EPRI | ELECTRIC POWER RESEARCH INSTITUTE

AI-BASED CONTROL FOR COMMERCIAL REFRIGERATION

Incubatenergy Labs 2020 Pilot Project Report

GRID FRUIT

Startup

Grid Fruit

SOUTHERN CALIFORNIA EDISON®

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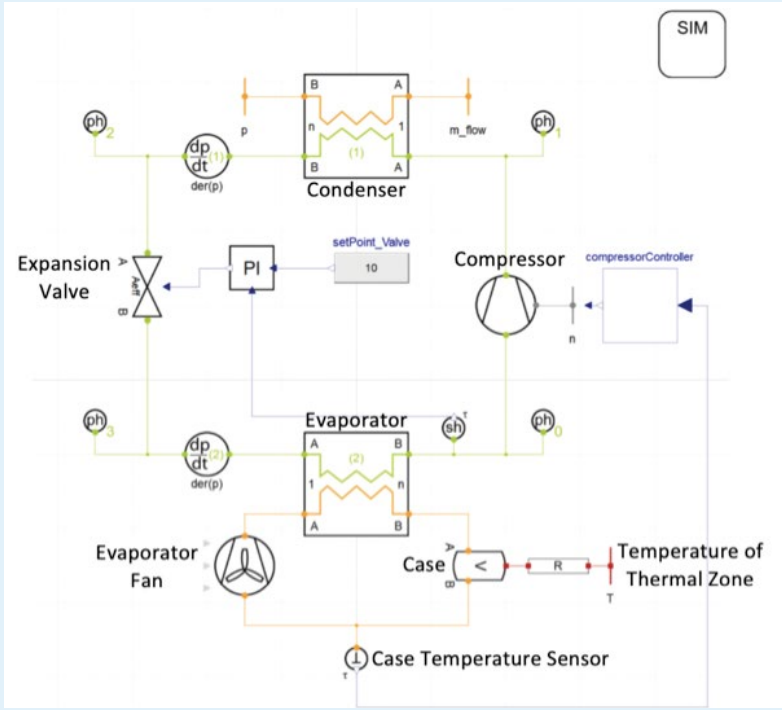
Host

Southern California Edison

Technology Solution

Refrigeration is a significant driver of overall electricity use and peak power demand for convenience stores, supermarkets, and other retail food outlets. Generally, these entities run on small profit margins and face additional challenges in operating and maintaining refrigeration systems and controls to optimize both for food quality and energy consumption. Thermal storage systems that form ice off peak then provide cooling during peak periods are an established solution for mitigating peak loads but require up-front investments in hardware.

This pilot project was launched to demonstrate Grid Fruit's data and software platform as a low-cost measure for optimizing refrigeration defrost control in convenience stores. Drawing on artificial intelligence (AI) methods, Grid Fruit builds digital twin models, which are physics-based and data-driven models of the building envelope and energy profile of individual stores, including the refrigeration (cooling and freezing), lighting, and heating, ventilation, and cooling (HVAC) systems that dominate consumption. The twins, when connected to real-world stores, guide implementation of control strategies for optimizing refrigeration operations to maintain food quality and achieve cost saving, peak demand reduction, greenhouse gas reduction, and other objectives on the basis of weather, utility rates, and additional variables.



Refrigeration Model Using Modelica

Project Overview

Working in collaboration, Grid Fruit, EPRI, and SCE defined a project scope for estimating the potential consumer cost, peak demand, and carbon emission savings available from AI-based optimization of refrigeration defrost controls in convenience stores across the utility's service territory. This simulation-based scope was revised from the original pilot project concept—involving both digital twin simulation and field

Challenge: Customer and Community Engagement

Potential Cost, Demand, and CO_2 Emission Reductions Based on Simulations

Annual:	TOU Charge	Demand Charge	Electricity Charges	CO_2 Emissions	Average Peak
Riverside County – Climate Zone 10 – 756 Stores					
Present Operations	$13.1M	$8.6M	$21.7M	35.8 kt CO_2	20.8 MW
Optimal Operations	$12.6M	$7.6M	$20.1M	34.1 kt CO_2	20.5 MW
Simulated Reduction	$0.5M	$1.0M	$2,061/Store	1.7 kt CO_2	0.3 MW
Percent Reduction	4.2%	11.8%	7.2%	4.7%	1.4%
San Bernardino County – Climate Zone 14 – 672 Stores					
Present Operations	$10.9M	$7.3M	$18.2M	29.9 kt CO_2	18.5 MW
Optimal Operations	$10.4M	$5.7M	$16.2M	28.5 kt CO_2	18.3 MW
Simulated Reduction	$0.5M	$1.6M	$3,054/Store	1.4 kt CO_2	0.2 MW
Percent Reduction	4.6%	21.3%	11.3%	4.9%	1.1%
SCE Territory – Nine Climate Zones – 5,345 Stores					
Present Operations	$92.7M	$55.2M	$147.9M	255.4 kt CO_2	145.5 MW
Optimal Operations	$88.7M	$45.6M	$134.3M	243.7 kt CO_2	139.0 MW
Simulated Reduction	$4.0M	$9.6M	$2,518/Store	11.7 kt CO_2	6.5 MW
Percent Reduction	4.3%	17.4%	9.1%	4.6%	4.5%

implementation—due to the COVID-19 pandemic and its associated restrictions.

Grid Fruit began by modeling a typical California 7-Eleven store using EnergyPlus and Modelica co-simulations to develop the digital twin models. Based on weather data and other inputs, EnergyPlus simulated buildings and fine-grained control and component conditions for all store refrigeration systems. Some refrigeration simulation capabilities included control of compressors, fan speed, and expansion valve position, as well as complete monitoring of case temperature. A total of six refrigeration units were included in the store models: 10-door reach-in case; 5-door reach-in case; 2-door reach-in freezer; 1-door reach-in ice storage case; standalone open-case wrap-around display refrigerator; and standalone freezer/ice cream chest. All refrigeration cases reject heat to the merchandise thermal zone. Condensers for the standalone cases reject heat to the merchandise zone or outdoors.

Using the digital convenience store twin models, the project team simulated current typical operations versus optimized refrigeration operations in all stores across the SCE service territory over a 1-year period. The optimized adjustments to refrigeration controls were limited to defrost scheduling parameters for individual units, an intervention that does not affect food quality or jeopardize food inventory.

To confirm realistic electricity consumption by end use and individual intervention, Grid Fruit benchmarked its simulated twin models against the documented demand of the average U.S. convenience store. Pricing was computed according to SCE rate schedules, including time-of-use (TOU) and seasonal rates. Weather data files for California climate zones in SCE's service territory were obtained from the Climate One Building website.

Results & Learnings

Pilot project results are shown in the tables at left for two representative counties and SCE's service territory. Year-long simulations using Grid Fruit's optimization algorithm to account for climate zone and utility pricing showed the potential for $13.5 million in annual customer electricity cost savings—an average of 9.1%—simply by rescheduling refrigeration defrost cycles for convenience stores across the service territory. Benefits are greater in cooler climate zones, where HVAC is a smaller load and smaller proportion of the total store load: Because refrigeration has a larger load share, rescheduling refrigeration loads makes a big difference in the overall energy bill.

In these simulations, Grid Fruit's algorithm was configured to put store cost reduction as the highest priority. Even without prioritizing peak shaving, the simulations showed SCE-wide reductions of 6.5 MW (4.5%) in the average evening peak (4:00-9:00 pm). Additionally, reductions in CO_2 emissions of 11.7 thousand tons (kt) per year (4.6%) were observed.

As a final step in the project, Grid Fruit evaluated the potential benefits of implementing the recommended defrost controls across almost 12,000 convenience stores in California, spanning 16 climate zones. Customer cost savings totaled $24 million annually—an average of about $2000 for each store. Statewide reductions in average evening peak load and CO_2 emissions were similar to those for SCE's service territory on a percentage basis and totaled 14.7 MW and 25.9 kt/year, respectively.

This pilot was limited in important ways due to the pandemic and related factors. Optimization did not prioritize peak demand or carbon emission reduction. Grid Fruit offers more involved interventions—notably adjusting compressor operations—for further reducing a store's energy use, costs, demand, and electricity-related emissions and for achieving other goals such as resilience against power outages. This pilot considered only low-cost defrost control. Field validation of digital twin simulation results, through demonstration of refrigeration interventions in real-world stores, is needed.

Implications & Next Steps

Despite the altered scope of this 2020 pilot, Grid Fruit's digital twin simulation has quantified substantial customer, grid, and societal benefits available from implementing software-based refrigeration controls in convenience stores. The project generated optimal scheduling commands to coordinate high-demand refrigeration cycles in stores operating within the SCE service territory, accounting for climatic conditions, time-of-day pricing, and other grid incentives.

The original plan for field implementation by Grid Fruit will now benefit from project results and learnings, with SCE initiating store connections in Southern California for a potential future demonstration project. By integrating the Grid Fruit software platform with customer equipment and running digital twin store models, the field test would evaluate use of improved control settings for time-shiftable, high-demand defrost cycles in refrigeration. Anticipated benefits include reductions in energy bills and peak demand costs at the store level, and, when managed in aggregate, smoothed power demand across the study area and reduced CO_2 emissions.

TESTIMONIAL: Grid Fruit

Despite restrictions on in-store deployment in 2020, we are grateful for the opportunity to partner with SCE and EPRI to show significant benefits for individual counties and across the utility's service territory, in terms of cost reductions and emissions. With their support, we were also able to scale our algorithms and demonstrate potential benefits over all of California.

Jesse Thornburg

TESTIMONIAL: SCE

We're excited that Grid Fruit was able to validate to a fairly good degree of certainty where the opportunities are and to bring value in this way.

Edwin Hornquist

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