SCE DRET Findings
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DR17.06: Smart Water Heater Retrofit Controller Lab Study

WATER HEATERS IN DEMAND RESPONSE EVENTS

Southern California Edison has created an integrated blueprint to help the State of California achieve its greenhouse gas (GHG) emission reduction goals. This blueprint is referred to as "The Clean Power and Electrification Pathway." Part of what is explored in this pathway, is establishing a goal of up to 30% efficient electrification of commercial and residential space and water heating.

Water heating is generally regarded as the second largest contributor to energy costs for homes, at approximately 14-18% of utility bills. Water heaters present substantial opportunities for reducing GHG emissions and assisting with grid management. Retrofit controls are available for water heaters, to manage demand/energy consumption and enable Demand Response (DR) control. A retrofit controls product's demand response capabilities are investigated with laboratory testing at SCE's Technology Test Centers.

The three main DR control schemes that are of interest to this study are:

- **Load Curtailment Controls:** The water heater responds to temporary DR event signals, to reduce electrical demand by cycling off for the duration of the DR event.

- **Time-of-Use (TOU)-driven controls:** The water heater adjusts its operation (setpoint and operating times) based on the real-time TOU pricing of electricity. Operating times will be shifted to occur during periods of cheaper electricity prices. The water heater controls may take advantage of elevated setpoint temperatures to ensure sufficient thermal capacity for water heating needs.

- **Thermal storage/Grid-Interactive Water Heater (GIWH) controls:** The water heater responds as part of a fleet of aggregated water heaters to shift water heater operating times to influence the electrical end-use load shape (flatten the "duck curve").

INTRODUCTION

What is this technology?

RETROFIT CONTROLS

Retrofit controls are available for water heaters, to reduce demand/energy consumption and enable Demand Response (DR) control. The product investigated in this project enables three main DR control schemes: load curtailment controls, TOU-driven controls, and thermal storage/grid-interactive water heater controls.

Details and specifications of the retrofit controller (RC) include:

- Compatibility with gas and electric (excluding heat-pump) storage water heaters
- Connects to WiFi, cloud-based web portal and smart device app interface and the following features are available:
  - Hot water availability, manual scheduling, auto-efficiency settings, usage/energy monitoring, alert settings, tank top temperature
  - TOU-driven controls can be enabled
  - Connectivity with HVAC Nest Learning Thermostat
- Fitting for tank sensor connects to pressure relief valve
- Internet-browser-based "fleet" dashboard for device provisioning and management, with Measurement and Verification available through AWS S3 data "pipeline"
- Autonomously cuts power to the water heater and issues an alert if the tank temperature crosses a high threshold that potentially indicates a dangerous thermostat failure
- Electrical Input:
  - Electric Water Heater: 208/240 VAC, 50/60 Hz
  - Gas Water Heater: 120 VAC, 50/60 Hz
- Power Consumption: 5W

What was done?

SMART WATER HEATER RETROFIT CONTROLLER TESTING FOR DEMAND RESPONSE

The Calorimeter Controlled Environment Laboratory (CCEL), a general purpose test chamber located in SCE's Technology Test Centers (TTC) in Irwindale, CA, was used to test the water heater retrofit controller. Two tanks, conditioned by two separate chillers, were used to simulate a typical electric tank water heater with dual heating zones.

A realistic annual water draw profile was created using the U.S. Department of Energy's Building America Program's spreadsheets. Two dates were chosen for the testing, Sunday 1/14 and Monday 1/15, to represent typical weekend and weekday winter draw profile.

The figure below shows the test scenarios, descriptions, and draw profiles that were chosen for laboratory investigation.

Baseline testing, load curtailment controls testing, TOU-DA-driven controls testing, and grid-interactive water heater (GIWH) controls testing were all performed. The following outputs were provided: temperature setpoint, top tank temperature, cold water supply temperature, and energy transfer due to heating, heat loss, and hot water usage.

TEST SCENARIOS

TEST #		DESCRIPTION	DRAW PROFILE
1	a	Base-weekday	Monday
	b	Base-weekday-repeat	
	c	Base-weekday-repeat	
2	a	Base-weekend	Sunday
	b	Base-weekend-repeat	
	c	Base-weekend-repeat	
3	3	Base-weekday-retrofit controller active	Monday
4	a	Load Curtailment-weekday	
	b	Load Curtailment-weekday	
5	a	TOU-DA-weekday	
	b	TOU-DA-weekday-repeat	
6	a	TOU-DA-weekend	Sunday
	b	TOU-DA-weekend-repeat	
7	a	GIWH-weekend	
	b	GIWH-weekend-repeat	

ABILITY MAINTAINED TO MEET WATER HEATING NEEDS The retrofit controls appear to be capable of delivering hot water temperatures per hot water draw event, similar to those of baseline operation, for load curtailment, time-of-use controls, and grid interactive water heating controls. While there were mild deviations of water heat outlet temperatures per hot water draw event, they were within typical deviations observed during the baseline repeat testing.

LOAD CURTAILMENT Load was successfully curtailed by the retrofit controller as expected. Load curtailment may be scheduled through the internet-based fleet dashboard as single load curtailment events or recurring load shift events. Single load curtailment events can force the water heater to shut off heating or modify the temperature setpoint of the retrofit controller. Recurring load shift events did not offer the selection between setpoint and heating shut-off.

TIME-OF-USE CONTROLS Water heating element runtimes and energy consumption were successfully decreased from the On-Peak period to Off-Peak periods using TOU controls under the selected weekday usage profile. At the time of this project, all SCE TOU rates could be configured into the TOU controls of the retrofit controls product, but only through the user portal. There did not appear to be any other telemetry/monitoring to confirm the TOU schedule that was selected.

GRID INTERACTIVE WATER HEATER CONTROLS The approximated GIWH controls reduced energy consumption during non-overgeneration periods and showed baseline operation during the generation period. This is not a selectable mode in either the user portal or the fleet dashboard and was approximated with load curtailment from the fleet dashboard, in conjunction with temperature boost scheduling configured in the user portal. It is unclear what utility grid condition telemetry would best feed into the product in order to inform real-time GIWH operation and how those signals will be communicated.

Figure 1: User Portal Screenshots

CONCLUSIONS

What We Concluded?

FUTURE STUDIES NEEDED

Demand response controls for water heaters present great opportunities for GHG reduction and grid management. However, it involves complex interactions that should be well-understood in order to successfully operate demand response programs for water heaters. This laboratory study offers detailed insight into the complex interactions that can take place in a water heater. A continuous balance must be maintained between meeting hot water needs, mitigating safety concerns for scalding and pathogen development, and managing energy use. This investigation confirmed that this technology shows promise to enable utility programs to implement the three main DR strategies identified, with some given nuances that can be addressed.

Further market studies are needed to establish more understanding of characterizing broader market offerings for retrofit controls and onboard controls. Classifications of product families should be established and pursued for DR program development. DR program requirements/specifications related to communications and DR scheme capabilities should be established.

These Findings are based on the report "Smart Water Heater Retrofit Controller Lab Study," which is available from the ETCC program website, https://www.etcc-ca.com/reports.

Recommendations

Before implementation of demand response controls for water heaters can be widely distributed to the available market, there are some next steps which need to be taken.

ADVOCATE FOR INDUSTRY BEST PRACTICES

Any demand response programs associated with water heaters should advocate industry-accepted best practices for ensuring safe operation, emphasizing mitigation of risks associated with scalding and pathogen growth. Best practices for maintenance should be emphasized. Opportunities for temperature-boost controls, leveraged as pathogen growth mitigation strategies should be explored.

STANDARDIZE ENERGY-CONSCIOUS BEST PRACTICES

The industry-accepted best practices/design for water heaters do not appear to be as detailed and well-established as those in the HVAC industry (e.g., ACCA manuals, ASHRAE Handbooks, etc.). DR water heater programs should promote research and advocacy for standardizing energy-conscious best practices for water heater design and adopt those procedures as part of water heater DR program implementation.

WORK WITH UTILITIES

At the time of the project, this technology had a few deficiencies which can be addressed via collaboration with the utilities. They are:

- This technology was not enabled to communicate through openADR. Additional work is required to facilitate communication between this product and utility demand response automation servers.

- Utilities should work with controls manufacturers to ensure an appropriate communication pathway is established for setting and verification of appropriate TOU controls.

- Utilities should work with controls manufacturers to ensure an appropriate communication pathway is established to inform real time GIWH operation and controls schemes are informed with the appropriate telemetry.