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Photovoltaic energy in Colombia: Current status, inventory, policies and future prospects

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ABSTRACT

Along with the development of renewable energies in the world and the initiatives for alternative energy implementation in Colombia, it is important to make a national revision regarding the implementation and use of solar photovoltaic energy in Non-Interconnected Zones (ZNI for its abbreviation in Spanish) and the National Interconnected System (SIN for its abbreviation in Spanish). The objective of this article is to identify the development that it has had and its future panorama as far as the solar photovoltaic energy is concerned. The study presents the projects that have been executed and the ones in execution during the last decade, and the capacity that has been installed up to the present day in both SIN and ZNI (Photovoltaic Inventory).

On the other hand, the document describes its social and political development at a national level, as well as legal aspects of the advantages and disadvantages of the recent Law 1715 signed in 2014. This law aims to promote the development and use of unconventional sources of energy, integrating them into the national energy system, allowing a promising future for these alternative technologies such as electricity generation from photovoltaic solar energy. Finally, the article shows the different opportunities in the ZNIs where the radiation potential reaches up to 6 kW h/m^2 day and the projects do not exceed the 2.25 MW of installed capacity in Colombia, contrasted with the national average that is around 4.5 kW h/m^2 day, surpassing the world average of 3.9 kW h/m^2 day. Likewise, it allows seeing the opportunities that the new law offers for the development of generation projects in the SIN at a mega and gigascale, and of smaller projects that enable self-consumption and sales to the network, as well as distributed generation projects and hybrid power generation projects.

1. Introduction

The world's integration of alternative energies or renewable energies has been consolidated in the political, industrial and community fields in the last 20 years, with a significant increase in the supply of technologies at the photovoltaic (PV), wind, biomass, geothermal and marine energy levels. This provides a contribution of 23.7% in 2014, from which only 1.2% is per solar energy action equivalent to 175 GW [1,2]. Given the present scenario 2016, it is to indicate that the source of renewable energy with greater potential is solar energy [1]. For this reason, this market has grown rapidly, between the year 2000 and 2015 the growth of photovoltaic installations was 41% [3]. At the continent level, it is estimated that countries such as Austria, Germany, the Netherlands, France, England and Spain represent 98% of photovoltaic installations connected in the European Union. Germany exceeds its capacity with 41.22 GW installed, followed by Italy and France with 19.27 GW and 7.13 GW respectively. Spain as a leading country has an installed capacity of 5.4 GW equivalent to 1.8% of the 294.16 GW installed in the world [4].

In the Asian context and in the first place, the Republic of China raised up to 28 GWp installed in 2014 [5–7], which highlights the commitment of this power country with the alternative technological development of the energy sector and capacity for the production of this type of energy. Similarly, in 2015 they installed 15.2 GW, reaching a total of 78.07 GW installed by 2016. Japan ranks second with an accumulated installed capacity of 42.75 GW [4]. India as an emerging economy of the Asian continent has an average population of 1240 million and more than 600.000 villages, where 1/3 of the population does not have access to the electricity grid, which represents almost 600 million people. India presents high solar radiation that can be susceptible to generate electricity from solar energy; an example of this is the solar radiation in the zones of Kolkata and Madras with approximately 5000 kW h per year [7]. In 2010, India created the goal of installing 20.000 MW of photovoltaic energy by 2022 from approximately 1100 solar plants. Currently the installed capacity in photovoltaic energy in this country is 9.010 MW [8–10].

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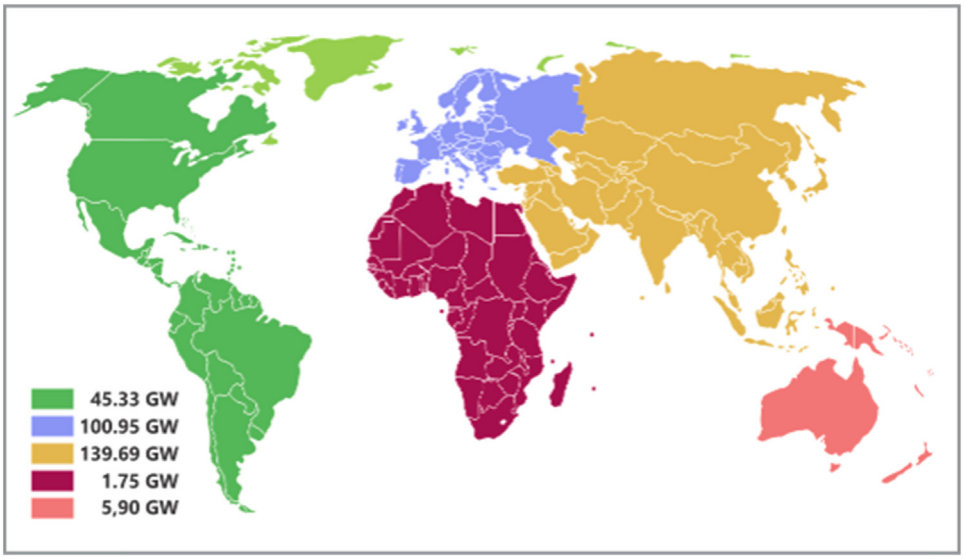

Fig. 1. Current worldwide installed capacity. Own elaboration.

Africa, being a continent with greater vulnerability to the effects of climate change, is beginning to gradually implement clean technologies. For example, in South Africa the potential in terms of solar energy, with a total of 194.00 km^2 of possible use in solar power. Currently the photovoltaic installed is used for lighting purposes, appliances, telecommunications, and water pumping. By 2030 it aims to install 8.4 GW with solar technology and by 2050 they expect to cover 14% of the energy supply [10]. Likewise, Nigeria and Egypt with 500 MW for 2025 and 700 MW for 2027, respectively.

In the American continent, the United States of America lead the photovoltaic field establishing a capacity of 40.3 GW by 2016 [4]. In countries of South America, photovoltaic energy has been venturing into more and more countries as an alternative to reduce impacts associated with climate change. As an example, Brazil being one of the countries that represent the 32% of the world's largest energy demand, however the high cost does not allow the inclusion of renewable energies so easily, for 2016 it was installed solar generation capacity of 51.1 MW, represented in 3851 independent photovoltaic installations [11]. In Fig. 1. We can observe the capacity that has been installed in the world, surpassing the 200 GWp represented by 47% and 34% in the Asian and European continents respectively. At the level of South America and Africa, the development of solar energy is slow.

Colombia, which belongs to the continent of America and is located in South America on the equatorial axis, has started to actively integrate itself into the field of energy sustainability and has penetrated the renewable energy matrix, allowing its commitment to reduce the economic dependence on fossil fuels and greenhouse gas emissions (GHG). Likewise, Colombia is increasing its alternatives towards economic, ecological and social efficiency following the example of the implementation of this type of technologies in developed countries.

The photovoltaic systems for electricity production in Colombia are less than 4% of the national electricity production. These systems have been positioning since the 70's with the arrival of efficient systems of thermal heating, which allowed the transition to a culture under the energy sustainability framework and gave way to a new century that is proposing technological offers and projects out of photovoltaic modules. Therefore, within the national energy model to be addressed in this document, Colombia is shown as a producer of electric power out of hydropower, being this one that generates the greatest energy impact in Colombia with 75.9% [12]. The renewable energy sources such as biomass, wind and solar have started to penetrate first in the populations with basic deficiencies in the service and that are not connected, because of their location in areas of difficult access, low capital development, deficits in infrastructure, and energy inaccessibility. This shows that areas with settlements that are characterized by conditions of vulnerability are the best option for this type of technology. Features such as difficult access, problems of public order and transportation logistics make the price drawn from Diesel to be between 0.4 and 0.53 US$/kW h.

The implementation of photovoltaic systems in Colombia has enabled 2% of the population in areas that do not have access to electric energy to meet their lighting, refrigeration and leisure needs, allowing them to expand their capacities and improve their quality of life. The systems that have been installed are mainly focused on the rural sector. Even with this panorama of positive development from the social and productive contexts, there are different barriers for an evolution of alternative generation technologies, being necessary to formulate programs in order to develop renewable energy sources that seek to diversify the national energy market and laws that extend the energy matrix and allow the implementation of self-consumption systems, distributed and hybrid [13].

This article presents a global and local overview regarding the use and utilization of clean energies fed by direct solar radiation, national policies that facilitate their access, and projects implemented at the level of Non-Interconnected Zones (ZNI for its abbreviation in Spanish), and from the National Interconnected System (SIN for its abbreviation in Spanish), covering from a macro and micro view, the photovoltaic era in Colombia and its legal and technical framework.

2. Energetic and political situation in Colombia

2.1. Social situation

Colombia is located in the northwestern region of South America on the equatorial axis; currently, it has 48.747.632 inhabitants located in 32 decentralized departments and its capital is Bogotá D.C. [14]. At the energy level, it is divided in two zones.

- Interconnected Zones, which have access to the electric power service through the National Interconnected System (SIN).
- Non-interconnected Zones (ZNI), identified according to Article 1 of Law 855 from 2003 as municipalities, districts, localities and villages that are not connected to the SIN, so this type of areas are supplied with energy through Diesel based generating plants, solar panels and small hydroelectric power stations, evidencing with this that the electrical infrastructure at national level has fallen behind

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