DR17.18 – Demand Response with Variable-Capacity Light Commercial HVAC Systems

OPPORTUNITY

WHAT IS THE PURPOSE OF THIS PROJECT?

Variable-capacity (VC) Heating, Ventilation, and Air-Conditioning (HVAC) equipment provides enhanced Energy Efficiency (EE) and customer comfort benefits over conventional, single-speed or two-speed equipment. For commercial applications, Variable Refrigerant Flow (VRF) systems as well as packaged Rooftop Units (RTUs) all leverage variable-speed compressors, electronic expansion valves, and a variety of refrigerant management controls to match HVAC system output to the building's cooling and heating requirements. These systems have extensive on-board instrumentation and processing power, which optimizes system operation and enables the comfort and efficiency advantages for which this equipment is known. In recent years, industry has gained a thorough understanding and insight to these systems through laboratory and field evaluations. Results from these studies found efficiency gains of between 20% and 40% from using VRF systems over baseline equipment.

While the efficiency and comfort benefits of VC HVAC have been well documented, their Demand Response (DR) capabilities have not been fully demonstrated. With their on-board instrumentation and communications capabilities, VC systems are prime candidates for implementing both EE and DR functionality, potentially offering dual program participation. Moreover, with their superior efficiency at part-load operation, VC equipment has the potential to provide improved DR over baseline equipment, in terms of response time, occupant comfort, and operating efficiency.

The main objective of this study was to evaluate the DR potential of VC HVAC equipment in light commercial building applications through demonstrations at two field sites in Southern California.

TECHNOLOGY

WHAT IS THE TECHNOLOGY?

After outreach to several companies to partner in this project, a producer of variable speed RTUs (Manufacturer A) and a major manufacturer of VRF systems (Manufacturer B) agreed to participate. Manufacturer B, the VRF system manufacturer, implemented a conventional DR strategy and supported OpenADR 2.0b, as well as three advanced DR strategies:

- Change in thermostat setpoint temperature (conventional strategy).
- Limit equipment thermal capacity (and therefore electric power) subject to a maximum allowable deviation in indoor temperature.
- Change in temperature setpoint to increase capacity delivery ("load up" to enable pre-cooling).
- Targeted capacity reduction, where cooling or heating is turned off for specific zones to meet the target reduction based on zone priority.

Image: RTU Unit

Note, the systems considered for this study came from product lines that ranged from five to 30 tons of cooling (17.6 to 105.5 kW thermal)

APPROACH

WHAT WAS THE EVALUATION APPROACH?

Objective: The study objectives were to show the capabilities of VC HVAC to provide DR by demonstrating emerging controls approaches at Southern California field sites, and to evaluate their response in terms of demand reduction, impact to occupant comfort, and potential to manage recovery.

Instrumentation plan: To verify system response and performance, the project team installed monitoring equipment to independently confirm the systems' electrical, thermal, and environmental conditions.

Field Site Characteristics: Selected field sites represented typical building types and climate zones in SCE's territory. Since VC equipment is not widely adopted, two sites known to have this equipment installed were considered for inclusion. The two sites were good representatives of where variable-speed equipment was installed to serve a portion of each building.

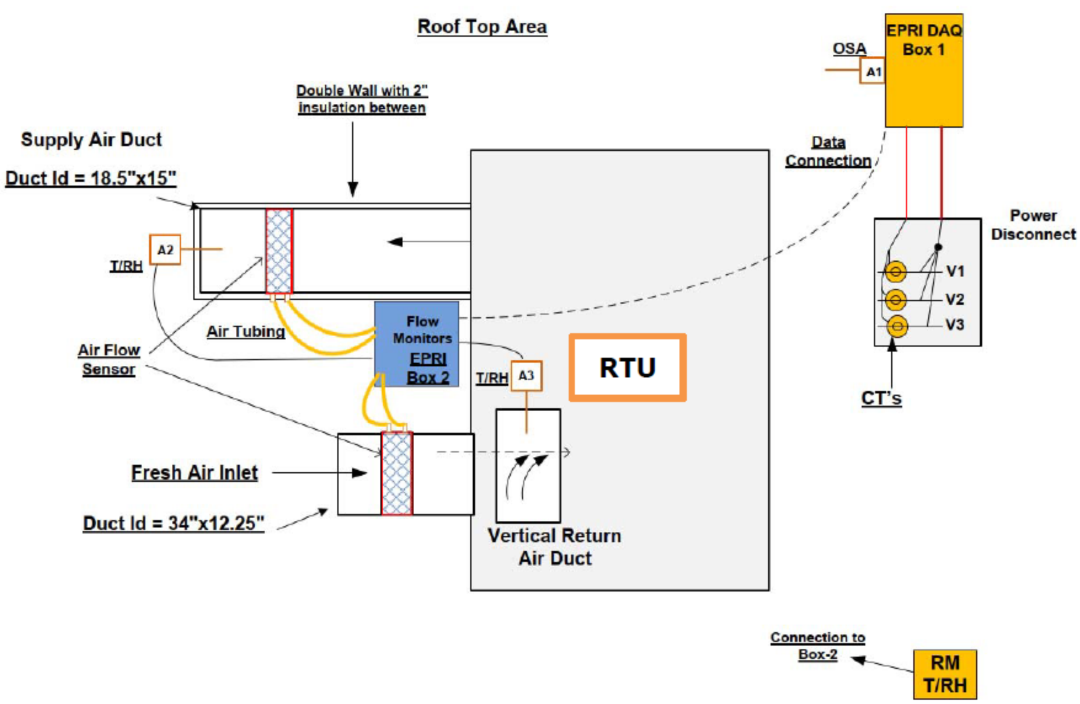

Figure 1: Site 2 monitoring equipment layout

Test Matrix: A test matrix was developed for each field site to evaluate the available DR functions with a range of control parameters. The test included DR event types, event lengths, offset temperatures, and recovery period configurations to evaluate equipment response under different parameters. The four functions included Capacity Limit, Temperature Setback, Precooling followed by Capacity Limit, and Targeted Capacity Reduction. Test events were timed to coincide with peak cooling load on the systems, keeping each space's occupancy patterns in mind. For example, Site 1 was consistently occupied from 8 a.m. to 4 p.m. (the VRF was scheduled to operate from 7 a.m. to 5 p.m.) so test events were selected for the event and recovery period to be concluded by 4 p.m.

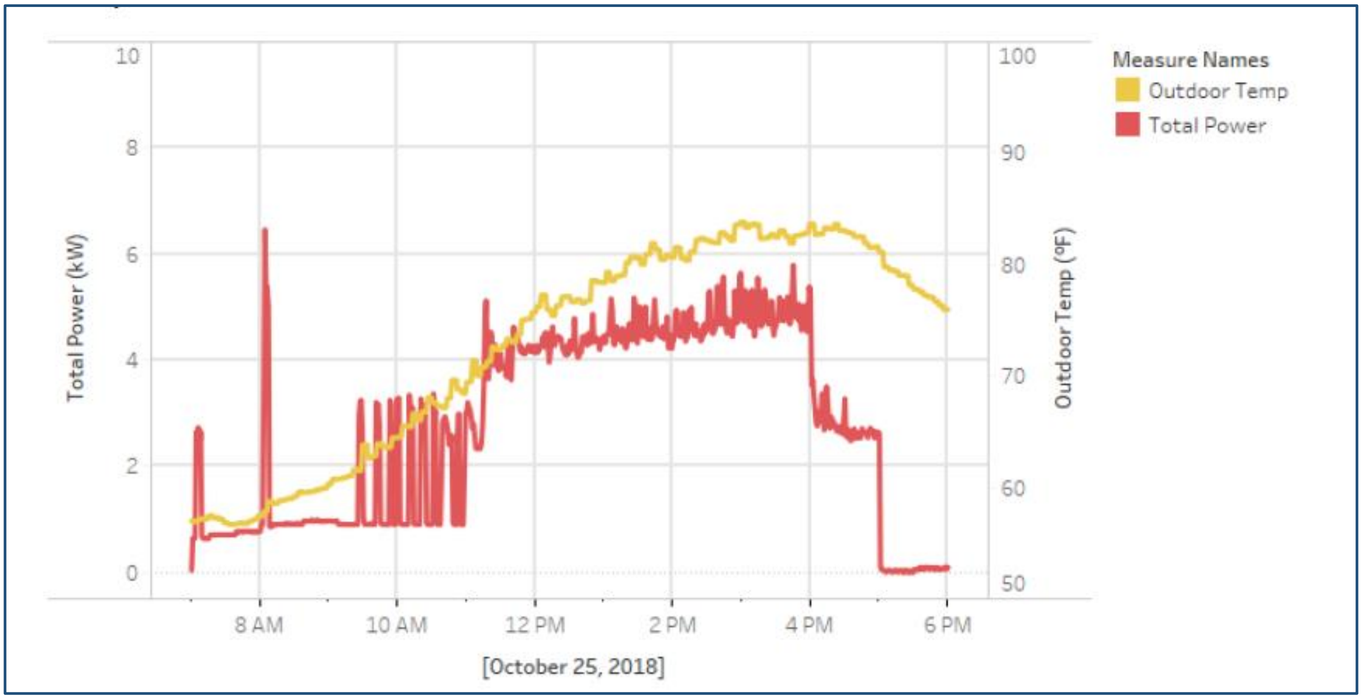

Figure 2: Site 1 VRF system's typical operating profile on a baseline day

FINDING

WHAT WERE THE MAJOR FINDINGS?

For the VRF system, the findings of this study indicate that **Capacity Limit control can reduce electrical demand with minimal impact on indoor temperatures**. During tests with outdoor temperatures around 95°F, Capacity Limit control consistently provided 15-25% reduction in average power during 1- or 2-hour DR events compared to baseline. **The strategy of Pre-cooling followed by Capacity Limit control also provided a 15% reduction**. However, the other two major control strategies testing—Setpoint Offset and Targeted Capacity Reduction, where VRF indoor conditioned zones were disabled in a specific order—did not consistently reduce demand on peak days. Test results indicated that Setpoint Offset—the strategy most similar to conventional HVAC DR control using thermostats—could also significantly reduce VRF demand at mild outdoor temperatures.

The VRF system was found to respond as expected to commands sent via OpenADR 2.0b, and an OpenADR Virtual Top Node (VTN) was used to schedule and initiate test events. As a result of participation in this study, Manufacturer B has integrated this advanced DR control strategy into a controller designed for commercial buildings.

For the variable-speed packaged RTU, **Manufacturer A, while understanding the benefits of DR, was unable to implement advanced DR controls or OpenADR support during this project**. For this RTU, remote control of conventional setpoint offset events could only be initiated manually via a web portal. Several tests were completed using the web portal method, with mixed results. A significant time delay (15 to 60 minutes) was experienced between when the DR signal was sent, when the unit reacted, and when acknowledgement was received. On-site power and **temperature measurements indicated the RTU did not take full advantage of its variable-speed capabilities for DR** and instead shut off in response to setpoint offset commands in several test events, much like a conventional single-speed system.

Project findings suggest several follow-on activities of interest. **An industry standard should be developed to harmonize DR responses from variable-speed HVAC systems in this class**. Unless a standard is available, manufacturers will continue to ask for a unified list of specific responses they can implement without creating custom solutions for each program.

Additional field testing of larger Manufacturer B VRF systems would be beneficial for several reasons. First, Manufacturer B recently integrated the DR controls tested in this study into a lower-cost controller, which has not been independently verified. Second, testing with a VRF system larger than approximately 14 tons would allow a greater level of demand reduction control, due to the additional capacity stages available. Furthermore, this project tested the equipment serving zones that had very low occupancy. **Additional larger-scale field testing will provide a better understanding of how these controls perform under various loading conditions and building types**, allowing a more detailed evaluation of the DR potential and possible impact on occupant comfort at scale, before full program rollout.

Lastly, it would be advantageous to work with additional equipment manufacturers to expand the EE DR opportunity for this class of equipment. **Several manufacturers are beginning to assess and implement these types of controls in their light commercial variable-speed products.** These manufacturers are eager to provide value to electric utilities with enhanced DR capabilities but need assistance in implementing and testing the new controls.

The full findings are based on the report "DR17.18 – Demand Response with Variable-Capacity Light Commercial HVAC Systems" which is available at **www.dret-ca.com**.