Evaluating DemandQ:
A Coordinated Air Conditioning Controller for Reducing Energy Consumption and Peak Demand

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Study Excerpts

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EXECUTIVE SUMMARY

Packaged rooftop air conditioners (RTUs), a major component of retail facility peak electric demand, typically run independently to satisfy their respective target zone temperature setpoints. When unmanaged, multiple RTUs may run concurrently by chance, leading to increased monthly facility peaks and higher demand charges.

Intelligent software-based controls, responding to real-time feedback on facility power draw and zone temperature, could coordinate RTU runtimes to save energy and reduce peak facility loads.

Using time-series facility and RTU electricity data, zone temperatures, and local weather, Fraunhofer modeled the energy savings and peak reductions associated with the DemandQ software. Linear regressions were derived for the total daily RTU energy consumption and peak facility load based on cooling degree days and DemandQ status. These models were then applied to typical cooling season weather data to estimate the expected annual savings. Demand reductions were modeled using a Monte Carlo approach to account for natural load variability.

Results

Reductions in electricity consumption and peak demand were observed at (*the respective target sites*.)

Energy savings of about 6 percent of total RTU electricity consumption (or 2 percent of facility consumption) were observed. This equals about 5.2 kWh per cooling degree day (CDD55, base 55 degrees F) or 60 kWh per day during the test. Applied to typical weather for the May to October cooling season, the linear regression models predicted RTU energy savings of about 10,400 kWh.

Peak load reduction estimates were about 18 kW (SD 5.7) and 15 kW (SD 5.4). This represents about 8 percent of total facility load or 10-15 percent of the highest observed RTU load. Applied to typical weather for the May to October cooling season, these models predict monthly facility load reduction potentials of 13-20 kW.

Baseline controls faults (*were*) encountered at both sites, (*causing*) some RTUs to run more than expected, increasing energy use and potentially peak load. At both sites, these faults were corrected while DemandQ was enabled. To the extent that other buildings have similar faults that would otherwise go unaddressed, DemandQ may provide additional energy savings benefits.

Conclusions

Results from this test indicate that the coordinated control of packaged rooftop units could plausibly and significantly reduce both energy consumption and peak demand without detrimentally affecting zone temperatures. Secondary energy savings came from controls fault correction. Issues related to overcooling and incorrect scheduling were seemingly corrected or overridden by the DemandQ software. In practice, actual savings and impacts depend on site-specific characteristics. Demand reductions are highly sensitive to outlier load spike events. Unpredictable spikes in demand could undo a significant portion of the potential demand savings.

INTRODUCTION

Packaged rooftop unit (RTU) air conditioners can strongly influence commercial facility energy use and peak electric demand. To reduce related costs, DemandQ has developed an automated service for coordinating the runtime of multiple RTUs to lower the total facility electricity consumption (kWh) and demand (kW). To evaluate these potential impacts, we analyzed performance data collected during (*a 2 month pilot.*)

Opportunity

The compressors on RTUs are normally configured to run automatically when their respective zones call for cooling. By chance, the compressors on many RTUs can occasionally run simultaneously, leading to higher facility demand charges. Intelligently managing RTUs, especially in response to real-time facility level power draw, to reduce concurrent compressor runtime could significantly reduce total facility demand.

The RTUs at a single facility may also operate with different efficiency characteristics. This could happen for many reasons, including differences in hardware, neglected maintenance, mechanical faults, or other issues. When multiple RTUs serve a common zone, preferentially running the more efficient units could theoretically reduce the total cooling energy consumption.

Technology Description

To address these opportunities, DemandQ has developed software service that automatically manages RTU compressors facility-wide (Figure 1). Using data from the Building Automation System (BAS), the platform models RTU performance and monitors facility loads to decide when to run the RTUs. Control algorithms are designed to maintain the existing zone setpoints while reducing both energy consumption and facility demand.

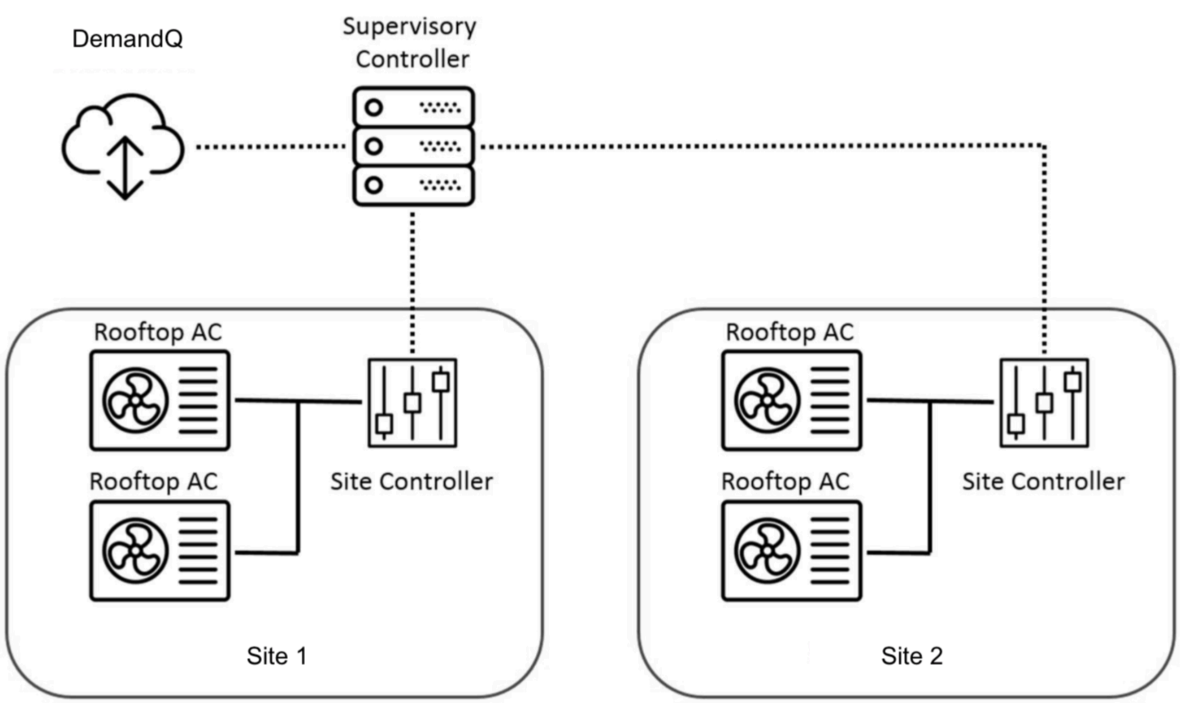

Figure 1. DemandQ system diagram.

TEST PLAN

Overview
An alternating on/off testing methodology was applied to measure DemandQ impacts on energy and peak loads. The DemandQ controls were alternately enabled and disabled on a weekly schedule. Switching took place late at night, normally on Sundays, while the building was unoccupied and cooling loads were lower. The on/off approach was chosen to reduce bias from changes in HVAC equipment performance or other site-specific changes.

Variables
Primary dependent variables include:

1. HVAC electricity consumption: kWh reduction
2. Whole-facility monthly peak demand: kW peak reduction

Secondary dependent variables that were supposed to remain unchanged include:

1. Zone temperature: maintain setpoint schedules
2. Ventilation: maintain ventilation levels

The independent variables include:

1. DemandQ status: on/off
2. Local weather: temperature, cooling degree days, relative humidity
3. Time of Day: peak/off-peak

Data Sources
Multiple data sources were used to evaluate system performance. Facility and RTU data (electricity, temperature, humidity, compressor status, and occupancy) came from the building management system (BMS). RTU electricity submetering was installed by a third-party contractor.

Monte Carlo Simulation of Peak Demand
Demand charges are assessed based on the highest peak incurred in a month during on-peak hours. Applying the daily peak power models derived earlier to actual or typical weather data gives the expected daily peaks for the baseline and DemandQ cases. Comparing the highest monthly peaks yields the expected difference in peak demand ascribed to DemandQ.

In reality, facility loads are stochastic, and random deviations from the linear models are expected. To account this natural variability, we form stochastic replicates by resampling the case-specific model residuals with replacement and add these back to the modeled results.

Taking the maximum monthly value of the modeled daily peak loads (one for each replication), yields a distribution of expected peak demand. The difference in expected values of the distributions for the DemandQ and baseline cases gives the expected peak demand reduction. The approach is outlined as follows:

1. Derive models for daily peak facility power as a function of CDD and DemandQ status
2. Compute model residuals
3. Calculate expected daily peak demand with and without DemandQ for 10,000 replicates:
   a. Add resampled case-specific residuals (e.g., DemandQ and baseline) to the modeled results
   b. Find the maximum daily peak demand with and without DemandQ
   c. Calculate the difference in monthly peak demand
4. Summarize the distribution of the difference in monthly peak demand

CONCLUSIONS

Software for managing RTU cooling loads was evaluated at two big-box retail stores in Massachusetts during a two month-period for its ability to reduce RTU electricity consumption and monthly facility peak electric demand. Overall, the coordinated control of packaged rooftop units could plausibly and significantly reduce both energy consumption and peak demand.

Due to confounding equipment controls factors and a limited test duration, the conclusions from this study are limited in scope to buildings with similar load profiles, cooling equipment, operational behavior, and weather conditions. Nevertheless, statistically significant energy and demand savings were observed, and the technology functioned as intended.

Through this demonstration, we observed and modeled the following:

1. Energy savings of about 60 kWh per day – 6% of total RTU energy consumption or 2.2% of total facility energy consumption.
2. Peak demand reductions of about 15-18 kW – 10-15% of the highest observed RTU load or 8% of total facility load.
3. Zone temperatures typically remained within 0.5 degrees F of the target setpoint.
4. Basic temperature control faults related to overcooling and incorrect scheduling were seemingly corrected or overridden by the DemandQ software.
5. Modeling the May-October cooling season with typical weather predicts potential seasonal energy savings of about 10,400 kWh and monthly demand reductions of 13-20 kW.

In practice, actual savings and impacts depend on site-specific characteristics. Control issues were encountered at both test sites that led to overcooling and increased baseline energy consumption. DemandQ was able to overcome these faults, and save energy, by overriding the faulty controls.

Demand reductions, in particular, were highly sensitive to outlier load spike events. Unpredictable spikes in demand could undo a significant portion of the potential demand savings. Longer-term study of historic data from a larger portion of sites would provide more reliable savings estimates and a better understanding of the frequency and impact of isolated load spikes.