The Current Status of Hydrogen Energy Industry and Application of Hydrogen Fuel Cell Vehicles

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Abstract. At present, traditional fossil fuels like coal, oil, and natural gas are the main sources of the world's energy supply. With economic development and the expansion of the world population, traditional fossil energy sources are getting depleted and environmental pollution is becoming more and more serious, so it is important to find new and alternative clean energy sources to ensure energy security, enhance the natural environment and encourage the modernization and transformation of the energy infrastructure. Hydrogen energy is a type of clean energy with attributes like being clean, highly efficient, having a flexible application form, having a wide range of application scenarios, etc. One of the most important sources of sustainable energy is hydrogen. The transportation sector is a significant user of gasoline on the global energy market. Hydrogen has the potential to be a viable fuel for eco-friendly transportation since it provides energy that is reliable, safe, practical, easy to use, and competitively priced. Meanwhile, as hydrogen-powered vehicles advance quickly, there is an urgent need to improve the construction of hydrogen infrastructure for transportation in order to accommodate the wide application of hydrogen energy in transportation in the future.

Keywords: Hydrogen energy industry; Hydrogen fuel cell vehicle; Carbon emissions; Renewable energy.

1. Introduction

Hydrogen energy is gaining popularity as a clean secondary energy source as the world's energy mix quickens its shift to a low-carbon one. In order to keep the increase in global temperature to 2°C, the International Commission on Hydrogen Energy forecasted in 2017 that using hydrogen energy may reduce CO2 emissions by 20% by 2050. The transportation industry is the largest end-use of hydrogen energy. The transportation sector is the largest hydrogen end-use, accounting for about 1/3 of the total demand for hydrogen energy, and could achieve 30% of the transportation sector's emissions reduction target [1]. The International Energy Agency (IEA) published "The Future of Hydrogen: Seizing the Opportunity Today" in 2019, which concluded that hydrogen energy is in the early stages of explosive development and is expected to be used on a large scale in "hard-to-reduce areas", such as heavy trucks and ships to achieve deep decarbonization in these areas. Future deep decarbonization efforts are anticipated to make extensive use of hydrogen energy in "hard to decrease" sectors such huge ships and vehicles [2].

Hydrogen vehicles are powered by hydrogen as fuel and are divided into two categories: hydrogen internal combustion engine vehicles, which are powered by burning hydrogen in an internal combustion engine, and hydrogen fuel cell electric vehicles (FCEVs), which are powered by an electric motor through the reaction of hydrogen or hydrogen-containing substances with oxygen in the air in a fuel cell. Nowadays, the automobile industry is investigating the creation and use of hydrogen FCEVs.

Under the "double carbon" strategy of carbon peak and carbon neutral, hydrogen energy has grown to be a key strategic initiative in the sphere of global energy. One of the components of the future of mobile mobility is hydrogen fuel cell automobiles. The introduction of hydrogen FCEVs during the Beijing Winter Olympics is a significant step toward the promotion and China's use of hydrogen-powered cars. It also represents a pivotal moment for China's use of hydrogen energy and its efforts to become carbon neutral.

2. Outstanding hydrogen energy technology in China and Japan at the Olympic Games

The 2022 Beijing Winter Olympic Games put forward the concept of "Green, Shared, Open and Clean". The Winter Olympic Village and the three competition areas are demonstration areas for the development of infrastructure for hydrogen energy systems in China, and the application of hydrogen fuel cell vehicle technology has received much interest. The "Meet in Beijing" winter sports test series employed a total of 80 hydrogen fuel cell buses, with good starting and driving performance in the low-temperature environment of Zhangjiakou. During the Beijing Winter Olympic Games, 710 hydrogen buses will be put into service in Yanqing and Zhangjiakou, Beijing to provide transportation services [3]. Beijing Winter Olympics hydrogen FCEVs have overcome technical difficulties such as improved hill-climbing power, low-temperature engine start, and increase heating function and other technical problems, can better adapt to low temperature better adapt to the low temperature, mountain road slope and other It can better adapt to complex Winter Olympics scenarios such as low temperature and mountainous road gradient.

As an early supporter of the hydrogen energy strategy, Japan has presented the idea of a "Hydrogen Energy Society" and produced the "Hydrogen Energy Fundamental Plan", which covers the whole industrial chain of hydrogen energy including hydrogen production, hydrogen storage, hydrogen energy utilization and infrastructure construction, and it is the country with more complete research and application of hydrogen energy around the world. It is the country with more complete research and world-wide application of hydrogen energy. The Tokyo Olympics proposed the "3R concept" - Reduce, Reuse and Recycle. In the Olympic Village, only pure electric vehicles and hydrogen FCEVs will be utilized to provide travel services for athletes and staff, in an effort to create a "zero-emissions village". The fuel for the Tokyo Olympic torch was also made of hydrogen energy, which was the first time in the history of the Olympic Games that the main torch used a fuel that did not emit carbon dioxide [3]. Through the sub-large-scale hydrogen show of the Tokyo Olympics, Japan has realized the large-scale application of hydrogen FCEVs in some areas of the city, which has built a solid basis for the application and sustainable development of the Japanese hydrogen energy industry for the whole society.

3. Introduction to global hydrogen energy industry development

3.1. Foreign hydrogen energy industry development

Since the 1990s, the U.S. has been accelerating the growth of the hydrogen energy industry (HEI) according to the lines of policy evaluation, commercialization prospect forecast, program development, technological creation, demonstration and promotion, and has invested a lot of money to solve the technical problems in the development of HEI. The U.S. has also concentrated on building infrastructure. It has the third-highest concentration of hydrogen refueling stations (HRSs) worldwide, behind Japan and Germany, and a high use rate. By 2030, it expects to create 1,000 HRSs.

Since 2020, the European Union has formulated a series of policies related to the development of HEI to achieve the goal of carbon neutral development by 2050, such as "European Union Hydrogen Energy Strategy", "European Union Energy System Integration Strategy", "2030 Climate and Energy Framework" and "2050 Low Carbon Economy Strategy". At the same time, the development of the HEI will create new jobs and promote the economic recovery of the EU in the post-epidemic era. In addition, in order to implement the development strategy of HEI, the EU has called on leading hydrogen energy companies, private institutions, regional energy officials and financial institutions to establish a "European Clean Hydrogen Alliance" to encourage the growth of the hydrogen energy sector and to satisfy the need for clean energy in EU member states [4].

Japan has long been concerned about energy and environmental issues, as about 94% of its primary energy supply comes from overseas. To reduce energy dependence, Japan announced its "Basic Hydrogen Energy Strategy" back in 2017, aiming to create a "Hydrogen Energy Society" and make

hydrogen fuel and other fuels equally affordable [5]. At the same time, it works to build hydrogen filling stations so that hydrogen energy can replace conventional energy sources for things like power generation and transportation. The "Hydrogen Energy Utilization Schedule" which outlines the primary objectives of applying hydrogen energy by 2030, was subsequently announced by Japan in 2019.

3.2. Domestic hydrogen energy industry development

After China's "Dual Carbon" strategic goal was put forward, the strategic significance of developing the HEI was raised to a new strategic height. Two significant points were made in the October 2021 documents: "Opinions of the Central Committee of the Communist Party of China and the State Council on: Completely, Accurately and Comprehensively Implement the New Development Concept and Do a Good Job of Carbon Neutralization for Carbon Peaking" and "Action Plan for Carbon Peaking by 2030". The growth of the complete hydrogen energy industry chain, the installation of HRSs, and the development and use of important technologies have all been referenced numerous times in relation to hydrogen energy in the pound policy. The "Medium and Long-Term Strategy for the Growth of the Hydrogen Energy Industry (2021-2035)" was formally unveiled on March 23, 2022, and it recognized hydrogen energy as a crucial component of the upcoming energy system and an energy-consuming terminal. The growth trajectory of strategically significant emerging industries and future industries is a key driver for achieving the low-carbon and green transformation. These positionings have indicated the course for the growth of the HEI in China. It is a significant step for the nation's development and views the transportation sector as the primary target of a variety of demonstration applications. It highlights the need of encouraging the use of medium and heavy hydrogen FCEVs, expanding the application space for cars and trucks in a planned manner, and progressively establishing FCEVs and lithium-ion battery pure electric vehicles and complementing model for development [6].

3.3. Development status of hydrogen vehicles

In line with statistics, the global transportation CO2 emissions are close to 8.5 Gt in 2019 and will still exceed 7 Gt in 2020. Hydrogen energy has green and clean characteristics and can be applied to the automotive industry to effectively alleviate carbon emissions in the transportation sector, and compared with traditional cars, hydrogen FCEVs are less noisy and environmentally friendly.

The creation and marketing of hydrogen FCEVs in China will increase year by year from 2016 to 2019, and the year-on-year growth of the creation and marketing of hydrogen FCEVs in 2019 will be 87% and 78% respectively. Due to the impact of the epidemic, the production and sales volume will decrease in 2020, but the annual production and sales volume will remain above 1,000 units [7]. Hydrogen FCEVs will be at the core of the hydrogen energy industry system. It is important to speed the study of and creation of hydrogen fuel cell vehicle technology and improve the utilization rate of hydrogen energy on a large scale to form an industrial system characterized by low carbon emissions all over the world.

The establishment of hydrogen refueling areas in traditional gas stations or the direct construction of HRSs can promote the rapid development of hydrogen FCEVs in the market. The data indicates that the goal of "100 Hydrogen Refueling Stations by 2020" will be achieved by the end of 2020 with 118 HRSs constructed in 20 Chinese provinces and cities. At present, the technological path of HRSs domestically and internationally includes two types of HRSs: external hydrogen supply station technology and internal hydrogen refueling station technology, and the hydrogen refueling mode is divided into two pressure levels, 35 MPa and 70 MPa, for graded storage and refueling, which can not only improve the utilization rate but also reduce the cost of hydrogen storage [8-9]. In terms of core equipment design and manufacturing, although China has made some achievements in the study and creation of domestic hydrogen refueling devices, compressors and commercial skid-mounted HRSs, some equipment still cannot meet the technical requirements of HRSs.

China is now steadily promoting the formation of HRSs in cities, connecting hydrogen refueling station planning lines between cities, and completing the layout of hydrogen refueling station surfaces in numerous city-linked areas [10]. The operation of hydrogen FCEVs and the advancement of hydrogen storage technologies are both fundamentally dependent on HRSs. The two can only be changed from a bad condition of mutual restraint to a favorable scenario of mutual promotion and synergistic development if the interaction between FCEVs and HRSs is appropriately handled.

4. Development and construction of transport hydrogen infrastructure

4.1. Transportation infrastructure using hydrogen

Hydrogen is a widely utilized industrial gas that may originate from a wide range of sources, and transformed into meaningful work using a wide range of processes. It is most frequently employed in the manufacturing of ammonia, paper processing, and petroleum refining. Production, transport to the location (or station-based production), storage, compression, and distribution are all steps in the process of providing hydrogen to fuel cars.

Hydrogen must be transformed to mechanical work using either thermodynamic (such as an internal combustion engine) or electrochemical/electromechanical methods in order to produce useful motive work from stored hydrogen. FCEVs are the most effective and ready-for-production hydrogen technology at the moment [11-12]. To generate electricity, water, and heat, fuel cells use oxygen and hydrogen in an electrochemical reaction. A polymer electrolyte membrane (PEM) fuel cell system is the most widely used form of hydrogen-fueled fuel cell system, which also incorporates subsystems for safety, power electronics, electric drivetrain, thermal management and hydrogen storage [13]. An FCEV has many of the same characteristics as today's conventionally fueled vehicles, including the same range, mass and size, and typically has fuel efficiency that is two to three times higher than that of an internal combustion engine. Fuel cells can deliver a wide range of the more widespread positive aspects of electric vehicles, including zero hazardous exhaust emissions (releasing only water and a trace amount of hydrogen, as well as passing through nitrogen from the air), extreme performance and silent operation. These qualities are necessary for efficient fuel cell vehicle usage.

From the early 2000s, there has been a small amount of light-duty fuel cell vehicle production for fleet and personal use. Toyota, Hyundai, and Honda are a few FCEV manufacturers that are currently offering vehicles for business use [14-16]. In 2021, there will be more than 17,000 registered FCEVs sold worldwide, an increase of 83.0% from the previous year. In accordance with projections made previously by the International Hydrogen Energy Council (IHEC), FCEVs will account for 20–25% of all vehicles on the planet in 2050, with hydrogen energy providing 18% of the world's energy needs. This will generate a market worth over $2.5 trillion. In the domestic market, according to data released by the China Association of Automobile (CAA), the production and sales of FCEVs in China will be 1,777 and 1,586 units in 2021, up 48% and 35% year-on-year, respectively. In 2025, China is anticipated to have roughly 100,000 hydrogen FCEVs, according to the "Energy Saving and New Energy Vehicle Technology Roadmap 2.0" which was published in early 2021. Other automakers, including GM and Nissan, have FCEVs in various stages of research while Mercedes-Benz has been leasing pre-commercial FCEVs. Other manufacturers are also collaborating on the creation of commercial FCEVs.

Overall, these long-term industry expenditures in commercial fuel cell vehicle technology and implementation have surpassed analogous types of investments in hydrogen infrastructure technology. The effective deployment of energy infrastructure, hydrogen infrastructure, and FCEVs are interdependent, and multiple technical, sociocultural and consumer issues relating to increased FCEV adoption revolve upon the accessibility, affordability, and dependability of hydrogen infrastructure.

4.2. Accelerated construction of hydrogen stations

As of the end of 2012, China has more than 240 HRSs built, up from the country's anticipated total by the year 2020 by 112 stations, according to data made available by the China Hydrogen Energy

Alliance (CHEA). The dearth of HRSs is being addressed, and guidelines for their construction and operation are now included in many Chinese provinces and municipalities' guiding plans, such as the hydrogen energy industry plan. The policies on the approval, construction, operation and safety management of HRSs in pioneering cities provide useful references and lessons for other places in formulating policies on the management of HRSs and solving institutional and policy constraints [6].

With the implementation of the fuel cell vehicle demonstration policy, the construction of HRSs in various regions has generally been in a moderately advanced position, and large energy companies have been involved in the creation of infrastructure networks for hydrogen refueling. The demand for hydrogen refueling of special vehicles with hydrogen fuel cells will be effectively met.

5. Conclusions

Hydrogen energy is becoming more popular as a clean supplemental energy source as the shift to a low-carbon energy framework is accelerated globally. Hydrogen vehicles are more environmentally friendly and convenient to get energy than conventional fossil fuel powered automobiles. Major developed nations and regions have integrated the creation of hydrogen vehicles into their overall plans for the growth of their national hydrogen economies, and they are now in the process of lowering costs, enhancing performance, and getting ready for widespread commercialization. In contrast, China's hydrogen vehicle technology started late, lacks overall planning, and still suffers from an incomplete industrial chain and insufficient technological innovation in the key supply chain. Future Chinese hydrogen car development should take note of advanced international practices, improve the top-level design and clarify the positioning of hydrogen development and improve the standard system of hydrogen industry. In view of the high carbon emission intensity in the process of hydrogen production, it is necessary to strengthen the support for hydrogen production from renewable energy. In order to advance domestic demonstration and industrial development, we must simultaneously concentrate on basic research into bottleneck issues surrounding the hydrogen fuel cell vehicle industry chain, such as hydrogen storage, transportation, and refueling, and engage in international cooperation with a problem-oriented approach.

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