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Capital Cost of Solar/Wind Direct Hydrogen Refueling Station vs. BEV Charging Station

Michael Song

Introduction

It has been well known that some FCV manufacturers established mass production years ago. However, the FCV refueling infrastructure is still in its preliminary stages. While many assume that the investment in refueling stations has been delayed due to the high capital costs of FCV refueling stations compared to EV charging stations, data from reputable sources says otherwise.

Grid-tied EV charging stations are potential **carbon emission amplifiers** and that solar/wind direct FCV refueling stations have a **higher wheel-to-well (WTW) efficiency** than solar wind direct EV charging stations. This article takes aim at the overnight capital cost of solar/wind direct H_2 refueling stations which are far lower than solar/wind direct EV charging stations.

Overnight Capital Cost of solar/wind direct FCV refueling station vs. solar direct Supercharger Station

The overnight capital costs of solar PV ($2,534/kW), onshore wind turbines ($1,877/kW), and battery storage ($2,813/kW) are based on a **US EIA report** (2016). The capital cost of an on-site electrolyzer ($2,241,141/1000 kg H_2 per day) is from an **NREL report** (2008). Capital cost of Supercharger station is based on **8-bay Sagamore, MA, SuperCharger Project** (6/14/14, #24, Meetinghouse Ln, Sorenti Brothers). It should be noted that 2.2 MW electric power is required to generate 1000kg H_2 per day.

Table 1. The capital cost of 2.2 MW solar/wind direct EV charging station.

	Source (M$)	Battery Storage (M$)	8-Bay Tesla Supercharger (M$)	TOTAL (M$)
Solar	5.57	6.19	2.00	13.76
Wind	4.13	6.19	2.00	12.32

Table 2. The capital cost of 2.2 MW solar/wind direct H2 refueling station.

	Source (M$)	Electrolyzer 1000kg H2/day (M$)	1 Dispenser w/ 2 fueling hoses (M$)	TOTAL (M$)
Solar	5.57	2.95	1.00	9.52
Wind	4.13	2.95	1.00	8.08

For an "apples-to-apples" comparison of overnight capital cost, one hydrogen dispenser with two hydrogen injection hoses has a refueling capacity comparable to an 8-stall Tesla Supercharger station. If an 8-bay Tesla Supercharger station can handle 16 EVs in 30 minutes, 1 hydrogen dispenser with two injection hoses could refuel 14 to 20 FCVs in 30 minutes (with 3-4 minutes of refueling time).

Comparing the data in table 1 and table 2, the capital cost of solar PV/wind energy direct FCV refueling station is 30% or 34% cheaper than EV charging station for solar and wind energy, respectively. With superior WTW efficiency and over 30% lower capital cost for an H_2 refueling station, FCVs may provide a promising path to ZEVs. If we use updated data for electrolyzer and H_2 dispenser, the capital costs of a solar/wind refueling station maybe actually be far cheaper than a Supercharger station.

Rural/Freeway and Urban Version of Hydrogen Refueling Stations

There are two H_2 refueling infrastructure models we could suggest: a rural/freeway model and an urban model. The rural/freeway model is comprised of solar/wind direct H_2 generation and refueling system utilizing existing empty land and water resources near to freeway. The urban model uses excess renewables and a spinning reserve. Here, excess renewables are absorbed by the grid to support hydrogen refueling stations. Also, except for a set safety margin, the spinning reserve can be used to generate hydrogen for FCVs at urban H_2 refueling stations. By adjusting the number of operating cells in alkaline or PEM bipolar electrolyzers in real-time, the electrolyzer can be worked as a real-time adjustable load toward the grid operator depending on real-time power demand. Therefore, the urban model creates a utility of spinning reserve and excess renewables that are dissipative in nature. Utilities can generate a new source of revenue through the expansion of rural and urban models of H_2 refueling stations.

Is the same adjustability available to BEV charging infrastructure? If 16 vehicles are plugged into charging stalls and if the grid operator reduces power to the station, the charging action to some vehicles are stopped. To resolve this problem, battery storage would be required which would incur losses to efficiency (See Figure 1).

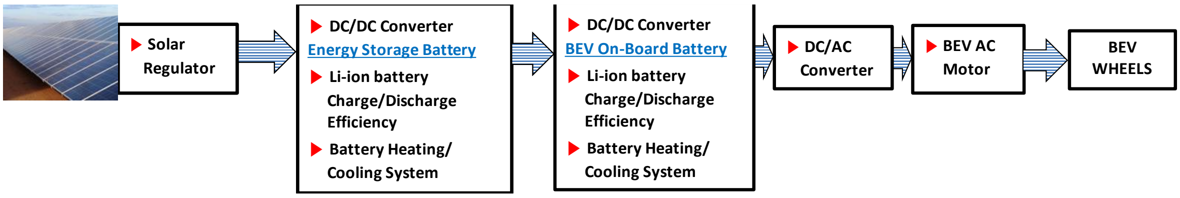
According to the 2015 Summer Loads and Resources Assessment of California Independent System Operator (CAISO), there was a 2,648 MW difference between the Forecast Peak and the Actual Peak. If this power is applied to the Urban model presented here to generate hydrogen gas, the resulting hydrogen gas could supply 4350 full forecourt sized refueling stations to serve 2,170,000 FCVs **driving 33 miles daily consuming 0.55 kg of hydrogen**. This number is equivalent to around 15% of registered vehicles in California at the time of 2015.

Regarding Claims of Limited Target Market of H_2 Fuel Cell

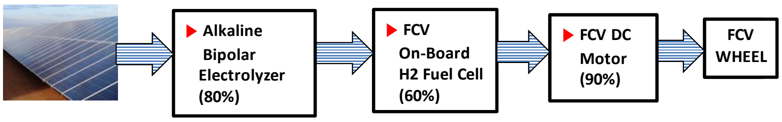
Some anti-hydrogen economists claim that hydrogen fuel cells could only serve a limited targeted market. According to a recent report, the round-trip efficiency of solar PV direct hydrogen storage and fuel cell power generation system was found to be 38% with **electrolyzer** efficiency of 80% and stationary fuel cell efficiency of 47%. Without a quantum leap in the energy efficiency of stationary fuel cell and electrolysis, hydrogen as a means of solar/wind direct energy storage may be inferior to Li-ion battery storage. However, with improvement in efficiency of stationary fuel cell and the increased demand for long-term energy storage, hydrogen may be used for energy storage.

One of the biggest complaints regarding FCV is the inability to refuel overnight at a domestic residence. Of course, grid-tied home EV charging acts as a CO_2 amplifier which is why it has been removed from consideration in this article. If rooftop solar PV energy is used to charge an EV battery in the evening, the WTW efficiency would be $0.9^9 = 0.387$, or 38.7% (see Figure 1). It is noted that energy efficiency of a PEM fuel cell is different from stationary application to transportation application: 47% vs. 60%. If rooftop solar PV energy is directly applied to an electrolyzer to supply H_2 to FCVs, the WTW efficiency of FCVs would be 43% (see Figure 2). For large building complexes with rooftop solar PV panels and miniaturization of electrolyzers in mind, a domestic H_2 refueling system is far from impossible.

[Figure 1] Power electronic devices affecting WTW efficiency of solar direct EV charging.



[Figure 2] Components affecting WTW efficiency of solar direct hydrogen refueling station



Conclusion

Solar/wind direct FCV refueling stations and EV charging stations are suggested as prominent paths toward ZEV. With the higher WTW energy efficiency of FCVs than EVs, coupled with over 30% to 34% lower overnight capital cost of FCV refueling stations, FCVs could be the ultimate means to promote decarbonization in transportation sector.

With rural model of H_2 refueling stations combined with longer driving ranges of FCVs, relatively smaller number of H_2 refueling stations could effectively promote the general acceptance of FCVs in the car market. Urban models of refueling stations will create a utility of excess renewables and a spinning reserve with dissipative nature. With improvements in energy efficiency of stationary PEM fuel cell, hydrogen could be a competitive means of energy storage for battery storage.