SOFC Systems (Vol. 8): Evaluations of Energy Conversion and Utilization Technologies for Hydrogen Economy

Summary

Renewable hydrogen stations have been attracting attention recently. These stations supply CO_2-free hydrogen by conducting water electrolysis in a hydrogen production unit using renewable-derived electric power. In this proposal paper, a hydrogen station that adopts a hydrogen production system using fuel cells and renewables (SOEC system) was designed, and the costs involved were evaluated. Specifically, while optimizing the operating conditions of the SOEC system, it was assessed that how the annual production (the number of units), lifetime, operation rate, and electricity cost of the SOEC module affect the hydrogen production cost under the SOEC system. Based on such assessments, the construction cost of a renewable hydrogen station for fuel cell vehicles (FCVs) was assessed, and then, the hydrogen production cost that included this construction cost was assessed. As a result, the following two facts were found. (1)If the electricity cost remains within the 15-2.5 JPY/kWh range, the hydrogen production cost will range from 120 to 37 JPY/Nm^3-H_2, depending on the operation rate. (2)Reducing the hydrogen production cost to a level equivalent to the gasoline sales price (40 JPY/Nm^3-H_2) will require downsizing the unit and redesigning the pressurization and storage processes.

Proposals for Policy Development

- Reducing the size and cost of equipment: Size and cost reduction of the hydrogen production module, compressor, and accumulator is vital to promote the development of hydrogen stations because it greatly affects the station installation cost.
- Redesigning the pressurization and storage processes: Lowering the pressure for the accumulator (high-pressure tank) will make it possible to reduce the costs of the accumulator and the compressor. For the longer term, efforts should be made to reduce the hydrogen production cost to 40 JPY/Nm^3-H_2, a level comparable to the current gasoline price. Two processes may be viable to attain this goal. One is to reduce the cost of the compressor by taking advantage of electrochemical pressurization that is made possible by adopting, for an electrolysis cell, a fuel cell that uses a proton-conductive electrolyte membrane [1]. The other is to chemically convert hydrogen into ammonia or other energy carriers for transport and storage before using it for power generation[2].

1. Designing a Steam Electrolysis (SOEC) System and Optimizing Its Operating Conditions

   An SOEC system was designed, and its operating conditions were optimized while taking the thermo-neutral point into account. As a result, it was found that the hydrogen production efficiency was 83%, or even considering the process of increasing pressure to 80 Mpa, it was 76%. The hydrogen production rate was 300.8 Nm^3/h, almost equivalent to the standard production level for commercial hydrogen stations (300 Nm^3/h).

2. Assessing the SOEC System Cost and the Hydrogen Production Cost

   The SOEC system cost was assessed based on two assumptions: (i) The lifetime of the SOEC module will be extended to three years; and (ii) the lifetime of BOS (Balance of system) will be 15 years.

   It was found that the SOEC module cost will be largely halved if the annual production is increased from 100 units to 1,000 units, and, in addition to the SOEC module cost, costs for compressor and accumulator account for a large part of the system cost.

   Based on these findings, the assessment showed that in order to reduce the hydrogen production cost, to a level equivalent to the gasoline sales price in terms of combustion heat (40 JPY/Nm^3-H_2), conditions of the level of an electricity cost of 5 JPY/kWh, an operation rate of 30% or more, and at least a 3-year lifetime of the SOEC module (Figure 1) are required.

3. Evaluating Hydrogen Stations for Fuel Cell Vehicles (FCVs)

   It was suggested that the construction cost of an on-site renewable hydrogen station, based on a SOEC system (with the hydrogen production unit installed on the site) (Figure 2), can be reduced to 400 million JPY or less by setting the lifetime of the SOEC module to three years or more (Figure 3).

   If the construction cost of hydrogen stations are included, the hydrogen production cost on the condition that the electricity cost is in the 15-2.5 JPY/kWh range will be 120-70 JPY/Nm^3-H_2 at an operation rate of 33% (or 8h/day) and 86-37 JPY/Nm^3-H_2 at an operation rate of 90%.

[1] Smart Hydrogen Station (SHS) developed by Honda Motor Co., Ltd. https://global.honda/innovation/FuelCell/smart-hydrogen-station-engineer-talk.html.

[2] Kojima, Yoshitsugu, ed. Hydrogen Energy System Using Ammonia, CMC Publishing, p239, June 2015.

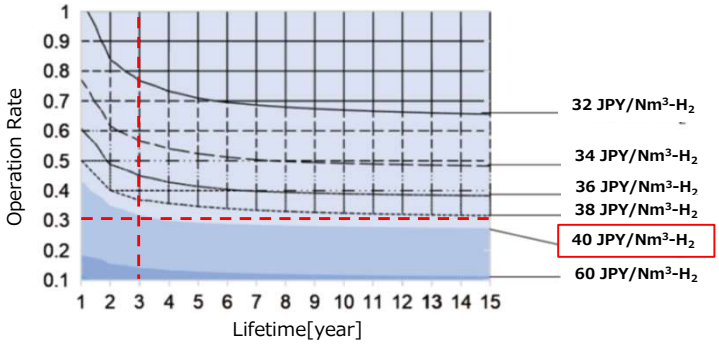

Figure 1 How the Hydrogen Production Cost Depends on the Operation Rate and the Lifetime of the SOEC Module (Electricity Cost: 5 JPY/kWh)

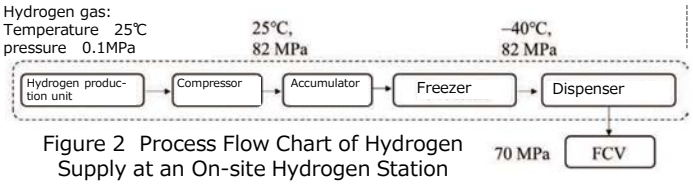

Figure 2 Process Flow Chart of Hydrogen Supply at an On-site Hydrogen Station

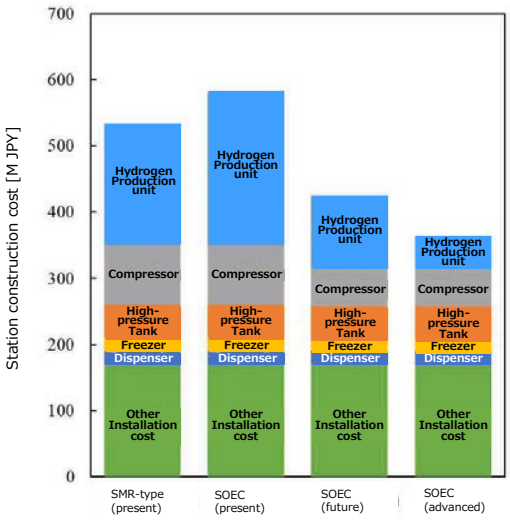

Figure 3 Construction Cost Structure of a Hydrogen Station (300 Nm^3/h) (SMR (present), SOEC (present): A 1-year lifetime of the module and an annual production of 100 units; SOEC (future): A 1-year lifetime of the module and an annual production of 1,000 units); and SOEC (advanced): A 3-year lifetime of the module and an annual production of 1,000 units)

https://www.jst.go.jp/lcs/pdf/fy2020-pp-02.pdf