SCE DRET Findings
August 2018

DR15.20: Characterizing the Transient and Aggregate Response of Dispatchable Condenser Air Pre-Coolers

EVAPORATIVE PRE-COOLERS USED FOR DEMAND RESPONSE

Evaporative condenser air pre-coolers, or "pre-coolers," use evaporative cooling methods to pre-cool the inlet air to the condenser of an air conditioning system. This results in a lower temperature for air conditioner heat rejection, reducing power demand and increasing air conditioning process efficiency. While significant work has been done to demonstrate pre-coolers as an energy efficiency measure, this project studied the technology as a dispatchable demand response resource, controlled by the utility for grid management.

This study describes a laboratory and field evaluation of a pre-cooler to improve the efficiency of packaged air-conditioning and heating RTUs. In laboratory testing, a four-ton RTU was retrofitted with a condenser air evaporative pre-cooler, and the transient response was characterized along with the load reduction achieved by turning the pre-cooler on and off. In field testing, 11 RTUs were retrofitted with condenser-air evaporative pre-coolers. This technology is being considered as a method of saving energy associated with air conditioning at part load conditions, reducing peak electricity demand, and permanently reducing electric load.

The laboratory results illustrate that at steady-state operation, the technology can reduce demand quickly, and by up to 25%. This trend was not as clear in field testing, because the RTUs could change cooling modes during events, potentially delaying cooling until shortly after event start. The field results did not demonstrate the full potential of dispatchable evaporative pre-cooling, because the controls did not reliably dispatch the pre-coolers for every available RTU. Based on these results, it is recommended the technology be considered for further study to identify the control changes that would be required to ensure all available units successfully dispatch.

INTRODUCTION

What is this technology?

EVAPORATIVE AIR PRE-COOLERS

Evaporative condenser air pre-coolers function by evaporating water to pre-cool inlet air to air conditioning system condensers. This lowers the temperature of air conditioner heat rejection, reduces the amount of power needed, and improves the efficiency of the air conditioning process. Condenser air pre-coolers are most effective in dry climates, and can reduce the condenser air dry-bulb temperature by as much as 20°F. For both phases of the project, a pre-cooler with 8" deep corrugated cellulose media was used to evaporate water with a demonstrated evaporative effectiveness of >70%.

Operating pre-coolers as a dispatchable demand response resource should be explored for the following reasons:

1. Utility peak summer demand is closely tied to air conditioning loads.

2. The demand reduction and efficiency gains for pre-coolers are largest at high outdoor ambient temperatures.

3. The water used for pre-coolers in relationship to the energy saved (known as the water-use efficiency index) is smallest at high outdoor ambient temperatures.

4. The value of the pre-cooler to the utility is higher when it can be operated as a verifiable dispatchable resource, as opposed to an energy efficiency measure.

What We Did?

RTU LABORATORY AND FIELD TESTING

The objective of this project was to conduct laboratory and field testing to evaluate the performance of an evaporative condenser air pre-cooler retrofit package, used by a utility as a dispatchable grid management demand response resource.

For laboratory testing, the combined package was installed on a four-ton commercial York RTU. The transient response was evaluated along with the load reduction that occurred when the pre-cooler was turned on and off during three different California outdoor air climate conditions.

For field testing, the condenser air pre-cooler package was installed on 11 rooftop units (RTUs) that served a big box retail store in Corona, California. The data collection period ran from July 1, 2017 through October 31, 2017, and consisted of 26 remotely-triggered demand response events when the outside air temperature was above 95°F.

FIELD TEST EQUIPMENT SUMMARY

Unit #	Brand	Model	Number of Stages	Cooling Capacity	Surface Area Ratio[1]	Pre-Cooling Retrofit
R1	Lennox	Strategos	2	10 ton	0.65[2]	Condenser Air
R8	Lennox	L-Series	4	20 ton	1.05	Condenser Air + Ventilation Air
R9	Lennox	L-Series	2	10 ton	1.07	Condenser Air
R10	Lennox	L-Series	4	20 ton	1.05	Condenser Air + Ventilation Air
R11	Lennox	L-Series	4	20 ton	1.05	Condenser Air + Ventilation Air
R12	Lennox	L-Series	2	10 ton	1.07	Condenser Air
R13	Lennox	L-Series	4	20 ton	1.05	Condenser Air
R14	Lennox	L-Series	4	20 ton	1.05	Condenser Air + Ventilation Air
R15	Lennox	L-Series	4	20 ton	1.05	Condenser Air + Ventilation Air
R16	Lennox	L-Series	4	20 ton	1.05	Condenser Air + Ventilation Air
R23	Lennox	L-Series	2	10 ton	1.07	Condenser Air

FINDINGS

LABORATORY TESTING – 4-TON COMMERCIAL RTU: Installing the pre-cooler reduced the condenser airflow by less than 2%. The decrease in the coefficient of performance was found to be negligible when the dry pre-cooler was added, meaning installing the pre-cooler would not appreciably affect the performance of the air conditioner when the pre-cooler was off.

A decrease in total power between 16%-25%, and an increase in capacity and coefficient of performance between 11%-21% and 32%-62%, respectively, was observed. Lastly, the transient times necessary for the reduction in power was determined, which demonstrate 75% of the maximum power reduction for all test conditions occurred in less than two minutes.

The time necessary for the total power, total capacity, and coefficient of performance to return to the dry pre-cooler state ranged between 37 and 43 minutes

FIELD TESTING – 11 RETAIL RTUS: In six of 10 dispatch events, more than 70% of the available RTUs successfully dispatched, and the aggregate power reduction was between 2.87 kW and 17.05 kW. For these six events, water usage varied from 11.07 Gal/kWh to 51.90 Gal/kWh, with a median of 11.33 Gal/kWh.

In four of 10 dispatch events, 10%-63% of the available RTUs successfully dispatched, and the aggregate power reduction was between 0.07 kW to 7.65 kW. For these four events, water usage varied from 4.78 Gal/kWh to 249.05 Gal/kWh, with a median of 14.51 Gal/kWh.

Figure 1: Lab Results for Transient Response Time for "Pre-Cooler On"

Test Outdoor Air (Dry-Bulb/Wet-Bulb) °F	Time to achieve 50% of maximum power reduction (min)	Time to achieve 75% of maximum power reduction (min)	Time to achieve 100% of maximum power reduction (min)
95/70	0.6	1.6	13.4
105/73	0.6	0.9	12.5
115/76	0.6	1.1	13.3

Figure 2: Summary of Field Testing Events with Largest and Smallest Power Reduction

Event Statistic	07-08 11:00	07-22 16:00	08-27 15:00	08-30 12:00
Duration (minutes)	60	120	60	120
Average Outdoor Air Temperature (°F)	96.5	88.2	97.1	103.1
Number of RTUs in Cooling Mode	9	11	10	8
Number of RTUs that Dispatched	8	9	1	7
Percent of RTUs Dispatched (%)	89	82	10	88
Water Use (gal)	196.7	297.6	17.6	391.0
Power Difference between Event and Baseline (kW)	17.56	2.87	0.07	17.05
Percent Difference from Baseline to Event (%)	12.7	2.5	0.4	14.9
Water Use / Energy Saved (gal/kWh)	11.2	51.90	249.05	11.47

CONCLUSIONS

What We Concluded?

LAB & FIELD TESTING OF CONTROL CHANGES

The laboratory test results show most evaporative pre-cooler power reduction benefits are achieved quickly, within less than two minutes of turning on the pre-cooler (Figure 1 from the previous page). This demonstrates that power reductions from pre-coolers could be useful to utilities as a demand response and grid management tool. Capacity increases take longer to achieve and stabilize after approximately 15 minutes. Equipment operating at increased capacity will reduce equipment run times, although equipment cycling behavior is less predictable than the quick drop in RTU power consumption that occurs when a pre-cooler is turned on.

Field testing illustrated that dispatched pre-coolers can reduce RTU power usage; however, the aggregate response differs based on the number of dispatched RTUs. Across the 10 analyzed events, the number of RTUs that dispatched varied from 10% to 89%, and the aggregate power reduction was between 0.07kW and 17.56 kW (Figure 2 from the previous page). These results illustrate that improvements are needed to increase the reliability of dispatch controls, which will ensure RTUs successfully dispatch during each event and improve overall results.

Lessons Learned

There are gaps for managing demand response using pre-coolers at present that should be addressed before implementing evaporative condenser air pre-coolers for DR on a large scale.

VARIABILITY IN FIELD EQUIPMENT TESTING

The research team called 26 dispatch events between July 1 and October 31, 2017. Out of the 26 events, 16 were excluded from the final analysis, because they either overlapped with actual SCE demand-shedding events, or the dispatch signals failed and no RTUs responded. The 10 analyzed events showed results differ based on the number of dispatched RTUs.

The number of RTUs in cooling mode during field testing did not trend with the outside air temperature. The number of RTUs that successfully dispatched was highly variable, ranging from 10% to 89%. The reason available RTUs did not successfully dispatch is unknown; however, this represents one area in which the technology could be improved.

RECOMMENDATIONS

Laboratory results illustrate that at steady-state operation, the technology can reduce demand quickly, by up to 25%. In field testing, this trend was not as clear, because the RTUs could change cooling modes during events, and potentially did not start cooling until shortly after event start. The field results did not demonstrate the full potential of evaporative pre-cooling, because controls did not reliably dispatch pre-coolers for every available RTU. Based on these results, it is recommended the technology be considered for further study to determine the control changes required to ensure all available units will dispatch.

These Findings are based on the report "Characterizing the Transient and Aggregate Response of Dispatchable Condenser Air Pre-Coolers" which is available from the ETCC program website, https://www.etcc-ca.com/reports.