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Design and operation of renewable energy sources based hydrogen supply system: Technology integration and optimization

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ABSTRACT

The benefits of hydrogen as a clean and efficient fuel can be realized fully only when hydrogen is produced from renewable energy sources (RES). In this study, a new methodology is proposed to identify the optimal configuration and operation of an RES-based hydrogen supply system. The key is a superstructure-based optimization model using mixed-integer linear programming (MILP), which can integrate multiple resources and various technologies, such as electricity generation (e.g., wind turbine, photovoltaic panel, and dish-stirling power systems) and hydrogen production technologies (e.g., water splitting using alkaline electrolyzer and biomass gasifier), to minimize the total annual cost. The performance of the proposed methodology was validated through an application study on Jeju Island, Korea. In the case study, process economics and main cost drivers were analyzed. In addition, the effect of integration of technologies along with different resources on the economics was discussed.

1. Introduction

The depletion of fossil fuels and effects to the environment from consuming them have stimulated global interests in a sustainable energy system. The current carbon-based energy system should be switched to a new energy system that can balance energy supply and demand, protect the environment, and ensure energy security and economic viability. Among various alternatives, hydrogen-based systems are one of the most promising solutions to succeed the current system.

The main advantage of hydrogen as an energy carrier is the diversity in production of primary resources. Hydrogen can be produced from not only nonrenewable energy sources, such as oil, natural gas, and coal, but also renewable energy sources (RES), including wind, biomass, and solar energy. This diversity in production source contributes significantly to balancing energy supply and demand and ensuring energy security.

Employing RES for hydrogen production is central for better transition to a sustainable hydrogen economy because hydrogen is a low- or zero-emission energy from the end users perspective [1]. For instance, the use of hydrogen in fuel cell vehicles (FCV) offers a number of advantages over using conventional transportation fuels; e.g., better fuel economy and lower greenhouse gas and air pollutant emissions [2,3]. To successfully implement the RES-based hydrogen production system, it is essential to analyze the features of the system components (e.g., RES potentials and conversion technologies) and their interactions and to design new future hydrogen systems with suitable technologies [4]. In particular, the economic viability of the RES-based hydrogen production system depends strongly on identifying the optimal configuration of the integrated system. Thus, one of the challenging questions for design of RES-based hydrogen production systems is which energy sources and what configuration should be selected with what capacity for regionally different potentials for RES and hydrogen demands?

Many studies have explored the design and integration of RES-based hydrogen production systems. Several authors have assessed the availability and potentiality of RES for hydrogen production using the approaches based on geographical information system (GIS) [5–9]. Also, researchers have developed approaches and models for the development of hydrogen production and supply systems, which range from the supply chain and infrastructure design [10–12] to a focus on the components of the

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