A Pilot Project:
Hydrogen Fuel Cell Assembly
For Emergency Power

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Introduction

In 2021, the hydrogen fuel cell (HFC) assembly pilot project was developed to determine the effectiveness of hydrogen fuel as a source of emergency power during public safety power shutoff (PSPS) in rural locations where annual high winds and low humidity trigger a utility power shutoff.

This paper illustrates HFC assembly as an alternative to carbon-based power generation.

Design Criteria

Power generation and energy storage must be carbon free to meet Senate Bill 100 mandate and to meet the Governor's accelerated de-carbonization of California by 2035 with either equal or less maintenance support compared to current technologies. The equipment's hazardous material must be insignificant.

Considerations

Design:

Electrical superintendent concurs with the location. Electrical technicians were fearful of a potential explosion for the hydrogen storage units (K cylinders) in case of an out-of-control vehicle.

Minimum maintenance support: The fuel cell stack's inlet filter needs washing every summer prior to the months where PSPS events occur. Refueling is done by a hydrogen refueling company.

The HFC assembly must provide 7 days of continuous power to vital ITS elements. To determine the volume of hydrogen for 7-days of continuous emergency power, calculate the electrical load. Usually, the hydrogen storage unit is in the form of K cylinders.

The lifecycle must be of sufficient length to be cost effective. The assembly must have a 20-year lifecycle. The hydrogen storage must have a minimum of 10-year lifecycle.

At the test site, the vital ITS elements are Traffic Signal System (TSS), Surveillance Camera System (SCS) and Communication System (CS).

The HFC assembly's controller and DC power output were connected to the BBS. The HFC assembly senses the utility power outage via BBS. HFC assembly delivers DC power to the BBS' inverter. HFC assembly supply both DC charging to the battery bank and AC power output through the BBS' inverter.

Missing Design option: The service equipment enclosure must be modified to feed an automatic transfer switch (ATS) to switch between normal power source (utility) and emergency power source (HFC assembly). The load side of the switch feeds a distribution cabinet with branch circuits for vital ITS elements. An inverter to convert the DC output of the HFC assembly to AC is installed between the HFC assembly and the emergency power source of the ATS. If all the ITS elements are of the same DC voltage, the inverter is moved between the service equipment enclosure and the normal source of the ATS.

When the momentary loss of power to the vital ITS elements are trivial, a battery is not necessary to bridge an approximate 30 second loss of power during HFC assembly's startup. This is true to most ITS elements except for the TSS. When a TSS is part of the electrical load of the HFC assembly, the battery backup system (BBS) may reduce the number of batteries to one.

Construction:

Siting the hydrogen storage unit (usually in K cylinders) ensures a safe operation of the HFC assembly. Either protect the hydrogen storage unit using a barrier, install below grade in a precast crypt or install on an elevation not reachable by vehicle traffic. The hydrogen storage unit must be located where refueling is reachable by a refueling truck. The refueling truck used in the pilot project had a hose reel. The location of the K cylinder must be accessible for replacement. When the K cylinder is below grade, the precast crypt must have a metal insect screened vent above the grade.

Lesson Learned

Fire Marshall approval of the site is essential to ensure proper permit is obtained before the design phase.
The permit may be obtained during K phase and be inactive until construction phase. The fire Marshall determines the labels to be placed at the cabinet and advises where to install the hydrogen storage unit.

Determine the vital and non-vital ITS elements.

Calculate the electrical load to determine the number of K cylinder to meet the 7-day threshold.

Engage with maintenance in determining the site, maintenance support, and future replacement of various components. A minor B project would be the best option in replacing major components of the HFC assembly, i.e., K cylinders, fuel cell stack, and communication system.

Since the HFC assembly has a monitoring and communication module. The Designer must determine who will receive error messages from the HFC assembly and how to remedy the problem.

Conclusion

General:
This pilot project had a limited scope, a short installation period, curtailed design options and limited funds. There were design features that could improve the performance of the HFC assembly but were not included.

The HFC assembly is an option to replace aging technologies that do not meet current environmental policies. It is a means to future proof the Department's need for clean and reliable emergency power. The HFC assembly is scalable for both power needs and durations. The minimum power generation is 1 kW which is sufficient to support most ITS element combination in a vicinity. The minimum delivery period is 7 days which allows a refueling company to deliver hydrogen to multiple sites with sufficient reserves at every location. During wildfire events, 7 days is sufficient to operate vital ITS elements for the evacuation of a vicinity. Remote deenergizing of other vital ITS elements further extend the operation of critical ITS elements. The test site did not have a remote power management but will be configured with communication system in the future.

The only limiting factor for scalability is the right of way. When necessary, road geometry must adjust to allocate sufficient areas for installation.

The HFC assembly may augment the existing BBS for TSS and support other vital ITS elements in a vicinity.

The total cost of the material and labor was $50k. The construction period was 2 weeks. Testing, synchronizing with other ITS elements and commissioning was 1 week. The installation project took under 30 days to complete.

The Negatives:
The Fire Marshal was not involved in the beginning of the pilot project and was only notified after a few months of operation. The Fire Marshall informed me that there is no section in the NFPA (National Fire Protection Association) manual for HFC assembly installation for ITS elements near the roadway. The

Fire Marshall struggled in recommending proper labels, area clearances for fire hazard and barrier protection. It was also noted that every Fire Marshal might have a slightly different recommendation base on site condition.

The availability of hydrogen delivery at certain locations can be difficult. The designer must evaluate the availability, delivery options and the different refueling cost scenarios before installing an HFC assembly. The pilot project which lasted a year did not consume a significant amount of hydrogen. To charge the K cylinder took all but 30 minutes. The site only experienced a 6-hour power lost for the entire year. The PSPS events were few and of short duration. There was a power outage due to a failure in the utility's power distribution yard. The HFC assembly operated on all events as expected. Until hydrogen is widely used, the availability of hydrogen delivery is a factor to be considered when installing at a particular site.

During the one-year test period, there were 3 events during a 90-day periodic maintenance testing of the BBS. The HFC assembly failed to operate automatically. The manufacturer's tech and a Caltrans maintenance person did a joint investigation and discovered there was a problem with the BBS software. The existing BBS operating system was cleared and reloaded. A utility power-lost test was conducted and the HFC assembly operated properly. However, just prior to the end of the 1-year pilot project, a power transfer failure occurred again during another 90-day periodic maintenance testing of the BBS. The power transfer failure of the HFC assembly could not be ascertain if the problem is on the BBS, on the HFC assembly or the interface of both. Further investigation is necessary.

Future Installation Recommendation:
The cost of the HFC assembly does not warrant the installation of the HFC assembly for each vital ITS element. It is prudent to install the HFC assembly between the service equipment enclosure and multiple vital ITS elements to achieve cost effectiveness.

It is under very extreme circumstance to install an HFC assembly to provide emergency power to a single ITS element.

The relocation of the service equipment within the Department's right of way will aid in installing necessary power transfer components.

A robust communication system with remote power management features would aid in remote monitoring the ITS elements' health, remote troubleshooting and de-energizing unnecessary vital ITS elements to extend the operation of critical ITS elements.