SCE DRET Findings
December 2018

DR16.05: Laboratory Assessment of Demand Response RTU Controller

DEMAND RESPONSE ASSESSMENT

Roof top units, RTU, are used in about 58% of all cooled commercial buildings, serving about 69% of the cooled commercial building floor space (EIA 2003). The growing need for electrical power demand can have an adverse impact on grid reliability, especially when there is not enough electric generation, and can result in power outages. To prevent such instances, utilities offer their customers economic incentives to reduce power demand and usage at certain times of day under Demand Response (DR) programs. However, to fully take advantage of these programs, facility owners and operators need equipment that is capable of responding quickly and reliably to electric grid conditions. Utilities and grid operators need to have direct access to reliable load shedding resources that can automatically react to the standard communication protocols. This study looks at retrofitting an RTU with the automated demand response controls technology so it can respond directly to utility signals and adjust its operation to reduce its power usage.

INTRODUCTION

What Is This Technology?

AFTER-MARKET, DR-CAPABLE VFD CONTROLLER

This laboratory project evaluated the DR capabilities of an add-on retrofit controller for a five-ton rooftop unit (RTU). The controller is a Variable Frequency Drive (VFD) unit, which modulates the speed of the A/C compressor and indoor fan simultaneously, according to cooling load requirements. The unit also had embedded DR capabilities with preset strategies outlined below. Finally the controller was able to communicate through a protocol gateway using the utility's accepted demand response communication protocol, OpenADR 2.0. This protocol allows the utility to send messages directly to equipment and the equipment can respond automatically to the utility's DR requests. This project was conducted at SCE's Technology Test Center (TTC) controlled environment test chambers, and the controller had been tested previously at the TTC.

Figure 1: 5-TON RTU fitted with: VFD Controller

Under normal operations, the controller modulates the speed of the A/C compressor and indoor fan simultaneously, according to the cooling load or thermostat setting. As part of the DR strategy, however, the controller modulates the speed of the compressor and indoor fan according to the DR signal. The controller's DR strategies for moderate and high event signals are:

- **Moderate Event (or low-load event):** limit the speed of the A/C compressor and indoor fan to no higher than 42 Hertz (Hz).
- **High Event (or high-load event):** run the A/C compressor and indoor fan at 40Hz for about nine minutes, then shut off the compressor for about six minutes. When the compressor is off, the indoor fan runs at 20Hz

Along with the demand response capable VFD controller and gateway, the RTU was equipped with the following typical control devices that might be included to for standard operations; tested project programmable thermostat, supply and outside air temperature probe, and a return air carbon dioxide (CO_2) sensor. While the technology offers various control capabilities, this study focused mainly on the cooling mode. Its cooling control logic can turn on and simultaneously vary the frequency, and therefore speed, of both the compressor and indoor fan, to maintain the target thermostatic set point.

Figure 2: 5-TON RTU fitted with ADR Controller

What We Did?

VARIED SPEED OF 5-TON CAPACITY RTU

The test unit was a standard-efficiency heat pump (13 SEER), five-ton nominal. It used R-410A refrigerant and a TXV. A VFD was used to modulate the compressor and the supply fan. The controller was pre-programmed with the "moderate" and "high" event strategies. Testing was done to quantify the power and energy reductions for each strategy under two indoor and two outdoor climatic conditions. The indoor conditions were DBT of 80 degrees Fahrenheit (°F) and WBT of 67°F, as well as DBT of 75°F and WBT of 63°F. The outdoor DBTs were 95°F and 105°F. A total of eight tests were run shown in Table 1.

TABLE 1. TEST PROTOCOL (GENERAL PARAMATERS)

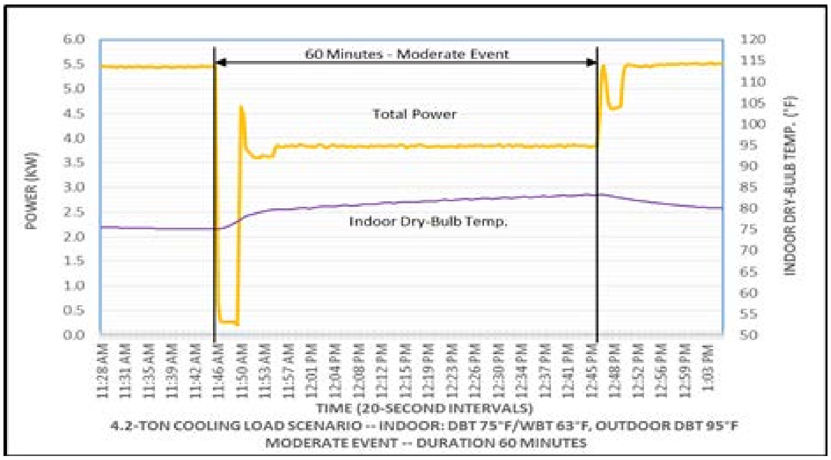
SCENARIOS	OUTDOOR DBT	DR SIGNAL TYPE	DR DURATION	COOLING LOAD
Indoor DBT of 75°F and WBT of 63°F	95°F	Moderate	60 minutes	4.2-ton
	95°F	High	60 minutes	4.2-ton
	105°F	Moderate	60 minutes	4.2-ton
	105°F	High	60 minutes	4.2-ton
Indoor DBT of 80°F and WBT of 67°F	95°F	Moderate	60 minutes	4.5-ton
	95°F	High	60 minutes	4.5-ton
	105°F	Moderate	60 minutes	4.5-ton
		High	60 minutes	4.5-ton

MODERATE DR EVENT

During normal operation (prior to a DR event), the system was running at full speed, or 60Hz with a total power around 5.4 kilowatts (kW). When the event was initiated, however, the controller unexpectedly shut the unit off for about three minutes, then ramped up the speed (or frequency) to 40Hz, and stayed there until the end of the event.

During the event, the total power was dropped from 5.4 kW to 3.6 kW, which was a 33% reduction in power consumption for the RTU. Once the event ended, the unit operated normally. This event also started with an indoor Dry Bulb Temperature, DBT of 75°F and Wet Bulb Temperature, WBT, of 63°F, and an outdoor DBT of 95°F. Once the event started, however, the indoor DBT started to rise, and by the end of the event, it was about 82°F. This 7°F increase in DBT was due to running the unit at low speed, causing a reduction in the unit's cooling capacity.

Figure 1: Moderate DR Event, indoor DBT of 75°F and WBT of 63°F, at an outdoor DBT of 95°F. The power profiles are for indoor fan, outdoor fan (condenser fan), compressor, and total unit.

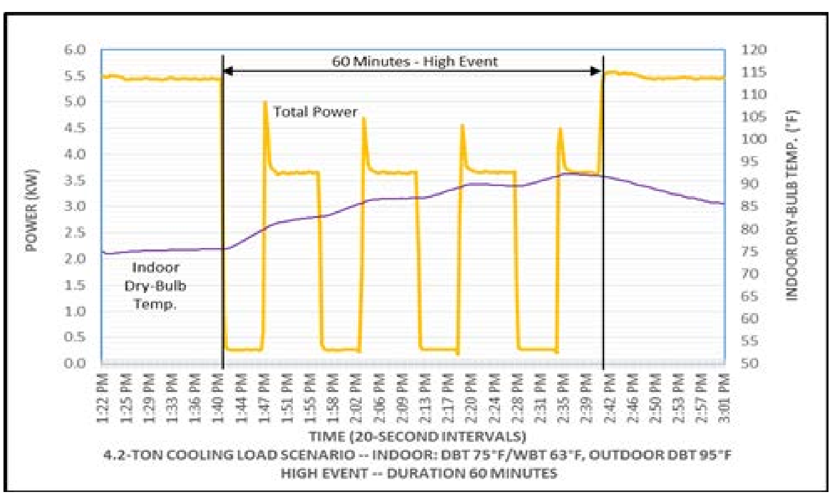


Moderate Event resulted in a **33% reduction** in power and a **7°F increase** in space DBT.

HIGH DR EVENT

Prior to the event (normal operation), the unit ran at full speed (60Hz) with an average total power of 5.5 kW. Once the event was initiated, the controller shut the compressor off for six minutes, then ran it for nine minutes at 40Hz before shutting it off again, as intended (the controller cycled the compressor on and off during a 15-minute interval). This cycle continued until the end of the event. The average total power dropped from 5.5 kW to 2.2 kW, which is a 60% reduction in power. Once the event ended, the unit operated normally. Prior to the event, the indoor DBT was at 75°F. However, the indoor DBT reached approximately 92°F by the end of the event.

Figure 2: High DR Event, indoor DBT of 75°F and WBT of 63°F, at an outdoor DBT of 95°F.



High Event resulted in a **60% average** reduction in power and a **17°F increase** in space DBT.

CONCLUSIONS

What We Concluded?

CONTROLLER RESPONSIVE TO MODERATE AND HIGH DR SIGNALS

This assessment involved conducting a set of eight test runs, to quantify the power demand reductions for high and moderate DR events under two indoor and two outdoor climatic conditions, using a five-ton RTU. The indoor conditions were DBT of 75°F and WBT of 63°F, as well as DBT of 80°F and WBT of 67°F. The outdoor DBTs were 95°F and 105°F.

Results indicated the controller was capable of responding to both moderate and high DR signals through a central gateway. It also verified the pre-programmed strategy of the controller for each DR event.

Results also indicated that there is a potential for moderate DR events to reduce average total power demand by 20%, and up to 33%, depending on the operating conditions. For high DR events, the average total power can potentially be reduced by 60%. In addition, these DR events resulted in a rise in indoor DBT. For moderate DR events, the rise in indoor DBT was 6°F to 9°F. The rise in indoor DBT was more noticeable for high DR events, with temperatures ranging between 14°F and 17°F.

These Findings are based on the report "Laboratory Assessment of Demand Response Rooftop Unit (RTU) Controller," which is available from the ETCC program website, https://www.etcc-ca.com/reports.

Lessons Learned

MORE RESEARCH NEEDED

Follow-up for this study might be a simple financial analysis. This would include; cost estimates for installing the DR controllers and programming of the DR strategies, estimates of potential DR payments, and a simple payback analysis. This would be a first step in identifying potential utility program incentives.

UTILITY SUPPORT

The study shows that there is a potential for securing reliable DR load from the RTU user market. Perhaps a pilot program could be developed the shows the real world capability of this approach.