Underground Mine Cooling System - Optimisation to save utility costs

Deep level gold mines spend approximately 25 % of their costs on electricity. With the National Energy Regulator of South Africa (NERSA) approving Eskom's electricity tariff increases, this portion is likely to increase. The major consumers of energy in these operations include refrigeration plants that produce cold water used to cool the air underground.

A typical cooling water process consists of cooling towers, ice plants, various large storage dams and refrigeration plants producing cold water, as illustrated in Figure 1.

The cold water and ice produced above ground is transported below ground using a network of turbines and dams, to be used to cool the air. Thereafter, the warm water is pumped back above ground to repeat the cooling process.

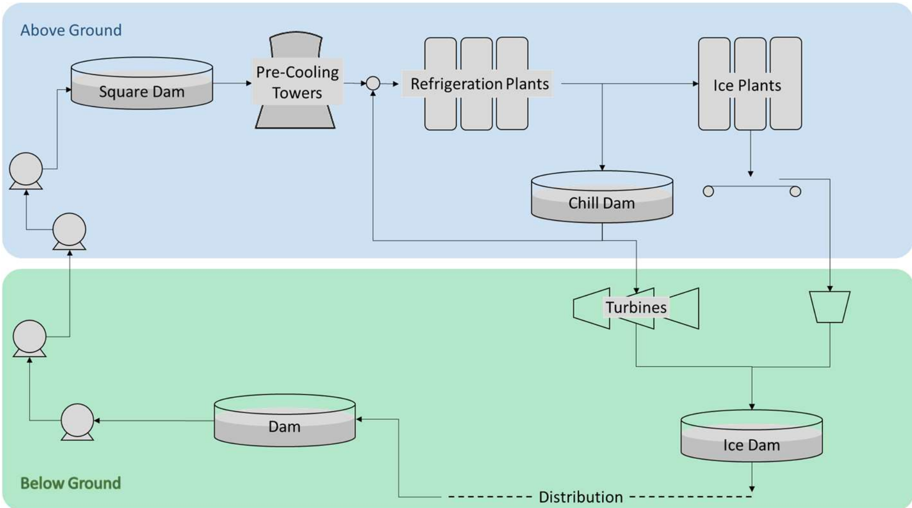

Figure 1: Cooling water process flow diagram

Mintek has developed and implemented a control and optimisation strategy in simulation that preferentially schedules operation of these energy intensive refrigeration plants during the periods when Eskom's electricity tariffs are at its lowest, by utilising the cold water inventory effectively. This aims to reduce the operating costs of the process significantly.

Mintek's StarCS Model Predictive Controller is at the basis of the control strategy. It uses a mathematical model of the process dynamics to predict how the process will respond into the future, taking disturbances such as ambient temperature into account, and then calculates the optimum control actions to achieve the desired process targets.

On top of this base layer control is the optimisation strategy, called the Dynamic Real-Time Optimiser (D-RTO) that uses the same mathematical model to decide **where** the process should be operating in order to achieve some economic objective; for example, minimise the cost of electricity. This particular optimisation strategy developed by Mintek is considered dynamic, because it determines **where** the process should be operating to be economic, as well as **how** to get to that point. The D-RTO is particularly advanced in its ability to also determine the number of optimum discrete elements required to achieve an economic objective.

Given the electricity tariff schedule as in Figure 2, where the cost between peak and off-peak times is six times greater, the optimisation strategy was constrained to ensure that the cold water inventory (chill dam) remains above 35 % at all times, and should specifically be above 90 % between 5am and 6am. It was assumed that the demand for cold water underground remains constant through-out the day.

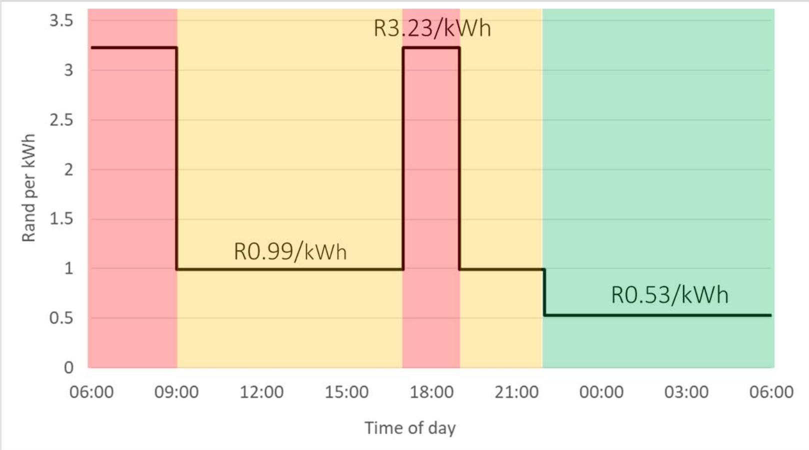

Figure 2: Hourly electricity cost variation

The strategy then predicts the optimum operating trajectory over a 3 day period. This optimisation occurs in real-time, and would therefore adapt to any external process changes that are not accounted for in the process model (e.g. if the underground cold water demand was to increase, or changes in the ambient temperature). It is therefore not a static optimum that is calculated offline, but rather a dynamic strategy that accounts for all factors and continually calculates new optimums and new trajectories to reach those optimums.

Figure 3 illustrates the simulation results of scheduling the operation of the refrigeration plants relative to the electricity tariffs (background colouring). As anticipated, the optimal result operates the most fridge plants (▬) during the cheapest off peak electricity times (10pm - 6am), filling the dam up (▬) to be used as a battery during the more expensive periods. The operation of two (2) fridge plants even during the peak and normal electricity tariff periods was due to the high underground cold water demand that was simulated.

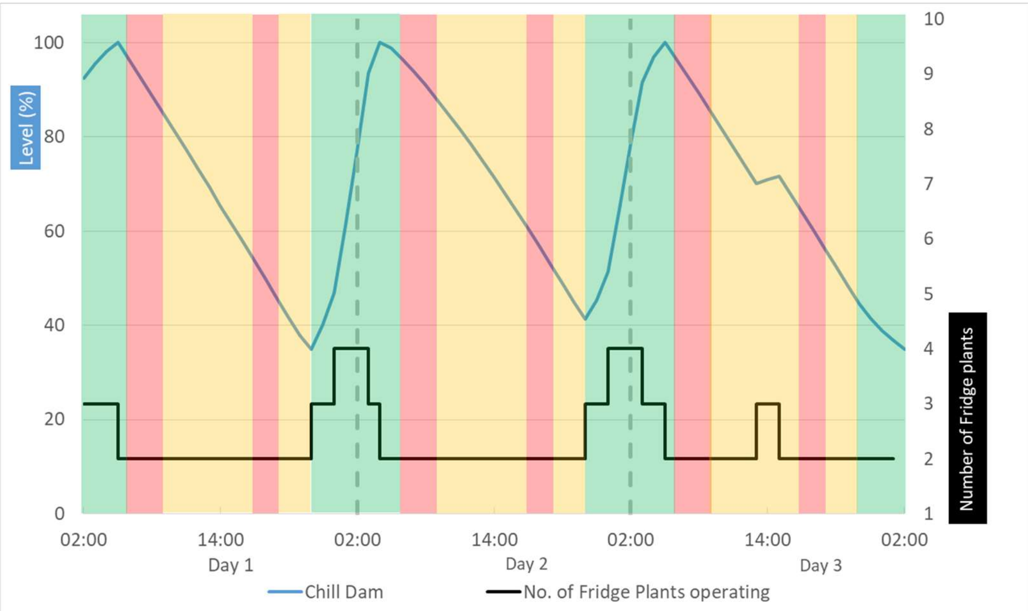

Figure 3: Optimal number of fridge plant operation and cold water inventory level trajectory

The process model and simulation is based on data collected at a South African deep-level mining operation, where Mintek currently has their system installed to control the refrigeration plant inlet temperature. The scope of the project started narrow, due to the complex, nonlinear and interactive nature of this process with several prior attempts of advanced process-control vendors at automatic control failing as a consequence. The economic impact of the dynamic optimisation approach still needs to be quantified, and will be dependent on each operation's baseline, but it is estimated that savings of between R1 and R2 million per year is achievable by scheduling the refrigeration plant operation and utilising the cold water inventory effectively.

This white paper has been brought to you by Mintek. Feel free to pose any questions you might have to the author at loutjiec@mintek.co.za. For more information on the Mintek Process Control group, click here.