

A comparison of solar photovoltaics and molten carbonate fuel cells as commercial power plants

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ABSTRACT

In line with the worldwide trend, Korea has recognized the importance of renewable energy and extensively supported its exploitation. As of August 2009, the largest incentives for renewable energy are offered to solar photovoltaic (PV) systems, which have vastly increased the installations of this system. On the basis of total paid incentives, the second largest beneficiary is the fuel cell (FC) system. This support has contributed to the successful commercialization of the molten carbonate FC (MCFC) as a distributed generation system (DG). Considering the status of energy systems in Korea, solar PV and MCFC systems are likely to be further developed in the country.

The present paper analyzes the exploitation of these two energy systems by conducting a feasibility study and a technology assessment in the Korea environment based on many assumptions, conditions and data involved. The feasibility study demonstrates the positive economic gains of the solar PV and MCFC power plants. The unit electricity generation cost of solar PV is twice that of an MCFC system. In addition, the study reveals the slightly greater profitability of the MCFC. Exact estimation of their future economies is impossible because of uncertainties in many future conditions and environments. Nevertheless, the development of solar cells with higher efficiency is undoubtedly the most critical factor in increasing future profits. On the other hand, reductions in the operation and maintenance (O&M) costs and the natural gas (NG) price are the most important issues in raising the viability of the MCFC system.

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1. Introduction

One of the most important issues in the world is climate change due to excessive emissions of greenhouse gases (GHGs). The exploitation of new, renewable and sustainable energy may be the most effective way to mitigate GHG emissions. Therefore, most nations are trying to exploit these energies.

Except for hydroelectric energy and some bio-fuels, the solar photovoltaic (PV) and wind power are the most commercialized among the renewable energy sources. Others are partially commercialized and remain in the stages of demonstration and R&D. The status of renewable energy and technology differs greatly between countries as each nation exploits its own renewable potential supplies and develops policies according to its energy sources, supply and demand, as well as social and economical environment.

Although the fuel cell (FC) system uses hydrogen (H_2) as the fuel for highly efficient electricity production, it is not considered a renewable energy because H_2 production remains mostly sourced from fossil fuels. However, the FC system has currently received much attention due to its even higher efficiency, utilization, quality of electricity produced and system stability compared to the other renewable energies. In addition, the system will be considered another renewable energy source when H_2 production without any GHG emissions achieves commercial viability in the near future. While the practical application of FCs for residence and transportation application field will require more research, the molten carbonate FC (MCFC) system with MW-scale power generator for distributed generation system (DG) has already begun commercialization and is offering the same benefits as those of renewable energies to the country. For example, Korea currently offers various benefits such as financial incentives, loans and tax reductions to FC systems with the same conditions as those for renewable energy [1]. These supporting policies will advance the successful commercialization of MCFC and contribute to the development of the FC as a commercial power plant [2,3].

Solar PV and MCFC systems share many similar, but also different, aspects. The most significant difference is the energy source: unlimitedly exploitable clean solar energy vs. H_2 from fossil fuels. Because of this fundamental difference in the resources, the two systems exhibit their own unique features. The main difference is the environmental friendliness (without emissions) or unfriendliness (with emissions). Another difference is the intermittence of the power generation, which induces a wide divergence in system utilization: very low for solar PV and very high for MCFCs. Therefore, solar PV is generally used as a power supply with restrictions, whereas FC systems can be used as constant and regular power sources with higher and more stable quality.

The two systems also share many common points. There are few constraints on the plant site condition. Unlike other renewable energy systems, they can be constructed anywhere such as near the consumer or in remote local areas, as well as locations providing easy connection to the power grid system. Therefore, both systems can be employed as the most efficient DG system.

Their other common feature is the installed capacity range available for commercial DG. While the two systems can be installed with various scales, many solar PV power plants have been installed with a capacity under 3 MW. The capacity of most of the MCFC power plants currently operated in Korea is around 2.4 MW, due to technology restrictions, the readiness of operation and maintenance (O&M), and the economy. However, the capacity of solar PV plants can easily be extended by bundling up modules or arrays. For FCs, the maximum capacity of the unit MCFC system (module) for commercial purpose is currently 2.4 MW [4]. Therefore, the two systems could be competitive or supplementary in the field of DG systems.

Korea, like other nations, has recognized the importance of renewable energy and extensively supported its exploitation. The

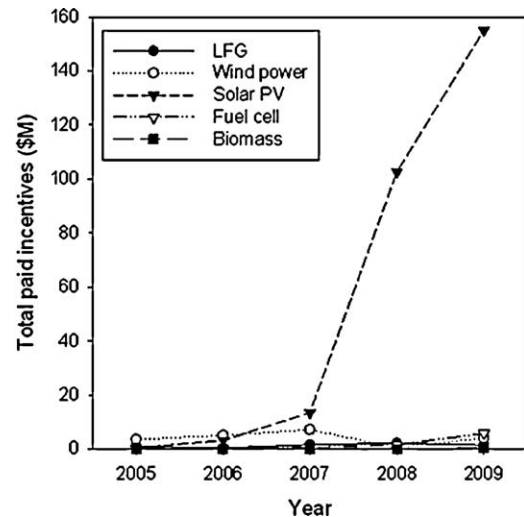


Fig. 1. Total incentives paid to renewable energy by the FIT program in Korea.

total incentives paid to the renewable energy sources (except for hydro power) under the feed-in-tariff (FIT) program over the last five years are shown in Fig. 1.

As of August 2009, US\$155 M was provided as incentives to the owners of solar PV power generation plants, which is 92% of the total incentives paid to all renewable energy sources. The second beneficiary was not wind turbine but FCs. While the power generated by wind turbines, 285.45 GWh, was larger than that produced by FCs, 35.95 GWh, the incentives paid to FCs, \$5.7 M, were larger than those to wind power, \$4 M [1,5]. In addition, the grid connecting MCFC systems using natural gas (NG) as the fuel for power and heat generation obtained approval from the UN as a clean development mechanism (CDM) methodology in July 2009 [6]. Therefore, CDM credits and a request for emission rights were granted to the MCFC-based DG systems using NG. Therefore, considering the status of these two energy systems, the solar PV and MCFC systems are confidently expected to undergo further development in Korea.

The present study analyzes the exploitation of these two energy systems, including their status, and assesses their technology by conducting a feasibility study and examining their competitiveness in the Korea environment. Many assumptions, conditions and data, including system performance and economy, are employed for the analysis. Most of them are based on real values from solar PV and MCFC power plants currently operated in Korea. Therefore, it is hoped that this paper will provide useful information to efficiently exploit the two energy systems and contribute to system improvement.

2. Status of renewable energy in Korea

No universally recognized definition of renewable energy has been agreed upon and its meaning differs slightly among countries and their statistics and related data reported are non-uniform. Nevertheless, the definition and data of the International Energy Agency (IEA) are the most widely used as standards. Many IEA members report their energy statistics based on the IEA standard. IEA classifies renewable energy into hydro power, geothermal energy, solar energy, wind energy, ocean energy (tide and wave), solid biomass, charcoal, bio-gas, liquid bio-fuels and renewable municipal waste.

In Korea, however, the term New and Renewable Energy is formally used instead of renewable energy. This term was defined in the Promotion Act for the Exploitation and Dissemination of the New and Renewable Energy by revising the related law in 2005. According to the Act [7], the New Energy is defined as the newly

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