore, in this paper is performed a prospective analysis using a scenario-based methodology for the smart grid in Colombia to the year 2050, which contribute to reach the energetic security and the diversification of the Colombian energy matrix\cite{5},\cite{6}. The paper is structured as follows. First, the parameters for smart grid evaluation are defined, which are power quality, distributed cogeneration and energetic security. Second, the Colombian energetic model is presented. Third, the three scenarios, Trend (ET), climate change (CC) and technological alternative (TA) are presented and implemented in the prospective software LEAP. Fourth, the behaviour of electric demand and electricity generation are analysed for each scenario, evaluating the compliance with the parameters mentioned above. Finally, conclusions are shown.

2. Smart Grid

Smart grid presents a new paradigm for the development of generation, distribution, marketing and consumption tasks\cite{1},\cite{2},\cite{3}, integrating the information and communication technologies (ICT) to the power management system, allowing the implementation of control schemes and energy management flowing through the grid. Figure 1 and Figure 2 shows the difference between a conventional power distribution network and an intelligent network.
As shown in Figure 1, the conventional electricity grid conforms by big generators that produce energy, which is transmitted via a distribution system from the generator to final consumers who are the residential and industrial sectors. This indicates that the energy flows in one direction. Moreover, Figure 2 shows the outline of a smart grid, in which big generators do not exclusively produce energy, but each user on the network can produce their own energy using renewable energies as solar panels and wind turbines, injecting power to the grid. Energy regulation is made by a control centre responsible for distributing energy efficiently according to the required demand. Identification of the robotic-joint dynamic model.

3. ASSESSMENT PARAMETERS FOR THE SMART GRID EVALUATION IN THE ENERGY PROSPECT

For the evaluation of the feasibility, impact and contribution of smart grids in the ET, TA and CC scenarios, the following parameters were employed.

3.1. Power Quality

Power Quality defines as all the inherent parameters of electricity waveform such as amplitude, frequency, wavelength, continuity; which to assess deviations in the voltage waveform and the effects of this on the equipment connected to the grid.

3.2. Distributed Generation

Distributed generation is one of the main features of smart grids, which presents the possibility for the power network users, both domestic and industrial to generate and inject energy to the grid using alternative power schemes as solar panels or wind turbines, large or small scale. This article will evaluate cogeneration, taking into account the levels of production of electricity from solar and wind renewable energy in each scenario.

3.3. Energy security

The energy security is a responsibility of governments, whose purpose is to ensure the power supply to the inhabitants of a country, by protecting energy infrastructure, diversification of sources of electricity supply, tending to ensure fair and regulated prices, always looking for energy sources with the least environmental impact. To evaluate the energy security, the types of generation technology employees in each scenarios to meet the energy demand of the country will be analysed which must comply with the above features.

4. COLOMBIAN ENERGY MODEL

Energy planning software LEAP is used for modelling the Colombian energy system [7], [8], which is based on the model proposed by the mining and energy-planning unit (UPME). This model is the technical-economic. That is, considered the most important macroeconomic and social variables with
the technical aspects of Colombia's energy matrix, such as energy reserves, the demand for each of them in different sectors, the processes of transformation of primary energy such as oil or water in fuel and electricity respectively, considering the losses and efficiency of these processes.

4.1. Colombian energy model features
The main characteristics of technical-economic model of the energy system for Colombian electricity sector (demand generation, transformation and loss) are:

4.2. Macroeconomic and demographic variables
As macroeconomic variables, the Colombia's gross domestic product (GDP) and the benefit of each of the sectors of the Colombian industry are considered. As demographic variable population growth rate, which according to the national statistics unit (DANE) is 1.3% to 2050. Each of these variables has as starting point for the development of prospective analysis referred to the time series since 2008 until 2012, projected until 2050.

4.3. Electricity demand
Electricity demand takes into account the residential, industrial, transport, commercial, mining, construction, agriculture and consumption sectors. According to the information provided by the UPME, it will have a total demand of electricity historic sectors for 2012 of 44.44 TWh.

4.4. Generation and transformation processes
At this stage, model considers the necessary processes for the transformation of primary energy such as coal, wood, oil water or electricity to meet demand for electricity. Energy conversion processes, the percentage share in power generation and energy losses of the transformation process are allow for each energetic.
of the scenarios, parameters show in section 3 were assessed by analysing the production of electricity in Colombia 2050.

6.1. Generation of electricity in the scenarios posed

6.1.1 Trend Scenario
The generation of electricity in the baseline scenario shown in Figure 3, which shows the power generation by 2050 will be 152 Twh, which, 86% will produced using hydric resources. Meanwhile the share of renewable energies will be at 2.3% and fossil fuels with a share of 11%.

6.1.2 Technological alternative scenario
The electric power generation technology in alternative scenario shown in Figure 4. In this figure, the power generation by 2050 will be 150 Twh, which shows that 38% will be produced using water resources. Meanwhile the share of renewable energies will be in a 59.55% and fossil fuels with a lower share of 3%.

6.1.3 Climate Change Scenario
The generation of electricity in the Climate Change scenario shown in Figure 5. Which shows the power generation by 2050 will be 150 Twh, which shows that 41% will be produced using fossil fuels. Meanwhile the share of renewable energies will be at 0.26% and hydroelectricity will have a share of 56%.

6.2. Generation of electricity in the scenarios proposed by the UPME
The scenarios presented below correspond to those raised by the UPME in [5], which electric world and energy efficiency are having into account as the most important for the analysis of smart grids.
6.2.1 Electric World Stage
The generation of electricity in the baseline scenario shown in Figure 6, the electric power generation by 2050 will be 241 Twh, which will be produced in a 78.63% using water resources. Meanwhile the share of renewable energies will be at 1.86% and fossil fuels with a share of 19.51%.

6.2.2 Energy efficiency scenario
The generation of electricity in the baseline scenario shown in Figure 7. As can be seen, the power generation by the year 2050 will be 41.4 Twh where 86% will be produced using water resources. Meanwhile the share of renewable energies will be in a 13.11% and fossil fuels with a lower share of 1%.

7. Result analysis
From the results obtained in Section 6, we can see that in the energy prospects of Colombia 2050, electricity production in all scenarios is covered mainly by hydro, leaving second alternative energies (solar and wind). However, the threat of climate change for Colombia is quite high, since according to [8], a change in rainfall patterns will cause a shortage of water resources throughout the country. In Figure 8 the deficit of electricity to be presented by department for 2050 is presented.

According to Figure 8, if the level of climate change is high or medium, the department of Antioquia will present a deficit of up to 2,500 GWh due to the scarcity of water resources. Considering the above for smart grids evaluation according to the parameters described in Section 3. In the electric world or energy efficiency scenarios, it will not be possible to guarantee a constant and uninterrupted service of electricity to system users, this implies a lower power quality, thus making energy security of citizens is not ensured, since not having a large share of renewable energies, implementing rule cogeneration schemes urban, rural and industrial, making it difficult the implementation of smart grids in these scenarios. In the climate change scenario, if a part of this deficit is supplied using fossil fuels, again not resort to cogeneration schemes to replace lost due to water scarcity, but instead used energy based on fossil fuels , which have a greater environmental impact, in breach of the principle of further reducing
emissions from energy security. Thus in this scenario not intelligent network scheme implemented is observed. In the case of alternative technological scenario, the implementation of renewable energy, cleanly contribute to reducing emissions of greenhouse gases and mainly supply the energy deficit due to climate change. Importantly, these alternative sources can be installed in residential, rural and industrial sectors, making possible the small-scale generation in a distributed, decentralized system of power generation. Therefore, it can be said at this stage the implementation of smart grid for constant monitoring of system power and a fulfilment centre that controls the distribution of energy according to the demand for electricity brought at any time of the day will be needed. Further reducing dependence on water sources, will allow using this resource in other activities such as human consumption or agricultural production, optimizing its use.

8. Conclusions
This paper describes the development of a prospective analysis for the evaluation of smart grids and its application in Colombia 2050 employing a scenario based methodology, using as evaluation parameters the energy security, power quality and distributed generation. For this, the Colombia energy model is modelled using the energy planning software LEAP. The proposed scenarios in LEAP model are compared with the UPME scenarios. From the obtained results, the main power source in Colombia is the hydroelectricity, which in a Climate Change (CC) scenario will affect the energy security and power quality in Colombia in 2050 due to the hydric resource default. Thus, the smart grid turns into an option to avoid the energy deficit by integrating renewable energies in the Colombian energy matrix. Also, the scenario based prospective model is a tool that helps to predict the energy trends for a country. In the Case of Colombia, this model allows to understand the behaviour of the electric sector to create policies and regulations that be robust against climate, technological or social changes in Colombia until 2050, ensuring the energy security and power quality.

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