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A Power System Perspective for Harnessing the Green Hydrogen

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Abstract- In the energy sector, green hydrogen extraction from renewable energy sources is a novel idea. Hydrogen's ability as an energy carrier makes it possible to integrate renewable energy sources and create a robust linkage across different energy sectors. The technological aspects of the system as a whole that might restrict the quantity of producible hydrogen in a particular power system are examined in this research. To measure the effects of voltage security restrictions, the location and size of power to hydrogen facilities, and wind penetration levels on the harvestable green hydrogen, a non-linear programming formulation is suggested. The IEEE 39 bus system serves as an example of how the suggested framework can be used.

Keywords— *Quantity. Producible Hydrogen, Effects Of Voltage, Security, Restrictions, Wind Penetration Levels .*

INTRODUCTION

Green hydrogen, or hydrogen generated from renewable energy sources (RESs), may supply clean energy to the primary economic sectors of transportation, buildings, and industry. This would help achieve the Paris Agreement's aim of having 40% of electricity be the primary energy source by 2050, which should make it possible to achieve the decarbonised energy future is an example of how green hydrogen has affected the industry sector's lowering of carbon intensity. Because power systems constitute the backbone of large-scale electricity production and transmission, market forces, public concerns, and decarbonisation requirements compel them to run further near to their security limitations. As seen in Figure 1, green hydrogen energy carriers enable significant volumes of renewable energy to be channelled from power systems into end-use sectors including transportation, buildings, and industries. Water is treated to extract green hydrogen using an electrolyser that uses electricit. Green hydrogen might thus be used to integrate RESs with large-scale energy storage throughout the medium and long terms. By the following methods, the future carbon-free energy chain via green hydrogen can be achieved. Green hydrogen production will lessen the requirement for blue hydrogen, or the hydrogen obtained from natural gas via steam methane reforming, and consequently the creation of CO2.

- Up to a certain proportion, the produced green hydrogen may be fed into the natural gas network (as seen in Figure 1). This capability will result in a reduction of natural gas usage as compared to the absence of green hydrogen.
- Through the hydrogen supply chain, green hydrogen might be stored and used in aviation, marine, and other transportation systems.

The technology of electrolysers has advanced over the last several decades, and if they are scaled up soon, the percentage of green hydrogen in the global energy chain that has been decarbonised will rise. This technology will soon be a competitive energy carrier, according to cost-benefit evaluations. In order to meet the demand for hydrogen from other downstream hydrogen energy sectors (such as industry, buildings, and transportation), electrolysers, an essential component of green hydrogen technology, provide a flexible load to the power systems that can easily provide ancillary services like grid balancing services (upwards and downwards frequency regulation) at the same time operating at optimal capacity. Therefore, there are a variety of advantages and disadvantages to incorporating green hydrogen (as a new variable load) into power networks in the future. Positively, there has been a decrease in wind curtailment (stored as hydrogen), which has improved decarbonisation tactics. But because the green hydrogen will be considered a new electric load, there will be more tension. The transmission networks' available power transfer capacity (ATC) will be further constrained by this additional demand.

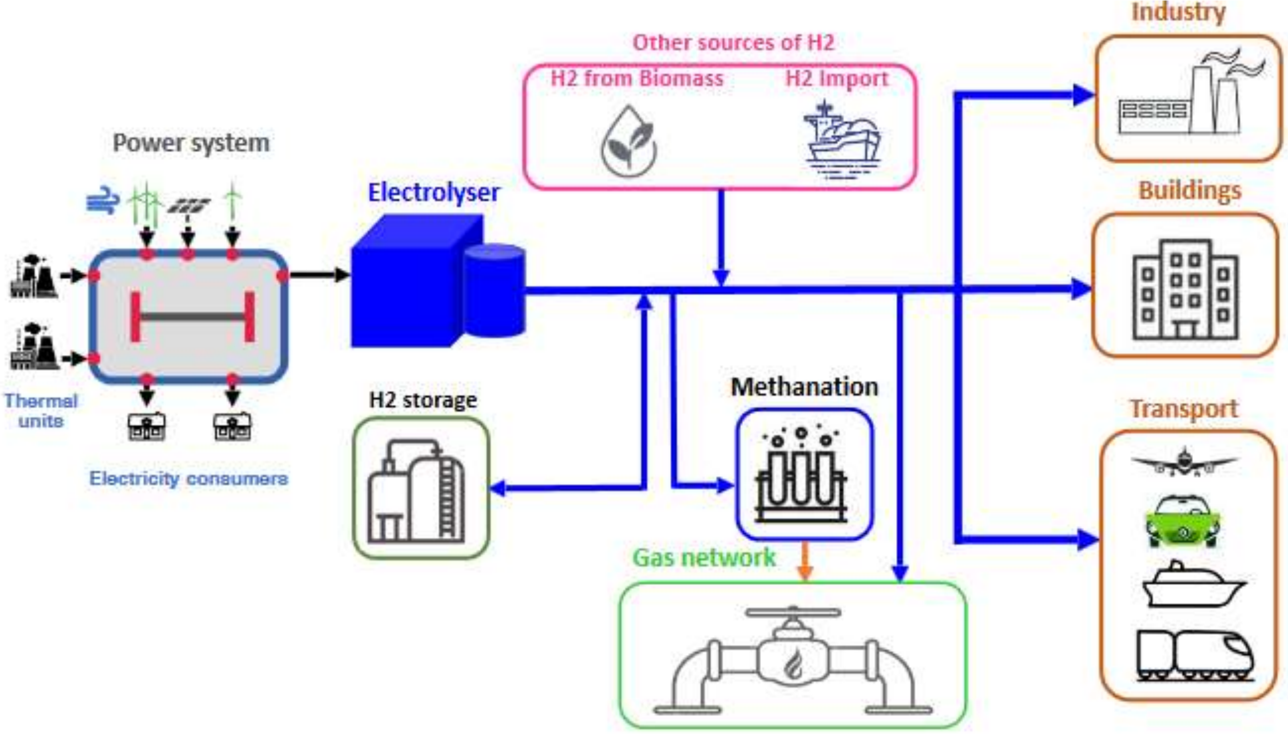

Figure 1- The link between various energy sectors via green hydrogen

LITERATURE REVIEW

While the literature on the interplay of hydrogen and power systems is vast and growing, in this section we focus on several recent papers that are closely related to our work. Countries are actively exploring hydrogen as an alternative to fossil fuels, with several recent studies highlighting the possibilities, drivers and challenges for the power supply chain that countries need to address summarise China's path towards a hydrogen economy. Despite substantial progress, several challenges remain towards achieving a hydrogen economy within China, including making technological improvements on the whole hydrogen supply chain that address the high costs of hydrogen infrastructure provision. Ren et al. emphasise hydrogen technologies as facilitators of large-scale development of renewable energy and decarbonisation within the economy and specifically conclude that hydrogen will not be an exclusive energy carrier but will complement and compete with electricity and biofuels in the future energy system. Maggio et al. undertake a broader literature review of the drivers and obstacles for a hydrogen economy. Policy and regulatory frameworks focusing on reducing greenhouse gas emissions, as well as the need for additional energy storage and electricity grid balancing, are among the positive factors affecting development of a hydrogen economy. The high cost of hydrogen and fuel cell technologies are among the obstacles facing hydrogen development but the interface with the power system, and specifically electricity prices, are identified as key parameters influencing the commercial sustainability of hydrogen electrolysers. There is still limited understanding of the interaction between scale deployment of hydrogen electrolysers within country-scale power system models though several recent papers are beginning to fill this gap. One set of papers entails a broad macro perspective on integration of hydrogen within power systems, often country-scale assessments, whereas another set of papers incorporate more technical constraints within their analysis. An assessment by Brey of Spanish plans to decommission 16 GW of fossil-fuel based generation and integrate 65 GW of renewable capacity by 2030 is an example of the former. Brey examines the role of hydrogen electrolysers in enabling such a high level of renewable integration finding that hydrogen plays a dual role, primarily as long-term storage to flatten seasonality patterns, and secondly as fuel for gas turbines. Using a cumulative residual energy analysis, the paper provides a broad overview of the potential role for hydrogen but does not consider issues related to the power grid or network physical constraints. Similarly, Kakoulaki et al. study Europe's potential to supply its hydrogen needs with green hydrogen. They estimate that 290 TWh per year of electricity required to produce Europe's hydrogen needs in contrast to combined technical renewable generation potential of 10,000 TWh per year. Thus, at a macro level there is ample renewable resource available to produce green hydrogen to satisfy demand, though Kakoulaki et al. acknowledge the need for more detailed technical analysis to fully understand the implications of producing green hydrogen. The deployment of electrolysers is subject to the technical constraints of the power system.

HYDROGEN FUNDAMENTALS

There are many different energy and industrial uses for hydrogen, which is a transporter of energy. It is also long-term storage-compatible. The energy properties of hydrogen present both possibilities and constraints. When it comes to energy content per unit of mass, hydrogen has a greater specific energy than most hydrocarbon fuels. However, it has the lowest volumetric energy density. This implies that in order for hydrogen to be utilised as a fuel, pressurisation or liquefaction are necessary.

(i) Black / Brown / Grey hydrogen – it is produced via coal or lignite gasification (black or brown), or via a process called steam methane reformation (SMR) of natural gas or methane (grey). These tend to be mostly carbon-intensive processes.

(ii) Blue hydrogen - it is produced via natural gas or coal gasification combined with carbon capture storage (CCS) or carbon capture use (CCU) technologies to reduce carbon emissions.

(iii) Green hydrogen- it is produced using electrolysis of water with electricity generated by renewable energy. The carbon intensity ultimately depends on the carbon neutrality of the source of electricity (i.e., the more renewable energy there is in the electricity fuel mix, the " greener" the hydrogen produced).

The electrolyser technology plays a vital role in the green hydrogen generation process. There are currently two commercially accessible methods for producing green hydrogen: alkaline and polymer electrolyte membrane (PEM) electrolysers. Advanced electrolyser technologies, such as anion exchange membrane and solid oxide, are also getting close to being commercially deployed. Other less common sources of production include bio-hydrogen, which is created either by bacterial fermentation or an SMR process centred on methane generated by the anaerobic digestion of organic waste.

METHODOLOGY

Hydrogen electrolyser effects may be assessed using the least cost generation and gearbox expansion problems (GEP and TEP, respectively) frameworks. Fundamentally, GEP and TEP formulate the needs for generation and transmission, respectively, as an AC-PF (alternating current power flow) issue that must be solved within the restrictions of the system and Kirchhoff's equations. A complicated non-linear set of equations is AC-PF. A GEP issue may be made simpler and solved using a variety of techniques, both concurrently with the network and independently of the OPF model recasts the model as an optimisation problem and is a popular method for solving the AC-PF problem. Solvers for the OPF issue are easily accessible and may be used to provide a solution for small power systems that are represented using a complete non-linear AC-PF method. However, tractability problems surface in large-scale real-world systems. The modelling framework used in this instance is the ENGINE model, which is based on the OPF methodology. ENGINE is a stochastic multi-stage joint optimisation method designed to solve the gearbox expansion planning (GTEP) and generation issues simultaneously. Kirchhoff's current and voltage rules provide a linearization of the complete AC optimum power flow, which is incorporated into the EN-GINE model. These stand for the physical limitations of the network as well as the equilibrium of supply and demand. Because a fully non-linear AC model becomes unmanageable for a large-scale, nationwide investigation, linearization is crucial. Two perspectives are used to evaluate the effects of the electrolysers in relation to a renewable target: the power system's perspective and the environmental perspective. Metrics such as transmission line reinforcement, power curtailment, load shedding, marginal energy pricing, and new generation/storage capacity are seen through the lens of the power system. The potential influence on CO2 emissions from burning fossil fuels to generate electricity and natural gas for heating is measured in the environmental assessment.

(i) Electrolyser model- In this study, the purpose of electrolysers is to combine natural gas with hydrogen to meet the need for domestic heat. The ESR model was added into ENGINE after being modified from El-Taweel et al. It takes into account the fact that not all electrical grid nodes have access to the gas network. Additionally, it is assumed that the gas distribution network's injection locations are where hydrogen mixing takes place. The ideal location of electrolysers to meet domestic heat demand is prioritised towards nodes where a larger percentage of residences utilise natural gas for heating, while only one-third of Irish dwellings are linked to the gas network.

CONCLUSION

This study looks at how the large-scale deployment of hydrogen electrolysers affects the electricity grid. Even if the additional load from electrolysers causes a slight rise in power costs (1– 2%), the impact is negligible considering that the policy's goal of significantly increasing renewable energy might result in price reductions of 75– 80%. In the domestic heating industry, greenhouse gas emissions are reduced as a result of recovered hydrogen replacing natural gas. The main driver of emissions performance in the electricity industry is the strategy to boost renewable energy. The current analysis offers a fresh viewpoint on the possibility of producing green hydrogen from excess renewable power within a real power system, even though there may not be a universally accepted definition of green hydrogen and many studies have attested to the viability of green hydrogen production in test power systems or as stand-alone plants. The findings indicate that there is not a clear decrease in emissions overall. According to the scenarios taken into consideration, the use of electrolysers increases power generation emissions in both the case of a high share (70%) of renewable power generation (RET þ ESR versus RET-only scenarios) and a moderate share (28 percent in 2018) of renewable power generation (ESR-only versus BAU scenarios).

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