Available online at www.sciencedirect.com
ScienceDirect
International Journal of Hydrogen Energy 31 (2006) 2378 – 2385
International Journal of HYDROGEN ENERGY
www.elsevier.com/locate/ijhydene

Preliminary analysis of transportation cost of nuclear off-peak power for hydrogen production based on water electrolysis

Makoto Sakurai[a,*], Shuichi Ueno[b]

[a]Department of Chemical Engineering, Tokyo University of Agriculture and Technology, 2-24-16, Naka-cho, Koganei-shi, Tokyo 184-8588, Japan
[b]EBARA Corporation, Japan

Received 30 August 2005; received in revised form 28 January 2006; accepted 10 February 2006
Available online 4 April 2006

Abstract

The paper describes transportation cost of the nuclear off-peak power for a hydrogen production based on water electrolysis in Japan. The power could be obtainable by substituting hydropower and/or fossil fueled power supplying peak and middle demands with nuclear power. The transportation cost of the off-peak power was evaluated to be 1.42 ¥/kW h (1 US$ is equivalent to in about 115 Japanese¥ at the end of 2005) when an electrolyser receives the off-peak power from a 6 kV distribution wire. Marked reduction of the cost was caused by the increase of the capacity factor.

Keywords: Transportation cost; Nuclear off-peak power; Water electrolysis; Hydrogen

1. Introduction

The establishment of a hydrogen infrastructure is one of the pressing subjects for the realization of a hydrogen energy society. From the technological maturity and energy productivity points of view, the hydrogen production from natural gas reforming and water electrolysis using nuclear power is attractive. With regard to the alkaline water electrolysis using nuclear off-peak power, Buteau et al. evaluated the hydrogen cost [1]. With focus on the nuclear off-peak power, we evaluated costs of the off-peak power and the hydrogen from water electrolysis and reported [2]. There are some references concerning with the off-peak power generation. Ogden evaluated the cost of off-peak power generation as 4–4.5 cents/kW h for small commercial customers (50–500 kW) and 3 cents/kW h for large customers (> 500 kW) [3]. Hydrogen production cost for off-peak power was also estimated. That was 1–1.5 cents/kW h. Thomas et al. evaluated the cost of off-peak power as 3 cents/kW h [4].

In order to make hydrogen by water electrolysis using the off-peak power more attractive, one must evaluate the off-peak power transportation from a power station to hydrogen filling stations. We already evaluated the transportation cost of off-peak power on the basis of Tokyo electric [5]. In this paper, we describe the evaluation results of the transporting cost of the nuclear off-peak power including an administrative cost for 9 measure electric companies in Japan.

* Corresponding author. Tel.: +81 42 388 7066; fax: +81 42 388 7064.
E-mail address: sakuraim@cc.tuat.ac.jp (M. Sakurai).

0360-3199/$30.00 © 2006 International Association for Hydrogen Energy. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijhydene.2006.02.023

Nomenclature

ATE	annual total expense (¥/y)
CE	capital expense (¥/y)
CF	fuel cost (¥/kW h)
CG	generation cost (¥/kW h)
OME	O&M (operation and maintenance) expense (¥/y)
P	power (kW h/y)
PT	transported power (kW h/y)
RC	rated capacity of facilities (kW*8760(h/y))
TI	transportation cost (¥/kW h)
TI_0	transportation cost for existing supply (¥/kW h)
TI(i)	transportation cost for existing supply under off-peak power transportation (¥/kW h)
TI(ii)	transportation cost for off-peak power (¥/kW h)
TL	capacity factor of transportation system (dimensionless)
TL_0	capacity factor of the facilities for existing supply (dimensionless)
ΔTL	increment of capacity factor of system due to the off-peak power (dimensionless)

2. Economic evaluation

2.1. View of nuclear off-peak power

2.1.1. Outlook of electric enterprises in Japan

Fig. 1 is the outlook of an electric power system in Japan from the view points of functionally classified sectors such as a hydropower station and of divisions classified due to financial reasons such as the administrative expense division.

Electric power is generated in three sectors, namely, hydraulic power, thermal power, and nuclear power sectors. Electricity is then transported to consumers through the four sectors of transmission, substation, distribution and sales sectors.

According to the divisional classification, the electric power system consists of eight divisions, namely, three generation divisions, four transportation divisions and the administrative expense division.

In Fig. 1, the seven functional sectors and the financially classified eight divisions are denoted by the square enclosures and elliptical enclosures, respectively.

2.1.2. Nuclear off-peak power

Although electric power is an outstanding energy medium, the demand for electric power fluctuates between day and night and between seasons. Therefore, power is produced by a combination of several different sources in order to minimize a total generation expense (cost).

Fig. 2 shows the power supply and demand fluctuation in a typical day and an example of the desirable (most economical) power source combination [6].

According to this large fluctuation, the capacity factor of the power source is less than 50% on average.

In this report, we made the assumption that nuclear power could substitute the mid-range and the peak electric power supplies. With these substitutions, a lot of off-peak power becomes available.

As a result of the off-peak power generation, the capacity factor for both the generating sectors and the transportation sectors would increase. If the benefit caused by the increased capacity factor of the facilities is allocated preferably into cost of the off-peak power, cheap electricity could be supplied to the water electrolysis.

In Japan, nine electric power companies except for the Okinawa Electric Power Company, generated 859,500 million kW h in the 2002 fiscal year, and 30% of this power came from nuclear power (nuclear power plants: 52 units). If half of the electric power generated by five nuclear plants rated at a 1300 MWe is regarded as off-peak power, the power and the amount of produced hydrogen will be 23 billion kW h/y and 4.6 billion N m^3/y, respectively. (For a 5 kW h power consumption per 1 N m^3 hydrogen production).

2.2. Method of evaluation and data used

2.2.1. Transportation cost for existing power supply

In general, a cost is determined by dividing the total annual expense by the total production during a certain period. The cost consists of a fixed expense like capital depreciation of the construction costs and an operation and maintenance expense, and a variable expense related to the amount of production. Therefore, the