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A RODAN ENERGY SOLUTION

CASE STUDY

Refrigeration Plant Phase 2: Project Measurement and Verification Plan Summary:

The electrical energy consumed in this refrigeration plant varies greatly based on operating conditions such as production schedules (running/ not running), production volumes (type of product) and weather (temperature and humidity). Since these conditions vary greatly seasonally, a baseline measurement model must include multiple seasons and account for production variation. This model will then be used to predict how much energy would have been used under the base case and compare it to actual measured compressor consumption to verify the energy savings. Since multiple energy improvement measures are being undertaken at the same time and they all directly affect the efficiency of the ammonia compressor system, we monitor the performance of these measures as one project.

Refrigeration Plant Model for Phase 2 M&V Summary:

Ongoing refrigeration data is being provided by the Refrigeration Plant in daily aggregation. This data is statistically modelled against various drivers such as production values, cleaning schedules, daily activity factors (holidays, weekends etc) and weather data. Figure 1 below shows the optimized correlation:

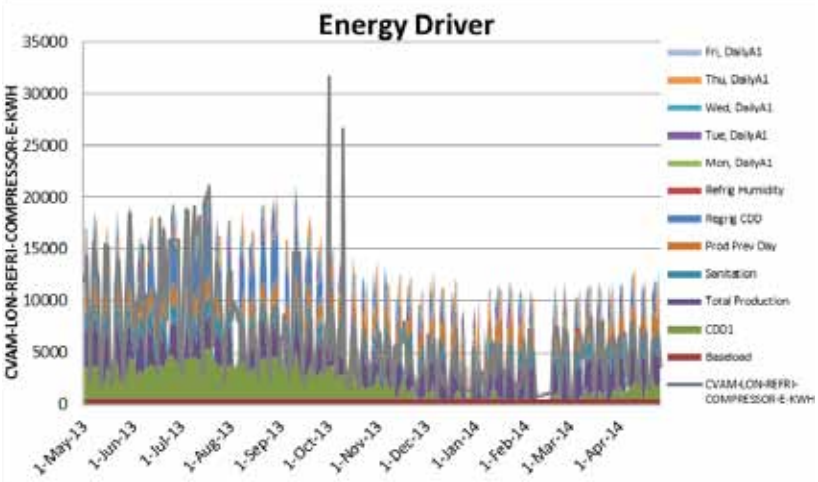

Figure 1 - Energy Driver Graph

SUMMARY

Organization

Large Refrigeration Plant, Ontario, Canada

Function

Provider of food, agriculture and risk management products and services.

Challenges

- Needed better understanding of what drives energy consumption
- Required baseline on energy consumption
- Verify actual energy savings

Solution

- Install EMIS System
- Energy Modelling to establish energy consumption baseline
- Email alerts on all utilities when outside of regular operating range
- Monthly teleconference to identify and investigate consumption anomalies

Benefits

- Address utility consumption problems quickly and avoid unnecessary costs
- Better understanding of energy use through baseline data
- Accurate calculations of extra costs during unexpected outages

This correlation is reliable with an $r^2 = 83.27\%$. The drivers found to be most important are:

- Baseload (the minimum amount of electricity was consumed across every day)
- Primary Cooling Factor (taking into account the weather influence on the building)
- Total Production (taking into account the mass of production produced daily)
- Sanitation Workers (taking into account the facility sanitation requirements)
- Previous Day Production (taking into account the night shift component of production)
- Refrigeration Cooling (taking into account the weather influence on production)
- Refrigeration Humidity (taking into account the weather influence on production)
- Daily Activity (taking into account the increased cooling requirements on certain weekdays)

The formula that the refrigeration predictive model uses is:

$$y = k_0 + k_1*x_1 + k_2*x_2 + k_3*x_3 + k_4*x_4 + k_5*x_5$$

This is a daily aggregation model.

- y = Predicted Power (kWh)
- k_0 = Baseload value (567.22 kWh)
- k_1 = Cooling degree day (153.72 kWh/degC, set point is -3degC)
- k_2 = Total production coefficient (.0339 kWh/lb of McDonalds production)
- k_3= Sanitation coefficient (29.33 kWh per person working an 8 hour overnight sanitation shift)
- k_4 = Production on the previous day (1836.51 kWh if McDonalds production occurred the day before)
- k_5 = Refrigeration cooling degree day (221.40 kWh/degC, set point is -3degC. If the particular day sees no production, this coefficient value is 0, no matter what the CDD value is)
- k_6 = Refrigeration humidity degree day (9.95 kWh/%, set point is -3degC and 50%. If the temperature is over -3 and the humidity is over 50%, the humidity value is calculated. If the particular day sees no production, this coefficient value is 0, no matter what the humidity value is)
- $k_{7\text{-}11}$ = Weekday baseload – additional baseload values attributed to specific weekdays

- k_7= Monday (1499.42 kWh/ day)
- k_8= Tuesday (3187.75 kWh/ day)
- k_9= Wednesday (2893.24 kWh/ day)
- k_{10}= Thursday (3177.60 kWh/ day)
- k_{11}= Friday (2883.19 kWh/ day)

The x values are daily numbers based on the events/status of that particular day.

Energent's M&V process includes the daily monitoring of the actual consumption of the refrigeration plant electricity and compares this to the model's predicted consumption based on the operating condition that day. A control chart is used to monitor "out of control" limits and trigger alerts. These alerts are investigated and tracked in our system to provide a comprehensive audit trail of energy performance changes with an explanation of what caused the change. It will also ensure that post project energy savings is monitored and maintained over the required M&V timeline.

Baseline adjustments can be made to address required production or equipment changes. These changes will be identified and quantified so that the changes to the energy use are measured against the adjusted baseline. Savings will be calculated by using a simple CUSUM (cumulative sum of difference between actual consumption and model predicted consumption) analysis. The CUSUM also provides valuable feedback on consumption trends.

In Figure 2 below, the pie chart shows the statistical importance of each driver in the refrigeration model:

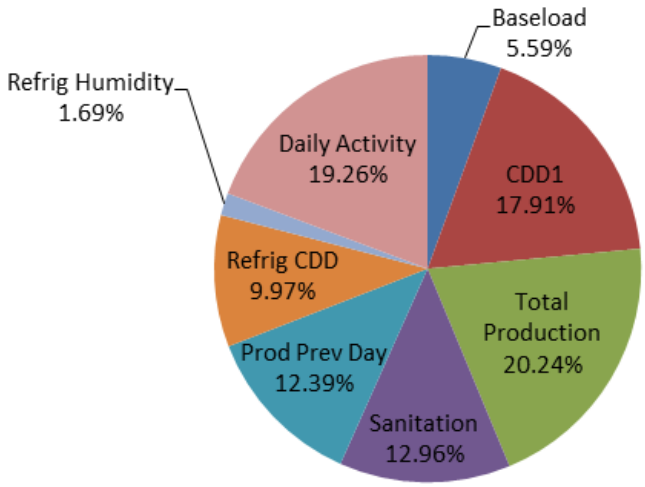

Figure 2 - Energy driver pie chart

Refrigeration Plant Project Phase 2: M&V Results Summary Overview

On June 1, 2012, the Refrigeration Plant completed an upgrade to the low pressure side of the ammonia compressor system that had tremendous results, reducing the head pressure in the system and reducing their annual electricity consumption by 1,211,000 kWh and qualifying for a $100,000 incentive from the OPA. This exceeded the design estimations of 1,060,000 kWh of savings. Figure 3 illustrates the monthly savings from the first project.

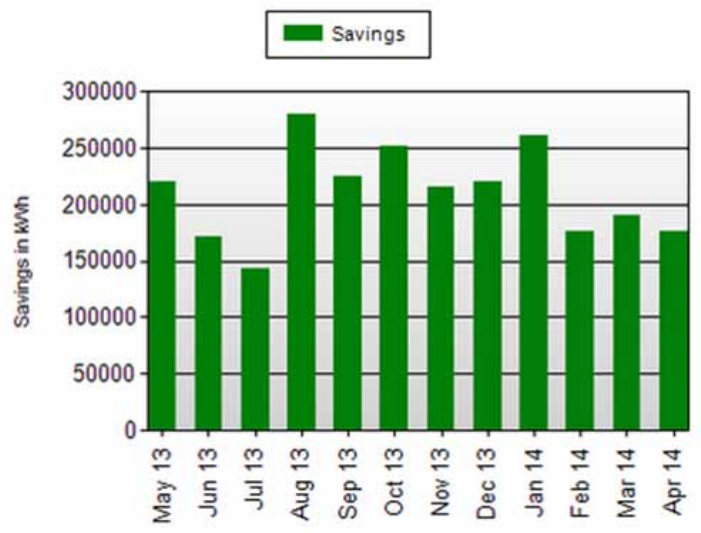

Figure 3 - Savings from Project 1

Encouraged by the exceptional results on the low pressure ammonia refrigeration compressors project, the Refrigeration Plant identified an additional opportunity for optimization. Increasing the pressure on the high pressure side of the compressor system, and optimizing the control strategy was expected to reduce the consumption requirements on the high pressure side, further reducing the demand of the overall process cooling system.

Two projects – the replacement of a 125 HP motor with a 150 HP motor, and the installation of integrated controllers helped to increase the head pressure, while decreasing the energy consumption. These two projects were effectively completed at the same time and are treated as one project from an M&V perspective.

Results

The following is a graph which shows the Refrigeration Plant's ammonia compressor consumption after the project as well as the calculated consumption based on the model prediction (see model description above). The actual and calculated values are tracking closely and thus can be used as a baseline to measure post project performance to high level of accuracy. The post project consumption clearly shows a substantial decrease compared to the baseline model (refer to Figure 4 below).

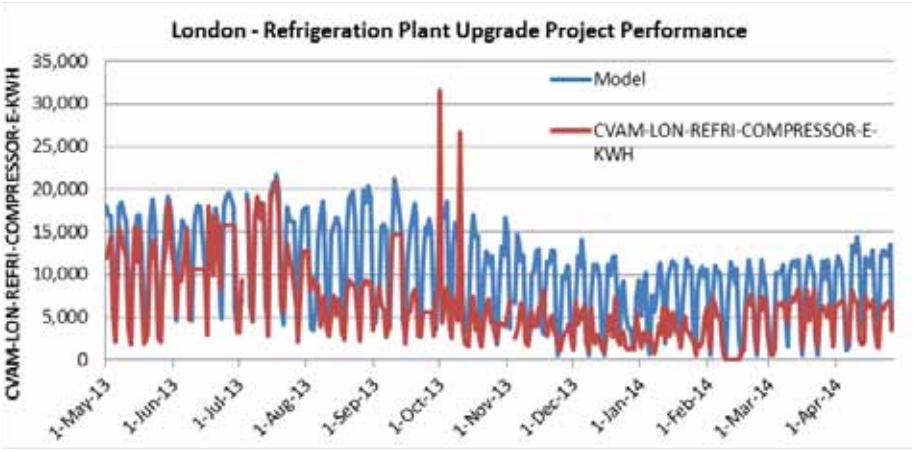

Figure 4 – Actual electricity usage compared to model predicted values

In Figure 5, the graph shows the daily CUSUM (cumulative sum of the difference), which summarizes the actual consumption minus the calculated model consumption which is accumulated daily. The CUSUM graph is a powerful tool to detect changes and trends in energy performance.

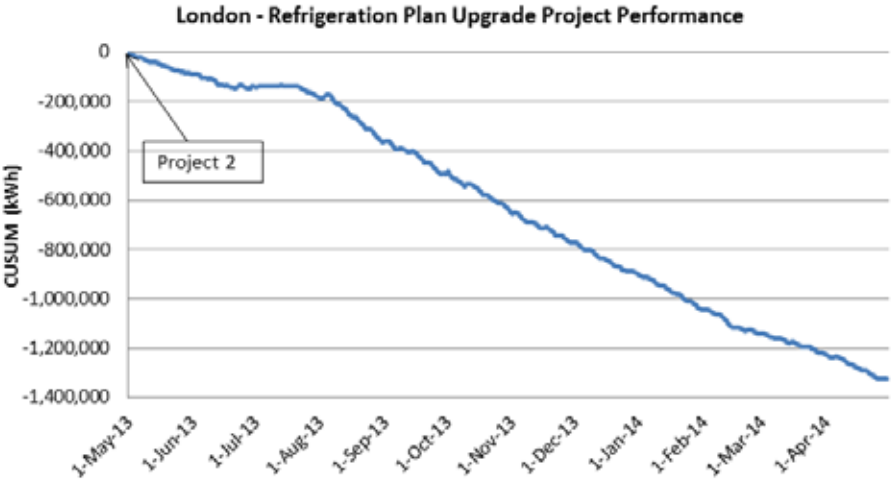

Figure 5 - CUSUM graph

Prior to June 1st, 2012, the actual and calculated values were similar and resulted in a relatively flat CUSUM. Once the projects were completed a negative CUSUM means that the Refrigeration Plant's compressors were using less energy than predicted.
The actual project performance was 3,690 kWh per day average (including the 2 days of gross overconsumption on October 1 and October 10).

Since August 2013, the refrigeration system has shows consistent savings that continue to the present period.

Conclusion

The installation of the new motor and controllers increased condenser capacity, increased the pressure on the high side of the refrigeration system, but the two project combined have resulted in a significant average reduction of 3,690 kWh per day in electrical consumption for the ammonia compressors.

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