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Improvement in policy and proactive interconnection procedure for renewable energy expansion in South Korea

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ABSTRACT

This paper presents the steps taken by the Korea Electric Power Corporation (KEPCO), the nation's only utility, to overcome limitations involved in increasing renewable energy penetration in an effort to support the government's movement for renewable energy expansion. While the government proposes reducing carbon dioxide emissions by 37% of the Business As Usual (BAU) value by 2030, which is about 315 million tonnes, it has improved energy policies for developing and deploying renewable energy technologies. To facilitate the integration of renewable energy into the future Korean power system, the government has announced a guaranteed interconnection policy for renewable energy sources under 1 MW. Based on this movement, the following measures have been enacted. First, examination of the hosting capacity of the current power system has been initiated to streamline the interconnection process for the distributed renewable energy sources and to reinforce the transmission and distribution network in a proactive manner. Second, to comply with reliability performance standards, an efficient planning procedure has been established for determining the optimal location and size of a renewable complex. To proceed with interconnection requests without delay, a prototype of a Renewable Energy Map (REM) based on PSS/e and Python has been developed. This tool facilitates more practical impact studies by incorporating capacity factors of renewable sources. In addition, it automates the screening process for determining suitable interconnection buses and feasible options for grid reinforcement. This tool is a step toward realizing the twin visions of "G-Platform" and "Carbon Zero" projects in Jeju Island." These efforts, which have been initiated in response to the Paris Climate Change Accord of 2015 and the 23rd Conference of the Parties 2017, aim to increase renewable energy from 7% to 20% of the total generated energy in Korea by 2030.

1. Introduction

The power system in South Korea is heavily dependent on primary sources such as nuclear, steam, and coal plants because of the high load demand relative to the size of the country. From spatial and economic perspectives, the contribution of renewable energy has been insignificant thus far, and interconnection among the different types of power systems has raised grid issues. Accordingly, among Organization for Economic Cooperation and Development (OECD) countries, Korea has been ranked first for increasing greenhouse gas emission rates from 1990 to 2014 and sixth for greenhouse gas emissions (690 million tonnes) in 2015 [1–3]. Following the Paris Climate Change Accord in 2015 and the 23rd Conference of the Parties 2017 (COP23), the Korean government has taken the stance of reducing greenhouse gases through increased penetration of renewable energy sources, thus ushering Korea into a new era for the renewable energy industry [1,4]. As a result, the government has proposed a policy for reducing carbon dioxide emissions by 37% from the current Business As Usual (BAU) value, which is about 315 million tonnes [1,4]. Within 315 million tonnes, the generation sector utilizes 19.4%, which is the largest of all categories. Therefore, increasing renewable penetration must be optimized to achieve this goal.

The total capacity of renewable energy sources is currently about 15 GW [5]. Although the renewable energy capacity in South Korea is behind that of European nations, China, and other countries, it has shown a consistent annual increase of 11,860 MW in 2014 to

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13,729 MW in 2015 and 13,846 MW in 2016 [6–9]. The Korean government put forward the 3020 Project, which presents its objective for increasing the proportion of renewable energy source penetration from 7% to more than 20% of total generation amount by 2030 [5]. To achieve this goal, approximately 60 GW of renewable energy facility is required.

In order to increase the various types of renewable source penetration, several studies have been undertaken that present feasibility studies of solar energy usage in Korea [10,11], the potential of ocean and tidal power [12–14], and the feasibility of offshore wind energy [15]. Additionally, efforts have been made to develop a forecasting model for renewable energy supply [16] and to evaluate the economic value of investments in the wind power energy sector [17]. Domestic studies have been conducted to determine the optimal renewable fraction and cost in certain grids [18], to observe economic feasibility maps for 17 cities in Korea for potential interconnection points [19], and to obtain statistical data on the efficiency of different types of renewable sources in Korea [20].

This paper presents the steps undertaken in three key areas in an effort to achieve this goal in Korea. First, the government's efforts toward improving policy and support schemes for the diverse expansion of renewable energy market growth are briefly introduced. An appropriate and effective support scheme and fair interconnection policies have been continuously improved over time. Next, the Korea Electric Power Corporation (KEPCO), the nation's only utility, will introduce efforts to fully explain the hosting capacity for the current power system structure and facilities to efficiently plan for the grid reinforcement without public opposition. Finally, the efforts of KEPCO and associated universities for developing a Renewable Energy Map (REM) will be introduced. REM is required to identify the optimal location and sizing for a renewable complex that does not violate the reliability standard. Planning for the hosting capacity of the current power system is necessary for successful interconnection because it facilitates the prediction of accurate generation in different time intervals, the determination of the optimal location for interconnection, and the installation of a system that complies with the grid code.

The government has acknowledged the need for necessary change in a support scheme for renewable energy penetration. The official record including public utilities in 2016 shows that renewable energy accounted for 7.24% of the total energy generated, or 40,656 GWh, as shown in Fig. 1 [7]. The increase in penetration rate is promising; however, an insufficient planning support scheme resulted in a biased participation of certain renewable sources such as waste energy. Although the capacity of photovoltaic (PV) energy is the largest among all types of renewable sources, the amount of generation is dependent on the waste energy, as shown in Fig. 2 and 3 [7]. This is far removed from the government's intention of focusing on increasing PV and wind penetration. Thus, the government has presented a vision to further support wind and PV energy so that they will become major renewable

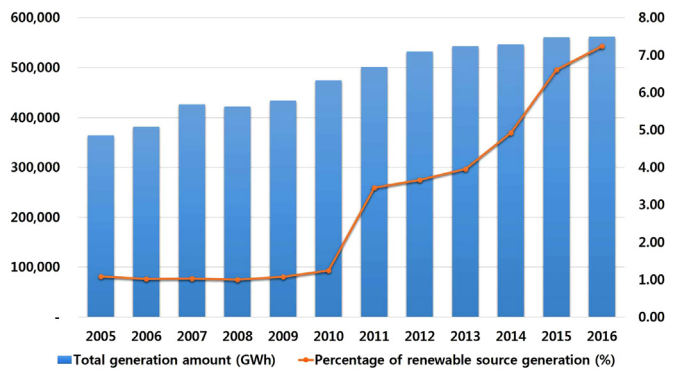

Fig. 1. Total amount of generation and the proportion of renewable generation in Korea.

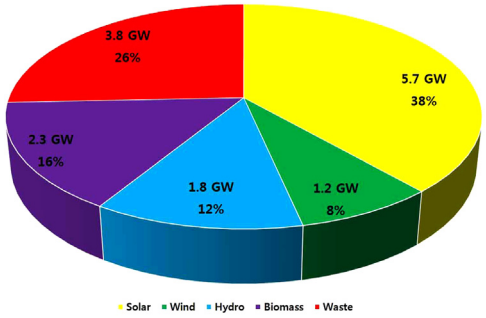

Fig. 2. Ratio of each type of renewable energy generation in 2016.

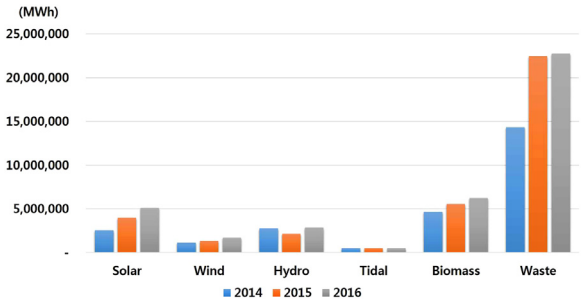

Fig. 3. Comparison of each type of renewable energy generation in 2014, 2015, and 2016.

power sources. One example of this support is the establishment of a large wind farm on Jeju Island [21]. Accordingly, the government aims to stop constructing more plants for waste energy and will continue to construct more PV and wind energy systems until it can account for 85% of the total renewable energy capacity, at about 50 GW [5].

Furthermore, the government has taken initiatives by proposing the “Guaranteed interconnection of renewable energy sources under 1 MW” plan in 2016 to invigorate the renewable energy industry by redesigning the traditional utility infrastructure [1,22–24]. Although this policy has dramatically increased the requests for renewable generation interconnection, the processing the interconnection has been delayed owing to a lack of understanding of the hosting capacity. The Korea power system must be analyzed to determine the correct hosting capacity of the current power system. This will minimize the cost of the interconnection and grid reinforcement and will enable compliance with the grid code. The interconnection and the grid reinforcement process is a very delicate and controversial issue in Korea because of the convoluted and slanted structure of the power system. The public has voiced strong opposition against the additional construction of power facilities, with zero tolerance for poor power quality [22–24].

A prototype of the REM is introduced in the present study. This map will be used to accept interconnection requests efficiently in the future and to determine interconnection locations and an appropriately sized renewable complex that fully utilizes the existing power system infrastructure [25,26]. In particular, this REM will be useful for determining the acceptable locations and sizing for wind and PV plants. The program is capable of analyzing loading, voltage deviation, and fault current contribution such that estimation of the hosting capacity is possible. By using the REM, a renewable interconnection zone known as “G-Platform” can be allocated to enable the construction of a renewable complex known as “Open Green Grid.” This measure will contribute to the transition from scattered and unplanned renewable interconnection to integrated interconnection [24]. In addition, the “Carbon Zero” project in Jeju Island can be initiated. Because approximately 2 GW of wind power complex is expected, careful interconnection must be conducted by utilizing the REM for maximum benefits. The renewable complex is continuously monitored and controlled to comply with the