

# Visions and Technical Challenges of Hydrogen Economy: Power System Viewpoint

Dong-Jun Won\* and Chen-Ching Liu<sup>†</sup>

**Abstract** - Hydrogen, as a future energy source, is thought as an alternative of fossil fuel in view of environment and energy security. Hydrogen has the properties of both fuel and electricity so that it can make the energy paradigm shift in the future. Therefore, researches on hydrogen in power system area are essential and urgent due to their huge effects on current paradigm. In this paper, the visions and technical challenges of hydrogen in power system are reviewed as energy storage, dispersed generation (DG), DC generator, and combined heat and power (CHP).

**Keywords:** Hydrogen, hydrogen economy, dispersed generation, fuel cell,

## 1. Introduction

Hydrogen economy, which comes first from the book 'The Hydrogen Economy' by Jeremy Rifkin, is now thought as the most probable alternative that can overcome the energy crisis and can change the current energy system revolutionarily. Because hydrogen is produced from various energy sources and satisfies all energy needs from transportation to electric power, all kind of energy resources can be integrated using hydrogen energy [1]. As same as the digital convergence has greatly changed the digital technology paradigm, hydrogen will realize the energy convergence and give birth to a huge paradigm shift in energy system.

Hydrogen itself is clean, sustainable and emission free. Depletion of fossil fuels, global climate changes and the issues related with national-wide energy security will make hydrogen become more important [2]. Especially, due to the increase of the oil cost in these days, hydrogen becomes more competitive in view of cost. Kyoto Protocol in 1997 and UN Framework Convention on Climate Change in 1992 also encouraged the tendency toward hydrogen economy.

There are still some technical and economical concerns in moving toward hydrogen economy. Firstly, the initial infrastructure needs much investment. The cost to get hydrogen still remains high compared to that of fossil fuel. The storage and delivery method of hydrogen are now developing but need more practical applications. Never-

theless, the transition from fossil fuel to hydrogen is inevitable. The future energy system will be based on hydrogen due to its emission-free and clean property. Hydrogen and electricity will give birth to a good combination and make good synergic effects [3].

Currently the researches on hydrogen energy are mainly concentrating on the development of fuel cell technology itself. Enhancing the efficiency, reducing the cost and improving the performance of fuel cell are among main research topics. The application areas of fuel cell technology are usually limited to the area of vehicles. Little papers are dealing with the power system application of fuel cell [4-6]. Lots of papers are still analyzing the basic performances of fuel cell. Therefore the studies on the interaction of fuel cell with power system and design of hydrogen energy system are necessary.

In this paper, the visions and technical challenges related with hydrogen economy in power system research area will be reviewed. The main paradigm shift which comes from hydrogen economy will be mentioned. In power system point of view, the role of hydrogen and fuel cell will be summarized and relating technical challenges will also listed. At the end of this paper, the development of hydrogen era will be reviewed.

## 2. Paradigm Shift in Hydrogen Economy

### 2.1 Energy buffer

Energy mainly comes from fossil fuel, nuclear reaction or natural source e.g. wind, solar, bio energy. The energy from these sources can be converted and stored in the form of hydrogen. In the past, only some kind of battery was able to store these energies in electric energy. But in hydrogen economy, most energy sources can be trans-

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formed to hydrogen and changed again into another form of energy. For this reason, hydrogen can be called as ‘energy buffer’.

These characteristics greatly change the formal power system operation. In power system, electric power is not stored and must be consumed at the same time when it is produced. But this assumption does not hold any more if hydrogen is used as energy buffer. Large amount of electric power can be stored in forms of hydrogen so that many technical problems can be easily solved. Fig. 1 shows that the energy supply structure using hydrogen as a energy buffer [7].

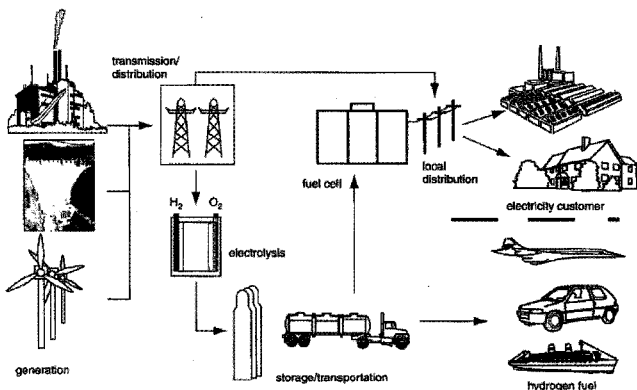


Fig. 1 Energy supply structure using hydrogen as a energy buffer

2.2 Energy Convergence

End users use energy mainly through fuel and electricity, e.g. gasoline for transportation, gas for heat and electricity for house life. In hydrogen economy, hydrogen can replace these fuels and electricity, which is called ‘energy convergence’. Most of energy source will be integrated in the form of hydrogen and consumed by the end user. Hydrogen meets two needs at the same time so that the energy usage of power system and the transportation system can be integrated with hydrogen. Fuel and electricity will be interchangeable each other in the form of hydrogen and hydrogen meets the energy needs. The transformation from one source to another source is relatively free in hydrogen economy.

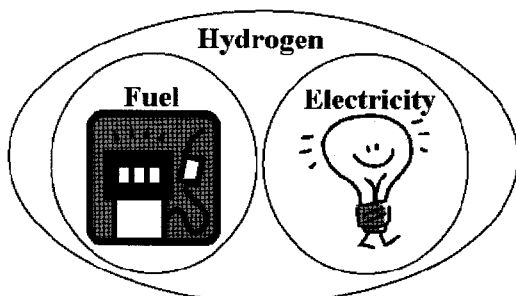


Fig. 2 Two aspects of hydrogen

3. Hydrogen Energy in Power System

Fuel cell produces electric energy from hydrogen. It converts hydrogen into electricity through an electrochemical process. Fuel cell can be used as a source of electric power so that it has an important role in power system. If fuel cell is installed in power system, they may change lots of parts in power system due to its characteristics. Its impacts on power system can be categorized as follows.

3.1 Huge Storage of Electric Energy

Fuel cell system functions as a huge storage device which stores electricity in a large scale. The word ‘huge’ means that it is not a kind of battery but a kind of generator. The power rating can reach several MW level. This property of fuel cell can diminish the assumption that the electric power is not stored and must be consumed at the same time when it is produced. The power output of fuel cell can be stored in the form of hydrogen and used when the load reaches peak level. This property has many advantages compared to the conventional assumption that power is not stored. At first stage, it can replace the pumping-up power generator and at last it will change the power system paradigm into storable system with energy buffer. The benefits and technical challenges are summarized in Table 1.

Table 1 Visions and technical challenges as storage

Benefit	Technical Challenge
- Peak shaving between day and night or between summer and winter	- Market bidding strategy change: separated bid for peak shaving as a demand, different price
- Low facility installation cost	- Small price difference between day and night
- Low transmission congestion	- Uncontrolled peak shaving: hard to predict the load level, increase uncertainty, careful load forecasting

3.2 Dispersed Generation

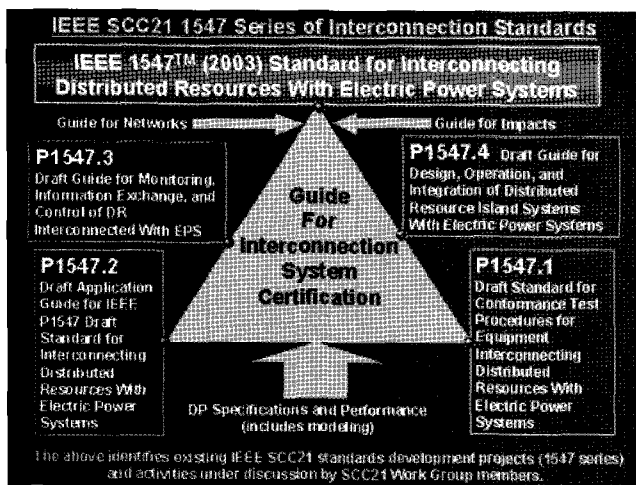
In the future, small dispersed generation (DG) will be applied in power system. They will include microturbine, wind power generation, photovoltaic generation and biomass generation, etc. These energy sources can be a good DG system and change the power system configuration and the operation. Fuel cell is also a good DG source and more demand-side oriented source than other renewable sources in that it can be installed close to consumer site. It can be installed in houses, building and

downtown of big city. Therefore, the importance of fuel cell as DG increases. DG can increase the reliability, power quality and stability of power system if it is adapted in power system appropriately. However, if the DG is not well organized with existing power system, then it can result in some kind of damages [8-10]. IEEE 1547 standard describes the general rules when DG is connected in power system [11]. They include the guidelines for protection, power quality, appropriate rating, etc. They are under development and the modification is now going on. Fig. 3 shows the details of IEEE 1547 standard and Table 2 summarizes the advantages of fuel cell as DG and the technical considerations.

devices will not be used any more. Although more researches are necessary for the DC system, the fuel cell can be a good alternative of DC source in DC system.

**Table 3** Benefits and technical challenges as DC source

Benefit	Technical Challenge
<ul style="list-style-type: none"> <li>- Replace the AC generators</li> <li>- Construct DC network</li> <li>- Simple wiring (integration of power network and communication network)</li> <li>- Reduce standby power loss and device size</li> </ul>	<ul style="list-style-type: none"> <li>- Initial investment for DC infrastructure</li> <li>- Loss increase</li> <li>- Supergrid (DC with superconductivity)</li> </ul>



**Fig. 3** IEEE 1547 standard for interconnection of DG

**Table 2** Benefits and technical challenges as DG

Benefit	Technical Challenge
<ul style="list-style-type: none"> <li>- Dispersed generation increases reliability</li> <li>- Reduce facility (gen., trans., dist.) installation cost</li> <li>- Reduce transmission loss</li> </ul>	<ul style="list-style-type: none"> <li>- Unpredictable DG amount</li> <li>- Precise load forecasting</li> <li>- DG control</li> <li>- Islanding</li> <li>- Coordination with protection</li> <li>- Micro-grid</li> </ul>

**3.3 DC Generator**

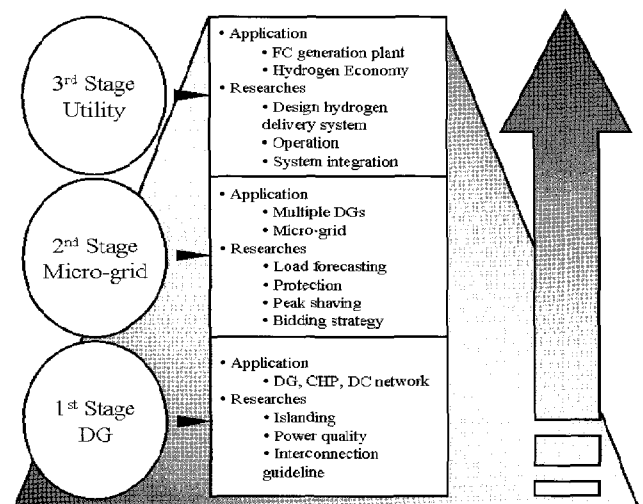
Fuel cell internally produces DC voltage. If it is connected with power system, the fuel cell interface transforms DC voltage into AC voltage through inverter. However, because it is naturally DC source, if it is connected to DC system, then it can act as a DC source. DC power system is not realized yet in a large scale. But some researches show that DC network is possible in near future and it can greatly improve the efficiency of power system. For example, if DC system is realized in a house, it will reduce the line connections by integrating power line and communication line. Most power supplies in digital

**3.4 Combined Heat and Power Generation**

Fuel cell produces electricity by means of reverse process of electrolysis. For the by-product of this process is heat and water, fuel cell can function as combined heat and power generation (CHP). In Iceland, fuel cell is already used as CHP system to warm the individual house. The total efficiency of fuel cell CHP system is fairly high and reaches up to 80%. Especially, because fuel cell can be installed close to load, it can be an ideal CHP system. The water from fuel cell can also be utilized to make hydrogen and this forms a closed clean cycle of recycling.

**4. Hydrogen Era in Power System**

Hydrogen era in power system area can be established through the following three steps. At first stage, the small number of fuel cells with a small power rating will be installed as a dispersed generation. Fuel cell system can act as a generator or storage. It can be also interconnected with DC system to function as DC generator.



**Fig. 4** Hydrogen era

The second is the stage at which the large number of fuel cells with a small power rating is installed so that it will construct a kind of micro-grid. Fuel cell can be a part of micro-grid and coordinate with other devices such as protection device or dispersed generators. Fuel cells will provide enough power to the customers at the close site with them.

At final stage, the hydrogen system and electric power system are integrated into one system. The hydrogen is delivered through its own pipeline or truck and replaces some part of existing electric power system. Hydrogen will act as energy buffer and control energy flows.

### 5. Conclusion

This paper has discussed about the visions and technical challenges of hydrogen economy in power system study. Hydrogen energy can shift current energy paradigm revolutionarily and it also holds for power system. Hydrogen has both aspects as fuel and electricity so that it enables energy convergence. In power system, the fuel cell system with hydrogen can be a huge storage of electricity, dispersed generation close to customer, DC source in DC network and efficient CHP system. These characteristics will greatly change the future power system. Although lots of technical challenges still remain and non-technical problems also have to be solved, the studies on hydrogen economy and fuel cell application in power system are inevitable. This is the right time to prepare hydrogen era step by step.

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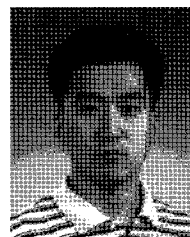
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