TIP 302: Demand Response Potential of Heat Pump Water Heaters

Context

CO_2 heat pump water heaters (CO_2HPWH) are an emerging technology. The Pacific Northwest has invested heavily inadapting a Japanese product to the US market and researching the energy efficiency performance in lab and field studies. However, the demand response (DR) potential of CO2 HPWH systems has not been studied. DR potential stems from the fact that they are designed to heat water to high temperatures that are lowered through mixing valves for use, thus increasing capacity. But questions remained about the use of the equipment for implementing DR strategies including:

a. What is the dispatchability of the system using standard utility protocol?
b. What is the energy storage capacity in long-term field use subject to typical hot water system end use and dispatch driven by actual events?
c. What is the impact on system efficiency of oversupply, load shifting and load balancing operation over a long-term?
e. How does the DR performance of the HPWH compare to a similar, baseline electric resistance water heater?

Description

The project described the DR potential of HPWHs with CO_2 refrigerant in both unitary configuration with a small storage tank, and a split system design with a large tank. In pursuit of this test protocols were developed that can be used for testing the DR potential of many types of water heaters.

Washington State University Energy Program (WSU), in partnership with the Northwest Energy Efficiency Alliance (NEEA), Pacific Northwest National Laboratory (PNNL), Sanden International U.S.A Inc. (Sanden), and Snohomish Public Utility District (Snohomish), participated in the researchand committed substantial matching funds. The assessment included lab and field test protocol development, lab and controlled field tests, data analysis, and detailed reporting. The equipment tested manufactured by Sanden.

The lab tests were performed by Ecotope and Cascade Engineering Services, and the field tests by PNNL at its Lab Homes Test Center in Richland, Washington.

The lab experiments assessed the detailed response to DR conditions and actions, while the controlled field experiments evaluated long-term performance in simulation of actual field conditions.

The specific tasks involved in this project were:

a. Develop protocol for controlled field test.
b. Conduct controlled field test to DR protocol, analyze and report.
c. Develop protocol for the lab DR experiments.
d. Conduct lab tests to the DR protocol, analyze and report using field test results for guidance.

Accomplishments

The research developed detailed protocols for DR testing of water heaters including HPWHs in both lab and controlled field situations. The tests conducted were:

- Baseline measurement;
- Balancing INC, which tests the response of hourly or sub-hourly changes in demand and the available dispatchable power/energy shift associated with it; and
- Oversupply mitigation, which identifies the total dispatchable power, and resulting energy shift, that a noncritical load like water heating can provide during a 3- to 12-hour window.

The Lab Homes tests reveal that both the unitary system and the split system HPWHs could provide water at the required temperature and could perform balancing INC consisting of three 1-hour periods without a loss of delivery performance. Both HPWHs could also deliver setpoint hot water after being shut down for six hours for oversupply mitigation. Ecotope developed the lab test protocols within the context of the controlled field study test protocol. The protocols are not customized for these specific water heaters; they can be used to test any HPWH or ER water heater for DR purposes.

Benefits

This project combined energy efficiency with demand response. Previous work demonstrated that CO_2- driven HPWHs have the potential to provide 300 to 400% energy savings over conventional electric resistance units. In addition to energy efficiency, these units were shown to have the potential to contribute significant benefits to BPA and regional utilities via the DR capabilities.

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Project Start Date: October 1, 2013

Project End Date: September 30, 2015

Project Cost

Total Project Cost: $638,960

Deliverables Received

Final Report: *Assessment of Demand Response Potential of Heat Pump Water Heaters*, Ken Eklund, Washington State University Energy Program

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Conclusions

This project successfully demonstrates a robust DR potential for all of the products tested. Because of this project, the region is in a better position to both influence the production of the U.S. models to include DR features, and assist in bringing them to the U.S and the Pacific Northwest markets.

Related Projects

TIP 292-Advanced Heat Pump Water Heater Research

Participating Organizations

Washington State University

WSU Energy Program in Olympia, WA

The Northwest Energy Efficiency Alliance

Pacific Northwest National Laboratory

Sanden International U.S.A. Inc.

Snohomish Public Utility District