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Is the concept of ‘grid parity’ defined appropriately to evaluate the cost-competitiveness of renewable energy technologies?

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HIGHLIGHTS

- A crucial limitation of the current LCOE based method used for analyzing the grid parity
- A bottom up energy system model based method to overcome the limitation
- Current method can overestimate the cost-competitiveness of renewable technologies
- Different technologies might be required to have different grid parity points
- A policy for renewable energy technologies must be harmonized with other policies

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ABSTRACT

The concept of ‘grid parity’ has emerged as a key indicator of the competitiveness of renewable electricity generation technologies. In this study, we firstly summarize the definition of the current levelized cost of electricity (LCOE) based methodology for the concept and address its limitation in not taking into account the systematic changes in an electric power system. Secondly, we introduce a bottom-up energy system model based methodology to overcome the limitation. Lastly, we apply the methodology to a case study, the grid parity analysis of solar photovoltaic and onshore wind technologies in the Korean electric power system, to highlight the differences between the results obtained using both methodologies. The results of the study show three implications. First, even if the LCOE of onshore wind is already lower than that of natural gas technologies and the average price of grid electricity, the LCOE is required to be much lower to achieve cost-competitiveness in the electric power system. Second, different technologies might be required to have different LCOE levels to be cost-competitive in the same power system. Third, a policy or plan for the deployment of renewable energy technologies must be harmonized with other policies and plans within the same system.

1. Introduction

Renewable energy resources have received greater attention in recent years as climate change and energy security issues have become key drivers of future energy policy all over the world. In particular, electricity generation technologies, such as solar photovoltaic (PV) and wind, have been the most actively developed because of their several advantages—they are clean, carbon-free, and infinitely sustainable energy resources. In the process of growth in related R&D and industries, many stakeholders and researchers have needed a way of assessing the cost-competitiveness of these technologies. In this context, the concept of grid parity has emerged as a key indicator of the competitiveness of renewable electricity generation technologies. The term can generally be defined as the time point at which the decreasing cost of electricity from a renewable energy technology due to its technological advances intersects the cost of electricity generated from conventional fuels, such as coal and natural gas, and it is generally thought that, without any subsidies, a renewable energy technology will have cost-competitiveness in the market when the technology reaches the ‘grid parity’ point.

According to a recent study (Munoz et al., 2014), the grid parity concept can be tracked back to experience or the learning curve theory. In the process of experience or learning curve analysis for the solar PV technology, the concept started to be used to examine the economic break-even point of the solar PV technology and quickly became widespread. Along the way, the earliest source relating to the term ‘grid parity’ was an article about the cost-

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competitiveness of solar PV technology in the magazine *Frontiers, the BP Magazine of Technology and Innovation*, published in 2005. The use of the term has increased dramatically since then, starting around 2007, and the concept, which was initially applied just to solar PV technology, has come to be used for electricity generation technologies from all kinds of renewable energy resources.

Therefore, the grid parity concept has been utilized by many experts and researchers, stakeholders in the related industries, and policy makers, and the term can easily be found in many scientific journal articles, technical reports, and official websites of energy-related agencies, such as the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), and so on. For example, a recent report by the IRENA states that onshore wind and bioenergy are already at grid parity with fossil fuel electricity and that solar energy might be at grid parity in some selected regions by the year 2020 (IRENA, 2013), and the US Department of Energy announced that the goal of the Solar Energy Technologies Program (SETP) is to promote the R&D for solar energy—solar PV and solar thermal –for the technologies to reach grid parity by 2015. In the Republic of Korea, the Korea Power Exchange (KPX) distributed a news article reporting that wind power generation technology had already reached grid parity in May 2012, and a government agency projected that solar PV will reach the grid parity point around 2023. In this circumstance, many stakeholders and policy makers have come to believe in the grid parity concept as an absolute indicator of the competitiveness of renewable energy technologies.

While the grid parity concept has widened its coverage and become more popular, the absolute indicator is required to carry greater responsibility. However, the current methodology used to define the grid parity concept causes some problems, so several experts have begun to concern themselves with its appropriateness for being regarded as the absolute indicator. Even though many reports and articles, such as the examples above, report that several renewable energy technologies have already reached the grid parity point and some others will reach it soon, even onshore wind still requires substantial subsidies to be deployed in reality, and a long-term policy framework for financial support is expected to remain vital to the competitiveness of renewable technologies in most of the world until 2020 (IEA, 2014a). This implies a contradictory situation in which, without the support, some renewable technologies are still inferior to the conventional technologies in terms of cost-competitiveness even though the indicator suggests their superiority.

In this situation, some recent studies have started to deal with the limitations of the current methodology used for analyzing grid parity. One study pointed out that using the current methodology of grid parity is inappropriate for the situation in which several stakeholders play and want to maximize their own benefits respectively in an electric power system (Jägemann et al., 2013). Another study qualitatively discussed some of the obstacles that need to be overcome for the grid parity concept to be expanded (Munoz et al., 2014). Nevertheless, we found no previous studies introducing new methodologies to overcome the limitations.

Therefore, the purpose of this study is not only to summarize the definition of the current methodology for the grid parity concept and its key limitation, but also to introduce a new methodology, based on a bottom-up energy system model, to overcome the limitation. In addition, the new methodology will be applied to a case study, the 'grid parity' analysis of solar PV and onshore wind in the Korean electric power system, to highlight the differences between the results obtained from the current and new methodologies.

2. Methods

2.1. Grid parity analysis based on the levelized cost of electricity

The current methodology for grid parity analysis was established before the term appeared in 2005. The methodology was originally used for the break-even point analysis of solar PV (IEA, 2000; Poponi, 2003; van der Zwaan and Rabl, 2003; Schaeffer and Moor, 2004), and the levelized cost of electricity (LCOE) of solar PV was calculated and compared with the price of grid electricity or the LCOE of conventional electricity generation technologies, such as coal-fired or natural gas-fired. Since 2005, this methodology has been used for grid parity, even in scientific journal articles and technical reports (Bhandari and Stadler, 2009; Lund, 2011; Hernandez-Moro and Martinez-Duart, 2012; Breyer and Gerlach, 2013; Fokaides and Kylili, 2014).

The LCOE of an electricity generation technology can commonly be defined as the ratio of "lifetime cost" to "lifetime electricity" based on a representative facility; both numerator and denominator are annualized over the lifetime of the facility with respect to the time value of money. The "lifetime cost" usually occurs irregularly and includes all the operating expenses, payment of debt and accrued interest on initial project expenses, and payment of an acceptable return to investors over the life span of a facility. The methodology based on the LCOE has the advantages of being simple and explicit, but it can hinder the grid parity concept from being used more generally. From the perspective of individual investors, comparing the LCOE of a residential- or commercial-scale renewable energy facility with the price of grid electricity seems reasonable. However, for a utility-scale renewable energy facility, the methodology by which the LCOE of the facility is compared with the LCOEs of conventional power plants seems to have a crucial limitation.

In the LCOE calculation for a particular technology, the lifetime electricity is calculated based on a predetermined capacity factor for that technology. The current methodology based on the LCOE implicitly incorporates the assumptions that the capacity factors of the target renewable energy technology and its competitor are invariant and that the capacity and generation output of the target technology perfectly displace those of the competitor—when a certain capacity of an electricity generation technology is introduced into an electric power system, the capacity of a competing technology is displaced and its capacity is perfectly proportional to the ratio between the capacity factors of the two technologies.

However, in reality, several factors, such as the balance of the electricity demand and the supply capacity, generation capacity portfolio, demand pattern, and characteristics of each renewable energy technology, synthetically affect the capacity factors for both the renewable energy technology and the competitor and the level of capacity displacement for the competitor. For example, if the electricity demand does not increase much and the existing power plants can supply enough electricity to the existing electric power system, then the introduction of a renewable energy power generation facility into the system will lower the capacity factors of the existing conventional power plants. However, the new facility will not displace the capacity of the competitors (the existing conventional power plants). On the other hand, if the electricity demand increases sufficiently and/or some of the existing power plants need to be retired, then the system requires new power plants and the new renewable energy power generation facility will displace some of the capacities of the competitors (the new conventional power plants).

Both variant capacity factors and non-perfect displacement effects cause indirect costs in the system, and the indirect costs can vary according to the situations in the target electric power