Optimal H2 Production and Consumption for Improved Utility Operations: Path to Net-Zero Emission Energy Production

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I. Abstract

DUE to population growth, electricity demand increases significantly, and a continued reliance on fossil fuels will contribute to the global warming crisis. According to the U.S. Energy Information Administration, electricity production accounts for 33% of annual carbon dioxide (CO2) emissions of which 65% of this amount is produced by large-scale coal and natural gas power plants [1]. As a consequence, the global temperature is estimated to rise more than 1.5°C to 2°C on average by the year 2050. To that end, the U.S. government set a nationwide Net-Zero Emission goal by the year 2050 in which the power sector, especially utilities and generation companies must supply their load with green energy by 2035, and the transportation sector must be electrified completely by 2050 [2]. Additionally, due to the advancements in distributed energy resources (DERs) technologies, such as solar, wind, storage, hydrogen (H2), and demand response programs, the capital costs of these technologies will drop by 60%-70% until 2050 according to the National Renewable Energy Lab's (NREL) reports, accelerating the growing trend of utilizing more DERs. [3].

In recent years, H2 energy has demonstrated a great potential for large deployment from economic, environmental, and technical viewpoints. Generally, H2 energy can be produced, compressed, stored, and consumed using an electrolyzer, a compressor, a storage tank, and a fuel cell (FC) [4]. There are various technologies for water electrolysis such as alkaline, proton exchange membrane (PEM), and solid oxide electrolysis, in which electricity is used to separate water into oxygen and hydrogen. The generated H2 can then be compressed and stored in a storage tank, in the form of cryogenic liquid or high pressure gas. The most important applications of H2 energy are 1) power generation with stationary/mobile FC units; 2) transportation fuel for light- and heavy-duty FC vehicles; 3) fuel for residential and commercial buildings (e.g. space and water heating); 4) feedstock for ammonia production, etc., 5) assist utilities with technical concerns such as PV smoothing, voltage, and frequency regulations, etc. [5] [6].

In this study, we consider the perspective of the distribution system operator (DSO) that manages the DERs, especially H2 production and consumption by H2 systems, to reach the goal of net-zero emission energy production. It should be mentioned that a vertically integrated design is considered for the operation of the distribution network. To have realistic analysis of distribution network considering the power flow and voltage challenges, a standard 33-node distribution network [7] based on Fig. 1 including utility-operated natural gas power plants (combined cycle units and combustion turbine units), PV units, Battery energy storage (e.g. Li-ion batteries, Vanadium Redox flow batteries, etc.), and H2 systems (including electrolyzers, compressors, storage tanks, and FC units) are considered. Different

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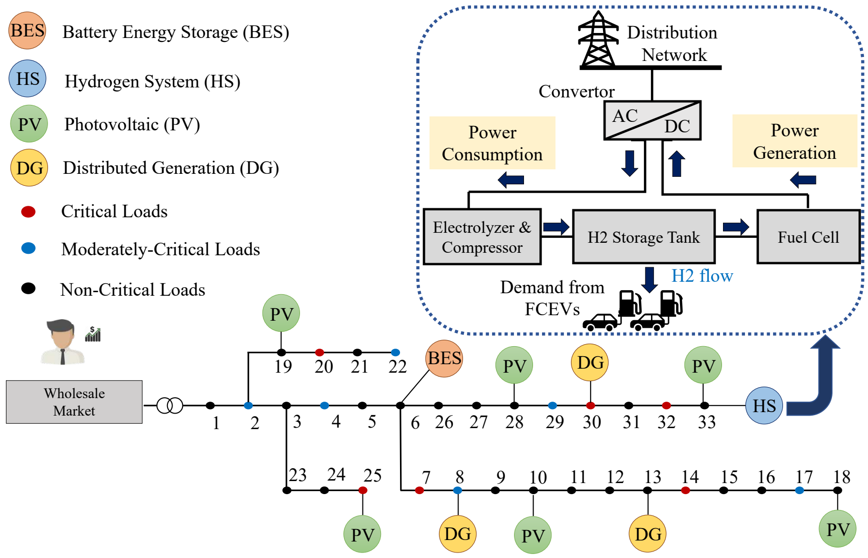

Fig. 1. 33-node active distribution network considering DERs.

types of voltage-dependent loads are considered such as critical, moderately-critical, and non-critical loads to resemble load types like hospitals, offices, grocery stores, etc. The goal of normal operation from grid operators' (utilities) perspective is to operate these assets to minimize the total operational and investment costs and maximize the green energy production for the power sector. Interested readers are encouraged to check [8]

Simulation results for different case studies assume costs for the year 2050, and demonstrate that with considering H2 systems and Redox flow batteries, the net-zero emission energy production for electricity demand supply is achieved in high PV penetration levels while addressing the technical and physical network constraints.

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