VII.11 Performance Evaluation of Delivered Hydrogen Fueling Stations

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Contract Number: DE-EE0005886

Subcontractor
Linde Gas LLC, Heyward, CA

Project Start Date: March 1, 2013
Project End Date: March 31, 2017

Overall Objectives

- Integrate non-intrusive data collection systems at five 100-kg/day delivered liquid hydrogen fueling stations located in California for 24-month performance period.
- Submit complete sets of the National Renewable Energy Laboratory (NREL) Hydrogen Station Data Templates to the National Fuel Cell Technology Evaluation Center (NFCTEC).
- Provide useful data to accurately benchmark and characterize station capacity, utilization, maintenance, and safety.

Fiscal Year (FY) 2014 Objectives

- Complete station assessments to confirm station sites and subsequent designs are adequate to ensure project deliverables are achievable.
- Complete engineering design review and data collection system design (mechanical, electrical, and software development) for first two station locations.
- Procure materials. Assemble and test system prior to deployment.
- Install and retrieve data of the first two project sites before the end of the year.

Technical Barriers

- Unforeseen construction permitting issues experienced by station developer.
- General construction delays experienced by the station developer.
- Efficient communications performance between GTI data collection equipment and functioning station equipment inherent to the stations' operations.

This project addresses the following technical barriers from the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(A) Lack of Fuel Cell Electric Vehicle and Fuel Cell Bus Performance and Durability Data

(D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

This project will contribute to the achievement of the following milestones from the Technology Validation section of the Fuel Cell Technologies Program Multi-Year Research, Development, and Demonstration Plan:

- Milestone 3.2: Validate novel hydrogen compression technologies or systems capable of >200 kg/day that could lead to more cost-effective and scalable (up to 500 kg/day) fueling station solutions for motive applications (4Q, 2014). The stations currently being constructed will incorporate Linde's patented ionic fluid compressor. This technology utilizes a liquid piston to compress gas rather than a diaphragm or metal piston used in conventional compressor technologies. Linde is optimistic that this technology can be cost-effectively scaled to larger capacity stations in the future.
- Milestone 3.4: Validate station compression technology provided by the delivery team (4Q, 2018). (See Milestone 3.2)
- Milestone 3.8: Validate reduction of cost of transporting hydrogen from central production to refueling sites to <$0.90/gallon gasoline equivalent (4Q, 2019). This project will yield data directly aiding to develop baseline benchmarking and measure improved cost of delivery of liquid hydrogen to fueling stations in California.
- Milestone 4.4: Complete evaluation of 700-bar fast-fill fueling stations and compare to SAE International (SAE) J2601 specifications and DOE fueling targets (3Q, 2016). This project will supply data to the NFCTEC that aid the program in the characterization of the stations' storage and delivery capacities, compression performance, fueling transactional data, operational cost, maintenance,

and safety. Data supplied will provide points of direct comparison to SAE fueling standards and DOE fueling targets.

FY 2014 Accomplishments

- Initiated and completed a no-cost time extension in order to reflect delays in construction experienced by the California Energy Commission (CEC) project funding.
- Station assessments were completed for the first two fueling station locations. The assessments produced confirmation to the project team that a data collection plan with multiple options to achieve project objectives was feasible.
- Engineering design review and data collection system design (mechanical, electrical, and software development) was completed.
- Materials were procured. Data collection system assembly and system testing was completed prior to deployment.
- The additional three stations within project scope have been awarded to Linde by the CEC. Final approval of funding allocation is expected in the third quarter of 2014.

INTRODUCTION

The objective of this project is to collect, organize, and report on operational, transactional, safety, and reliability data for five hydrogen fueling stations located in California. Goals of the project are as follows. 1) The data collected will be statistically meaningful and the stations will have sufficient throughput and vehicle fueling frequency to minimize data aberrations. 2) The data collected will be accurate. 3) The data collected will be comprehensive and timely.

This project will directly assist the DOE in assessing the readiness level of current infrastructure and state-of-the-art technologies utilized to support planned fuel cell vehicle deployment within the next five years. The data and observations collected during the performance period of this project will provide NREL with information detailing the operational costs, efficiencies, and reliability of the delivered hydrogen fueling station design. Furthermore, the Linde design utilizes the patented IC90 ionic fluid compressor package; through this project GTI will provide the performance data which will enable the DOE and original equipment manufacturer to evaluate re-world efficiencies further gauging the technology's adequacy in this application. This system is a first of its kind utilized for hydrogen fueling applications in the United States.

APPROACH

Hydrogen station data will be submitted quarterly to the NFCTEC at NREL using the appropriate hydrogen station data templates. GTI's project partner, The Linde Group, is currently developing delivered hydrogen fueling stations under programs sponsored by the CEC. The sites will be accessible to the public for fueling consumer fuel cell vehicles, commercial vehicles, or government-owned vehicles. All five of the sites will be developed at existing or at new sites along with conventional gasoline stations operated by major, branded fuel providers. This provides the project with vehicle fueling data from a broad, cross-section of "real-world" vehicle applications. The station sites were selected to provide convenient, consumer-friendly vehicle fueling for drivers of fuel cell vehicles. Development of each of these stations has the support of vehicle original equipment manufacturers and each site has passed stringent location selection requirements of the CEC to ensure the stations will be utilized by a high volume of fuel cell vehicle operators.

The data collection system will utilize a variety of methods in order to provide the entire data requirements set forth by NREL. This system will utilize the existing control architecture of the compressor and dispenser equipment as well as monitor and record signals from a set of installed instrumentation that will supplement information required that is not already captured inherently by the stations' operating system. There are multiple descriptive (opposed to measured data) deliverables that will be taken "manually" and submitted to GTI for processing and formatting prior to delivery to NREL. Manually collected data templates include:

- NREL Site Log: recording safety drills, training, or public meetings
- Storage & Delivery: compiling liquid hydrogen supplies delivery quantities and cost
- Fuel Log: transferring transactional data from monthly reports emanating from fuel management system
- Maintenance: station maintenance and operations reporting
- Hydrogen Cost: Collection of utility bills
- Safety: station environmental, health, and safety reporting
- Hydrogen Quality: SAE quality analysis completed annually and submitted

GTI will collaborate with Linde and create a reporting/submittal process to collect this type of data required to populate the NREL templates.

RESULTS

The project team's efforts in 2014 yielded an encouraging path forward that will enable the team to make

meaningful contributions to program objectives. The group has reviewed and verified the feasibility of extracting all the data required to complete technology validation of delivered hydrogen stations. Table 1 shows the accumulation of data signals identified as a result of engineering drawing reviews and discussion with project partners.

TABLE 1. Electrical Signal Input List for Delivered Hydrogen Fueling Station

Instrument Tag	Location	Signal Type	Range	Channel	Triggering	Instrument Description	Installation
LT-85-1-B	Liquid Hydrogen Level	Analog	4-20 mA	ILIM-7_0A	10 min	Endress Hauser, PMD55, differential pressure transmitter, 0 - 40" water column range.	This is an existing piece of instrumentation, the signal can be shared by Linde and GTI through a signal isolation board.The isolation board would be installed inside the Tel-Tank Enclosure located in the communications panel on site.
FT-1	Flow Meter Located on Inlet Piping	Analog	4-20 mA	ILIM-7_0B	1 sec (During operation) else 5 min	Sierra Meters, Quadra Therm 780 i, inline thermal mass flow meter, max flow: 40 kg/hr.	Device to be installed at inlet, meter would be purchased by GTI and installed inside the IC90 compressor enclosure by located in DWG #: 12406-T-D-102-01 by GTI in the field.
FT-1	Flow Meter Located on Inlet Piping	Pulse	VDC	DI-A	1 sec (During operation) else 5 min	Sierra Meters, Quadra Therm 780 i, inline thermal mass flow meter, max flow: 40 kg/hr.	See above
FT-301	Flow Meter Located on 350 -700 Bar Dispenser Line	Quantum PLC	SCADA		1 sec (During fueling) else...	By Quantum	This is an existing piece of instrumentation, the signal can be shared by Linde through the web based SCADA system installed by the dispenser manufacturer.
CT-1	Current Transmitter-IC90 Compressor	Analog	4-20 mA	ILIM-7_0E	1 sec (During operation) else 5 min	Powertek, RCTrms, rogowski coil current transducer,0- 250 Amp range.	The current transducer would be purchased by GTI and installed by GTI on-site inside a pressurized enclosure. GTI has shown this transducer in the IC90 enclosure in DWG#: 12406-T-D-102-01.
CT-2	Current Transmitter-Dispenser	Analog	4-20 mA	ILIM-7_0F	1 sec (During oepration) else 5 min	CR Magnetics, Split Core current transducer, 0-20 Amp range.	The current transducer would be purchased by GTI and installed by GTI on-site into a pressurized enclosure. GTI has shown this transducer in the Dispenser enclosure in DWG#: 12406-T-D-104-01.
CT-3	Current Transmitter-Refrigeration Loop	Analog	4-20 mA	ILIM-7_0G	1 sec (During operation) else 5 min	Powertek, RCTrms, rogowski coil current transducer,0- 50 Amp range.	The current transducer would be purchased by GTI and installed by GTI on-site inside a pressuized enclosure. GTI has shown this transducer in the IC90 enclosure in DWG#: 12406-T-D-102-01.
CT-4	Current Transmitter-Refrigeration Loop	Analog	4-20 mA	ILIM-7_0H	1 sec (During operation) else 5 min	Powertek, RCTrms, rogowski coil current transducer,0- 10 Amp range.	The current transducer would be purchased by GTI and installed by GTI on-site inside a pressuized enclosure. GTI has shown this transducer in the IC90 enclosure in DWG#: 12406-T-D-102-01.
TE-1	Ambient Temperature	Thermocouple	Type T	AI-A	10 min	Smart Sensor, type T thermocouple, -328 to 662 deg F range.	The thermocouple would be purchased by GTI and installed by GTI in GTI panel. GTI has shown this temp element in the GTI enclosure in DWG#: 12406-T-D-104-01.
TS-302	Pre-Cool Hydrogen Temperature (HE0XX-Outlet)	Quantum PLC	SCADA		1 sec (During fueling) else...	By Linde	This is an existing piece of instrumentation, the signal can be shared through web based SCADA link.
TS-312	Pre-Cool Hydrogen Temperature (350 Bar-Outlet)	Quantum PLC	SCADA		1 sec (During fueling) else...	By Linde	This is an existing piece of instrumentation, the signal can be shared through web lbased SCADA ink.
TT-3	Pre-Cool Hydrogen Temperature (HE092-Outlet)	Thermocouple	Type T	ILIM-7_0C	1 sec (During fueling) else 5 min	Honeywell, STT173, temperature transmittter, -328 to 662 deg F programmed range.	The thermocouple would be purchased by GTI and installed by GTI on-site. GTI request that Linde contractors provide taps to install instrumentation. GTI has shown this temp element in the field tubing in DWG#: 12406-T-D-104-01.
TT-4	Hydrogen Temperature (HE092-Inlet)	Analog	4-20mA	ILIM-7_0D	1 sec (during fueling) else 5 min	Honeywell, STT173, temperature transmittter, -328 to 662 deg F programmed range.	The thermocouple would be purchased by GTI and installed by GTI on-site. GTI request that Linde contractors provide taps to install instrumentation. GTI has shown this temp element in the IC90 Compressor Enclosure in DWG#: 12406-T-D-103-02. The first two units will be surface mounted and covered by pipe insulation/wrap.
PT-50A20PT026	Pressure Storage Vessel 1	Quantum PLC	SCADA		1 sec (During fueling) else...	By Linde	This is an existing piece of instrumentation, the signal can be shared by Linde through the web based SCADA system installed by the dispenser manufacturer.
PT-50B20PT026	Pressure Storage Vessel 2	Quantum PLC	SCADA		1 sec (During fueling) else...	By Linde	This is an existing piece of instrumentation, the signal can be shared by Linde through the web based SCADA system installed by the dispenser manufacturer.
PT-50C20PT026	Pressure Storage Vessel 3	Quantum PLC	SCADA		1 sec (During fueling) else...	By Linde	This is an existing piece of instrumentation, the signal can be shared by Linde through the web based SCADA system installed by the dispenser manufacturer.
PT-311	Pressure Transmitter-350 Bar Side	Quantum PLC	SCADA		1 sec (During fueling) else...	By Linde	This is an existing piece of instrumentation, the signal can be shared by Linde through the web based SCADA system installed by the dispenser manufacturer.
PT-302	Pressure Transmiter - 700 Bar Side	Quantum PLC	SCADA		1 sec (During fueling) else...	By Linde	This is an existing piece of instrumentation, the signal can be shared by Linde through the web based SCADA system installed by the dispenser manufacturer.

The data collection plan, system design, and software developed during FY 2014 will be used as a template for all subsequent station installations for the remainder of the project. The team's front-end development efforts will ensure a standardized system can be utilized through the duration of the project performance period. Figure 1 depicts the software programming that is utilized in order to program the data loggers to collect and automatically store data in remote servers for further analysis. Standardization of the design should decrease time and resources spent fabricating and deploying the systems while allowing the team to focus on the quality and completeness of data submitted to the NFCTEC. Figure 2 shows the standardization of project team design by making a side by side comparison of conceptual to actual data collection modules.

Furthermore, the project team has secured funding for the remaining sites listed in the project's scope of work. This ensures that the amount of data flowing into the data center is an adequate and appropriate representation of the delivered hydrogen station design methodology. Geographic diversity and multiple locations should provide an aggregate representation of the stations' performance and operational characteristics. The additional funding allocated to Budget Period 2 will enable the team to obtain and supply the database with accurate representation and characterization of the readiness of delivered hydrogen methodology as a vehicular fuel supply.

CONCLUSIONS AND FUTURE DIRECTIONS

- Installation and commissioning of the first station system will occur in the third quarter of 2014 at West Sacramento, CA site location.
- Installation and commissioning of the second system will occur in the fourth quarter of 2014 at San Juan Capistrano, CA site location.
- Produce the complete sets of data for the first two project sites at the end of each quarter after startup and commissioning is completed.
- Obtain approval to continue project efforts into Budget Period 2.

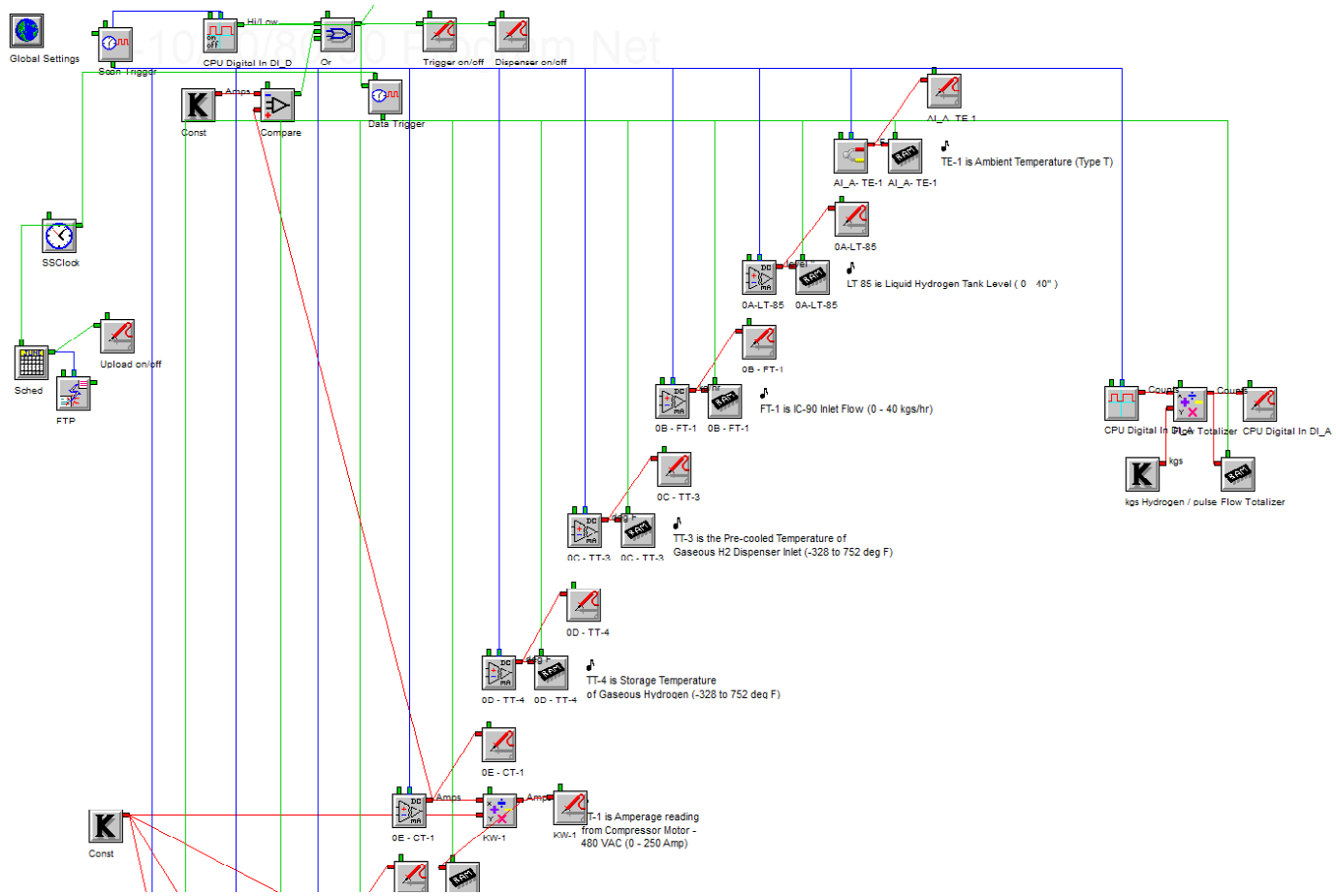

FIGURE 1. Logic Beach Hyperware Software Programming

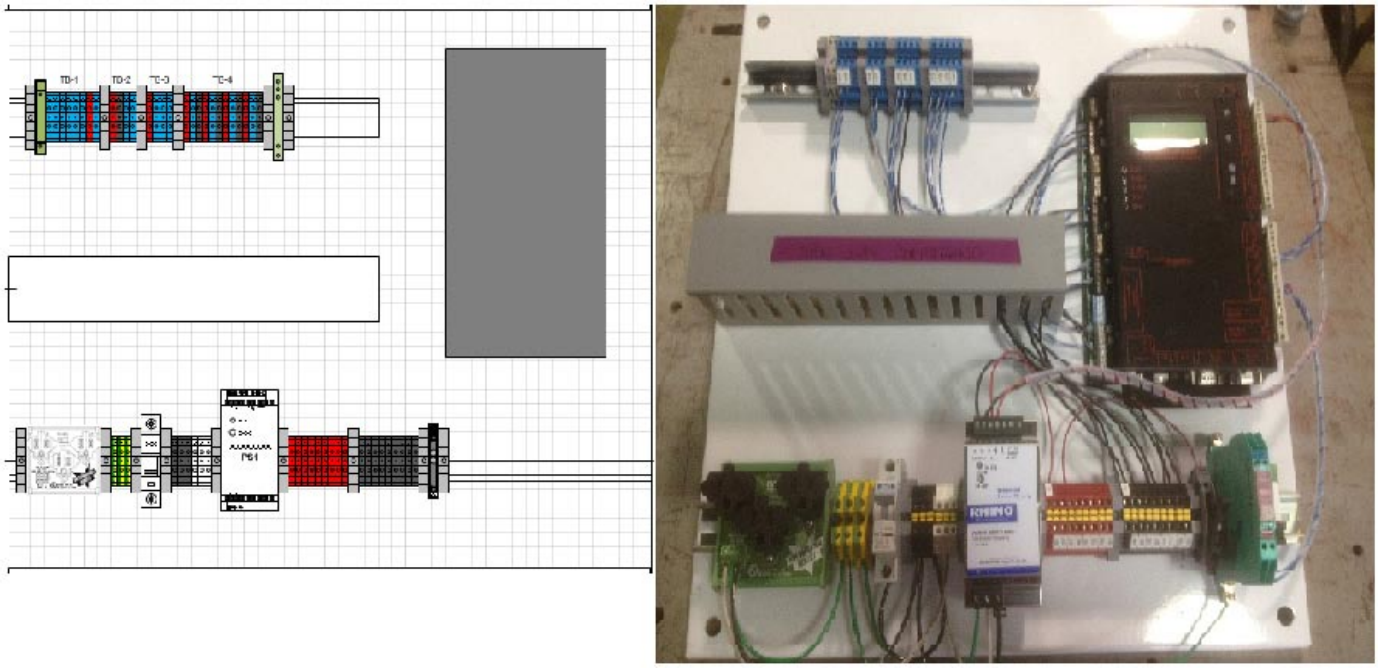

FIGURE 2. Conceptual (Left) and Actual (Right) Hardware

FY 2014 PUBLICATIONS/PRESENTATIONS

1. tv025_tieu_2014_o.pptx – Oral Presentation 2014 AMR.