Energy Savings Through Refrigeration Load Control with Assessment of Commercial Potential

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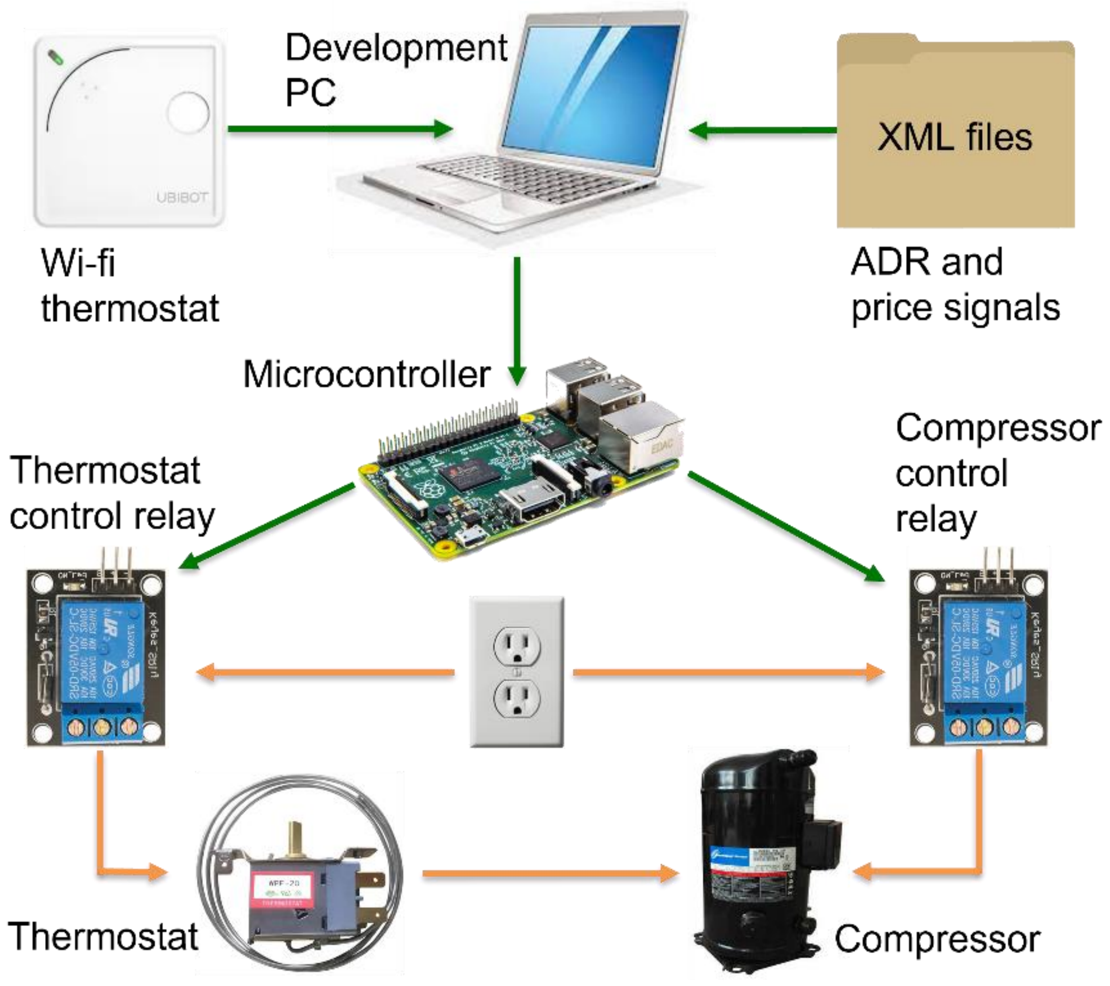
CONTRIBUTIONS

- Estimated cost and energy use reductions from implementing optimal load scheduling for commercial refrigeration
- Examined influence of refrigeration stock on optimal scheduling results
- Provides simple method of accounting for COP change due to change in outdoor temperatures

TESTING PLATFORM

- PC performs optimization and controls the compressor state
- ADR and price signals are transmitted via OpenADR protocol
- Test platform refrigerator is equipped with simple constant speed compressor



Simulation Methodology

Optimal Scheduling MILP

$$\min \sum_{0}^{144} p(i) * LMP_{DA}(i) * P(i) * \frac{600}{3600} * 10^{-5}$$

Subject to constraints

For i=1,2,…,144:

$$T(i) \geq 1\,°C, (1)$$

$$T(i) \leq 5°\,C, (2)$$

$$p(i) == 0 \gg tmed(i) == T(i) + 0.0004 * 600 (3)$$

$$p(i) == 1 \gg tmed(i) == T(i) - 0.0001 * 600 (4)$$

For i ∈ stock(i) ≥ 8000:

$$p(i) == 0 \gg talt(i) == T(i) + 0.0002 * 600 (5)$$

$$p(i) == 1 \gg talt(i) == T(i) - 0.00009 * 600 (6)$$

$$T(i+1) == tmed(i) + (stock(i) - 8000) * \frac{talt(i) - tmed(i)}{8000} (7)$$

For i ∈ stock(i) < 8000:

$$p(i) == 0 \gg talt(i) == T(i) + 0.0016 * 600 (8)$$

$$p(i) == 1 \gg talt(i) == T(i) - 0.0029 * 600 (9)$$

$$T(i+1) == talt(i) + (stock(i) - 0) * \frac{tmed(i) - talt(i)}{8000} (10)$$

Thermostatic Algorithm

For i in 0 through 144:

Calculate T_{heat} and T_{cool} using (1) and (2).

If $T_{heat} \geq 5°$ C:
T(i+1) = T_{cool}, p(i)=1, P(i) calculated using (5).

ElseIf $T_{cool} \leq 1°$ C:
T(i+1) = T_{heat}, p(i) and P(i)=0

ElseIF p(i-1) =1:
T(i+1) = T_{cool}, p(i)=1, P(i) calculated using (5).

Else:
T(i+1) = T_{heat}, p(i) and P(i)=0

Variable Equations

$$T(i+1) = T\Delta * t + T(i) (1)$$

$$Y = Y_1 + (X - X_1) * \frac{(Y_2 - Y_1)}{(X_2 - X_1)} (2)$$

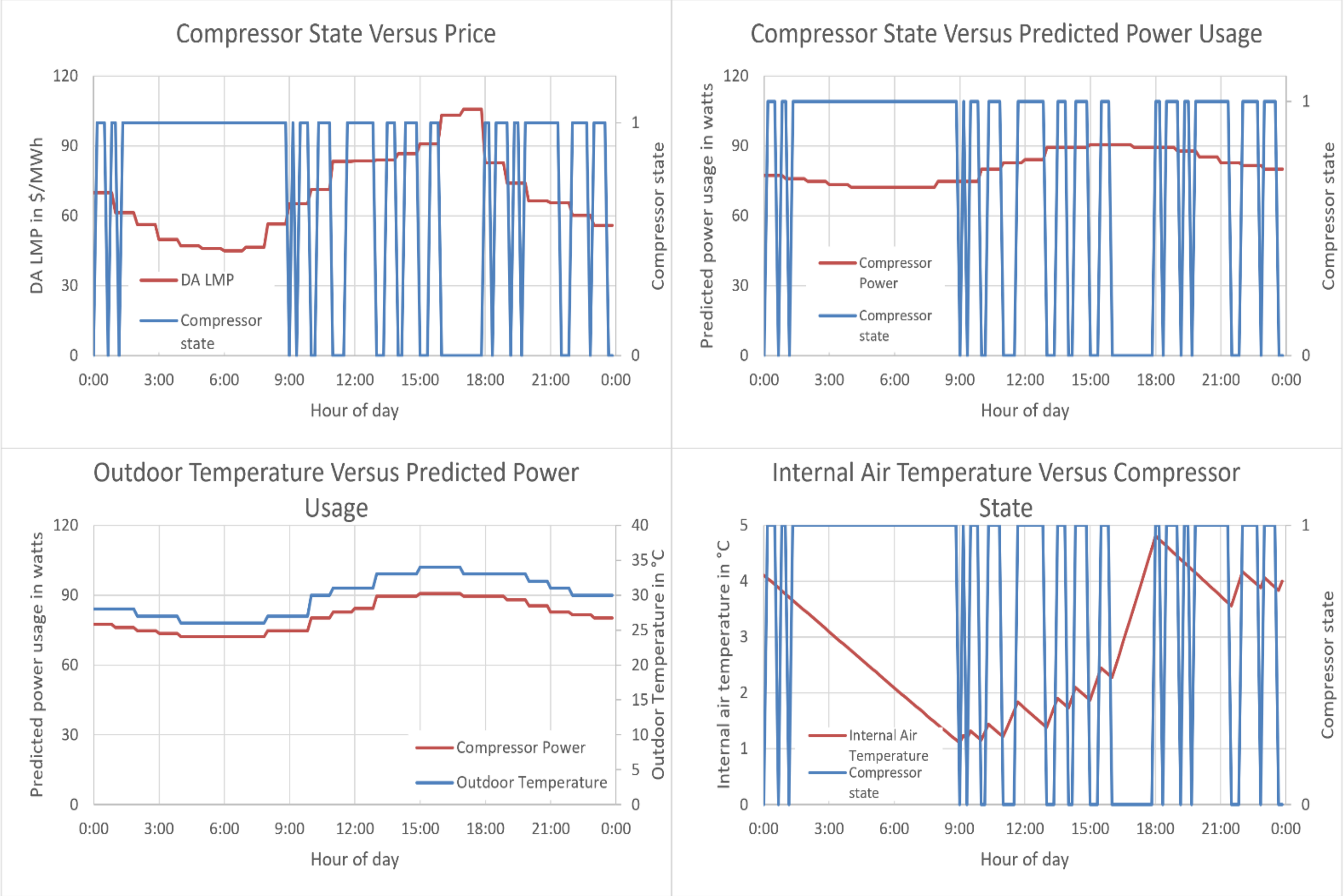
$$COP = \frac{Q}{W} = K * \eta (3)$$

$$K = \frac{T_C}{T_H - T_C} (4)$$

$$P = \frac{Q_{base}}{\eta * \frac{T_C}{T_H - T_C} * 3600} (5)$$

SIMULATION RESULTS

- Simulated one year of operation in response to historical hourly DA LMP and outdoor temperature readings



CONCLUSIONS

- Use of schedule optimization reduces electricity cost by 7.5% and energy usage by 5% on average
- Schedule optimization slightly increases peak power consumption due to precooling and peak price period interactions
- Relationship between stock levels, electricity cost, and energy usage is non-linear and undergoes trend reversal once stock mass <8 kg

FUTURE WORKS

- Incorporate use of defrosters and fans in schedule optimizer
- Collect thermal data on full-sized commercial system to build more realistic system model.

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