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Cost Evaluation with G4-ECONS Program for SI based Nuclear Hydrogen Production Plant

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1. Introduction

Hydrogen demand is expected to sharply increase in near future as a development of technology using hydrogen as a new energy source. Contemporary hydrogen is production is primarily based on fossil fuels, which is not considered as environments friendly and economically efficient.

To achieve the hydrogen economy, it is very important to produce a massive amount of hydrogen in a clean, safe and efficient way. Nuclear production of hydrogen would allow massive production of hydrogen at economic prices while avoiding environments pollution reducing the release of carbon dioxide. Nuclear production of hydrogen could thus become the enabling technology for the hydrogen economy.

A Very High Temperature Reactor (VHTR) with an outlet coolant temperature of 950 °C is considered as an efficient reactor to couple with the thermo-chemical Sulfur Iodine (SI) cycle to achieve the hydrogen economy[1].

The economic assessment was performed for nuclear hydrogen production plant consisting of VHTR coupled with SI cycle.

For the study, G4-ECONS developed by EMWG of GIF was appropriately modified to calculate the LUHC, assuming 36 months of plant construction time, 5 % of annual interest rate and 12.6 % of fixed charge rate.

2. Methods and Results

2.1 G4-ECONS Program

G4-ECONS(Generation 4 Excel-based Calculation of Nuclear Systems) Program is used for the economic evaluation of the nuclear hydrogen production system.

It is an Excel-based program developed by EMWG (Economic Modeling Working Group) whose goal is to achieve simplicity, university, transparency and adaptability.

The program needs capital cost, fuel cost , operation , D&D as input data, and gives levelized unit electricity cost as an output as shown in Fig. 1.[2].

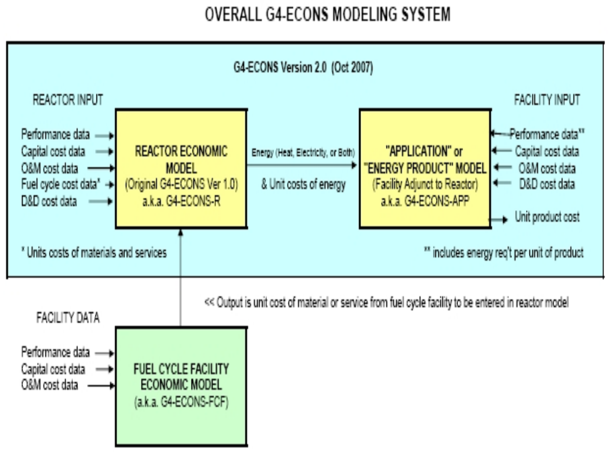

Fig. 1. Overall G4-ECONS Modeling System

2.2 Configuration of Nuclear Hydrogen Plant

The nuclear hydrogen production system consists of several major sub-systems as shown in Fig.2. [3].

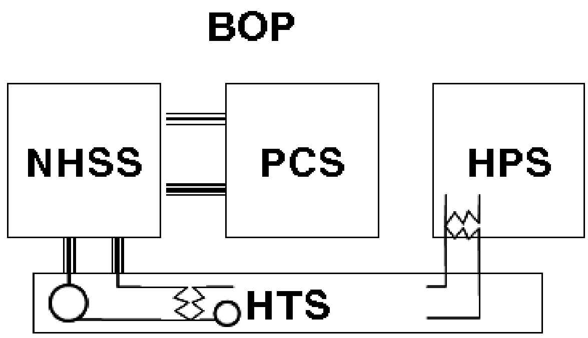

Fig. 2. Configuration of nuclear hydrogen plant

1) NHSS (Nuclear Heat Supply System)

NHSS is an advanced helium gas-cooled reactor with a core outlet temperature higher than 950°C, which is graphite moderated and equipped with passive RCCS system.

2) PCS (Power Conversion System)

PCS is a system that produces electricity from the high temperature heat from the reactor. PCS produces electricity using reactor high heat with gas turbine or steam turbine.

3) HTS(Heat Transport System)

The thermal heat generated from VHTR should be transported to the SI cycle to be used directly in hydrogen production. The pressurized helium gas is used as a working fluid to transfer heat from VHTR to SI cycle through the heat transport system.

4)HPS(Hydrogen Production System)

There are three potential nuclear hydrogen production processes, namely SI(Sulfur Iodine) process, HTE(High Temperature Electrolysis) process, and Hybrid Process.

2.3 Economic Evaluation

For the evaluation of the economic potential of the nuclear hydrogen production plant using VHTR coupled with SI cycle, the levelized unit hydrogen production cost(LUHC) was calculated. The four prismatic modular reactors coupled with SI cycle (PMR, 4 x 600MWth) were chosen as a model for LUHC calculation. The specifications of the nuclear hydrogen production plant are described in Table 1.

Table 1. Specifications of Nuclear Hydrogen Production Plant

Design Parameters	Specification
Reactor Reference Plant	GT-MHR
SI Reference Plant	H2-MHR: SI-Based I
Thermal Output	4 x 600 MWth
Operational Period	60 years
Reactor Outlet Temperature	950 ℃
Plant Availability	90 %
Capacity Factor over Life	90 %
Fuel Cycle	Open

The hydrogen production rate for four 600MWth prismatic modular reactors is calculated to be about 8.0 kg/s (230,000 tons/year), assuming a plant capacity factor of 0.9 and thermal efficiency of 48 %. To calculate the capital cost for hydrogen production plant of VHTR with SI cycle, capital costs for the GT-MHR and for the H2-MHR based on SI plant were used as a reference, respectively. The cost/size scaling equations are applied to calculate the corresponding capital costs and some input data were modified to reflect country-specific factors for hydrogen production plant of VHTR with SI cycle. Although the conventional scaling method for sizing and increase of design temperature was used in these calculations, it was no doubt that difference in design specifications between VHTR and GT-MHR gave rise to excessive assumptions in these calculations.

For the LUHC calculation, G4-Excell-based Calculation of Nuclear Systems (G4-ECONS) Version 2.0 was used. The general ground rules and assumptions follow those of G4-ECONS.

The costs of an intermediate heat exchanger, circulators and piping were included. Most of non-fuel operational, annually recurring costs were considered and the capital costs for chemical inventory for SI plant were included. The costs include all direct and indirect costs, plus interest during construction. The reactor operating costs include all fuel cycles costs (fuel, conversion, enrichment, fabrication, waste disposal and decommissioning), normal operation costs, maintenance costs and high purity water cost.

3. Conclusions

In G4-ECONS program, LUHC is calculated by the following formula;

LUHC = (Annualized TCIC + Annualized O&M Cost + Annualized Fuel Cycle Cost + Annualized D&D Cost) / Annual Hydrogen Production Rate

The LUHC calculated by the G4-ECONS program, turn out to be 2.9 $/kg for our model system.

REFERENCES

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