Energy management control system for refrigeration plant at Nestlé Ice Cream plant, Mulgrave

SUMMARY

Nestlé's ice cream plant, located on Wellington Road in Mulgrave, Victoria, utilises a very large refrigeration system for the manufacture and storage of Peter's brand ice cream products. The refrigeration system uses about 13 GWh of electricity per year, which at current market prices is around $960 000 per annum. Through the implementation of Energy Best Practice Technology, Nestlé achieved savings corresponding to over $100 000 in energy costs and 20% of maintenance costs on this refrigeration plant. Employing an energy best practice approach to controlling the refrigeration plant goes beyond the conventional step-logic controller, adopting instead a more holistic approach to system design. The end result was an intelligent control system that provides the required cooling demand for minimal energy consumption (and hence cost), while at the same time reducing operational and maintenance costs.

PC-based intelligent control system

HIGHLIGHTS

- Reduction in greenhouse emissions by nearly 2000 tonnes of CO_2 equivalent per year
- Energy savings of more than 10%
- Reduced run hours by 22%
- Improved operational stability, reducing the number of compressor starts by over 90%
- Reduction in electricity costs of over $100 000 per year
- Reduction in demand electricity costs of $10 000 per year.

BACKGROUND

Nestlé's ice cream plant, located on Wellington Road in Mulgrave, Victoria, utilises 19 screw compressors of various makes. The compressors are shared between four different suction headers with corresponding suction temperatures of −3°C, −12°C, −40°C and −50°C. The installed capacity of these compressors varies from 150 kW_e to 465 kW_e of electrical load.

Plant room showing screw compressors

Nestlé have always been active in implementing energy efficiency measures, and there has been a gradual development of their existing refrigeration system. These developments include introducing an automatic air purging system, a soft starter and a PLC based conventional step logic control system, all of which have enhanced system performance and reduced energy consumption.

THE CHALLENGE

The refrigeration or chilling system is the major energy consumer in food industries such as dairies and food processing, representing between 50% and 80% of their total electricity consumption in the refrigeration plant. The capacity and size of most old refrigeration systems has increased in relation to plant and hence the system configuration is not always optimal. In the majority of these cases, the refrigeration control system is either manual or PLC, based upon stepping and sequence control. Although these controllers provide complete automatic control, they do not provide optimal control with respect to energy cost. The energy consumption of a refrigeration plant can be minimised by implementing an optimal control system, which, in addition to providing complete automatic control will also provide Optimal Unit Commitment, which is the optimal selection of compressor capacity to match refrigeration or cooling demand.

The existing system utilised throttling valves between the different suction headers to balance the system due to load changes within each suction line. Hence the refrigeration load was shared between all running compressors, with the result that some compressors were running under low loading. On the other hand, the approach of the optimal control strategy is to look at the load within each suction line, and match the number of compressors running to that load.

In addition to the energy savings that can be realised by adopting a more complex control system, changing the operating temperatures of either evaporator or condenser will affect efficiency. For every 1°C change in temperature, the efficiency changes by approximately 1.8%. The operating temperatures of both evaporator and condenser are intimately related to system pressure, and hence the suction pressure should be maintained as high as possible while still meeting the cooling requirements of the process, while the condensing pressure should be kept as low as possible. The effect of these statements is to reduce the work performed by the compressor and the heat rejected in the condenser or cooling tower.

The challenge was to demonstrate to the client that investing in a new and more complex control system (i.e. an Energy Management System) will return a substantial savings in energy and maintenance costs, resulting in short pay back periods.

THE SOLUTION

An energy efficiency feasibility study for the refrigeration system was conducted, identifying the need for an energy management system.

The feasibility study revealed the following:

- at times, compressors were operating under no load
- there were a large number of compressor start ups
- the suction temperature of –12°C was far from the design temperature of – 3°C due to incorrect valve selection
- minimum condenser pressure maintained at around 1000 kPa over the winter months.

Based on the feasibility study, the following recommendations were suggested:

- modification of condenser controller to operate at a minimum condenser pressure of 750 kPa
- recovery of –3°C design suction temperature by installing a position actuated valve for suction control
- install an intelligent control system for compressor operation.

The first two recommendations are essentially adjustments to the existing system. Modifying the control system however requires a strategic integrated approach to the refrigeration process. The existing system was an Allan Bradley PLC5 and Citect SCADA system. The control algorithm was a conventional lead-lag stepped controller system. The proposed algorithm uses more intelligent logic to optimise the control of compressors. This involves correct selection of compressors for different headers so the compressors operate at a higher loading and minimise starting and stopping.

Fan-forced evaporative condensers

Implementation

Based on the consultant's recommendations, Nestlé refrigeration engineers implemented the project in-house. The overall project duration was around four months from the approval of the project.

The project cost was estimated to be around $63 800, and the actual project implementation cost was around $59 000.

THE BENEFITS

The energy management system involved upgrading the current PLC based step logic controller to an intelligent controller with an energy management optimal control algorithm, which provided enhanced plant monitoring and improved controllers and actuators. The energy management system not only improved the energy efficiency of the system but also improved stability of operation, resulting in vastly reduced number of starts, reduced run hours of compressors and therefore reduced maintenance costs.

The energy management control system became operational in October 2001. The overall energy consumption of the refrigeration plant decreased by around 3.3% although the volume of product processed increased by 10%. The electricity demand reduced by 340 kVA. After adjusting for the increase in volume of product, the actual energy reduction is in the order of 10.3% or 1340 MWh per year resulting in cost saving of $90 000 per year due to reduced consumption. Other benefits from the advanced controller as found to date are as follows:

- The run hours of the compressors reduced by 22%.
- The number of compressor start ups reduced from 2 per hour to 1 per 6 hours, which corresponds to a 92% reduction in start ups. This reduces the stress on the motor winding and therefore the frequency of rewinds. The result of this reduction in maintenance will not be realised for at least a year of operation.
- Reduction in electricity demand of around 340 kVA resulted in a cost reduction of $12 000 per year.
- Reduction in total electricity costs of over $100 000 per year.

The results achieved are overwhelming and are in line with the predicted savings.

THE FUTURE

Nestlé is considering installing additional condensers which will operate at reduced condensing temperatures, hence reducing the energy demand and improving energy efficiency. The existing energy management system will not require any modifications in control strategy to accept this modification to the process.

LESSONS LEARNED

Lowering the condensing pressure, and hence temperature, increases the energy efficiency of the refrigeration process. However, twice a day, Nestlé re-route hot discharge gas from the compressor direct to the evaporator coils (hence bypassing the condenser) in order to defrost the cooling coils. There was some question as to whether the reduced compressor discharge temperature would be effective for the defrost action, therefore Nestlé engineers ran tests at lower condensing temperatures and determined that the defrosting action remained satisfactory at the lower temperatures.

APPLICATION

The refrigeration optimal control is applicable for any refrigeration plant, and economically viable for medium to large refrigeration plants. The benefit found from this project can also be applied to other refrigeration plants.

PROJECT DETAILS

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