CASE STUDIES IN
SYSTEMS OPTIMISATION
TO IMPROVE ENERGY
PRODUCTIVITY
Systems optimisation to improve energy productivity

Case studies conducted with the kind assistance of:

- BHP Billiton Worsley Alumina
- AngloGold Ashanti Australia Ltd
- Simplot Australia Pty Ltd

The purpose of these case studies is to demonstrate how systems optimisation can be used to improve energy efficiency and productivity in a wide range of industrial applications. Examples from three companies highlight different aspects of systems optimisation.

Industrial processes are subject to numerous variables, which have traditionally required skilled and experienced operators to maintain optimal operating conditions. However, modern systems optimisation technology allows for this experience and judgment to be understood, modelled and automated.

The benefits can be significant. Depending on the process being optimised, they may include increased output, less downtime, increased energy efficiency, reduced energy costs, improved product quality or lower emissions.

Many companies have already implemented new technologies or processes to improve energy efficiency. Systems optimisation offers the potential for even greater efficiencies by optimising the performance of the facility as a whole to improve productivity. It does this by making changes to processes in real-time and by automatically taking into account a range of complex parameters, which could include commercial variables such as commodity prices and customer demand.

The three companies profiled in this case study highlight some of the different ways that systems optimisation can be applied, with varying levels of automation.

- **Simplot** optimised its refrigeration systems by upgrading motors to variable-speed drives, which enabled a much finer level of control, and applied new control algorithms to their programmable logic controllers (PLCs), to optimise the power consumption of their refrigeration plant. The ability to access real-time data also allowed the company to respond quickly and avoid lost production during an electrical failure.

- **AngloGold Ashanti** also found that significant productivity improvements could be achieved by modifying the software logic and control algorithms of their PLCs, without the need for new hardware. This has allowed the company to increase throughput and reduce downtime at its crushing mill.

- **Worsley Alumina** first optimised several individual processes within the refinery, and then implemented multi-variable, predictive real-time optimisation to improve efficiency and productivity at an overall system level.
What is systems optimisation?

Systems optimisation is an ongoing process involving the use of frequently measured and calculated system inputs, in order to manage and optimise productivity and quality.

It sits above existing process control systems, which are widely used to monitor and control particular processes within a mining, manufacturing or infrastructure plant. Based on information received from remote stations (sensors), automated or operator-driven commands are sent to remote station control devices (actuators). These systems control processes such as raw material feed rates or boiler temperatures in a manufacturing process, or lighting and air conditioning in a building.

An optimal control or 'expert' system sits above existing process control systems (Figure 1) and draws inputs from a wider range of sources, such as sensors monitoring other parts of the plant, operating states, commodity and energy prices, stock levels, orders, and other non-process related information. These are measured or estimated and then used to calculate optimal set points within the constraints imposed by other strategic objectives such as productivity, quality, energy use, energy tariffs or fiscal constraints.

This information is then used to control process set points in real time to optimise higher level performance indicators, such as profit or carbon emissions.

For example, a large-scale co-generation plant consumes gas to produce electricity and steam. The plant needs to generate sufficient electricity to meet demand without over generating, as this increases the amount of gas purchased but produces electricity that isn’t sold. The steam produced is also sold to a nearby customer whose demand varies during the day. The profitability of the business depends on the real-time demand for electricity and steam, and the current market prices for gas and electricity. Each process may be working at its optimum efficiency, but the system as a whole may be sub-optimal from a profit perspective.

Building management systems are among the most mature of available optimisation systems. These link HVAC (heating, ventilation and air conditioning), lighting systems and other building services to building occupancy, ambient temperatures and commodity prices to optimise the comfort of the occupants for the least cost.

How can systems optimisation improve energy efficiency?

Existing processes that are commonly used as part of an energy management system include energy-mass balance (EMB), regression analysis and off-line optimisation techniques. These processes involve off-line historical data analyses, manual optimisation modelling and operator implementation of the findings. An EMB is a static analysis that provides a snapshot in time for a certain operating state. However, it does not reflect the range of possible operating states, and it can quickly become obsolete.

Systems optimisation is more dynamic. It can support effective energy management by helping to identify areas of wastage, understand the energy consumption of the process, highlight changes to energy consumption patterns and reach an optimal condition for the supply of power. In most cases, energy efficiency benefits are achieved by improving productivity.
While the benefits are dependent on the primary objectives of the project, the following outcomes are those that are generally achieved through effective implementation of systems optimisation.

- **Increased output**
  Systems optimisation allows processes to operate closer to the specified constraints. This is achieved because systems optimisation has the ability to continually adapt to system variances. The safety factor can be reduced and the process can operate with greater efficiency. Systems optimisation also has the ability to manage output based on production demand to ensure oversupply doesn’t occur, which can essentially become waste product.

- **Increased energy efficiency**
  A primary objective of systems optimisation is to reduce the amount of energy consumed per unit of output in an industrial process or building operation. Depending on the previous experience of the vendor, or even similar processing operations where systems optimisation has been implemented, the estimated energy efficiency increases can be quantified for the specific activities undertaken on site.

- **Decreased energy cost**
  By decreasing the amount of energy consumed per unit, the direct cost of energy per unit also decreases. Systems optimisation can also utilise real-time energy tariff data to manage the time at which processes are conducted in order to benefit from off-peak tariffs where possible. This cost saving directly affects the gross profit margin of the operation and is immediately noticeable to management for the purpose of monitoring profitability.

- **Increased product quality**
  Systems optimisation has the ability to increase quality and minimise inconsistencies in the outcomes of the process by decreasing the variability in the process and operating closer to the process boundaries.

- **Reduced emissions**
  Systems optimisation can help to reduce emissions and waste per unit of output. An indirect reduction in emissions is also achieved through increased energy efficiency where the energy is derived from fossil fuels.

- **Decreased downtime**
  The core principle of real-time systems optimisation is the ability to predict future outcomes based on the inputs provided and adjust the system as required to achieve the desired outcome. Negative outcomes like system failure or breakdowns can be avoided through systems optimisation anticipating these in advance (see the AngloGold Ashanti example on page 16).

- **Environmental impact**
  An increasing emphasis on environment and sustainability is evident in most large organisations, and systems optimisation can be used to achieve strategic environmental objectives such as energy efficiency and reduced emissions.

- **Decreased human input**
  Systems optimisation allows for the control of several processes to be consolidated and often undertaken in a single control room (see the Worsley Alumina example on page 21). The level of staff time required to monitor and operate a processing plant is therefore reduced, which directly reduces overhead costs.
Current systems optimisation technology still allows for the control to be overridden via human input for safety purposes.

- **Occupational, health and safety**
  Minimising the level of human input also reduces the risk of safety incidents, such as near misses, injuries, and longer term adverse health effects.

The level of benefit achieved as a result of systems optimisation has included:

- increased output: 3 to 5%
- reduced fuel consumption: 3 to 5%
- reduced power consumption: 3 to 5%
- reduced quality variability: 10 to 20%

Each of these benefits would contribute directly to profit through reduced cost per unit of production.

**What are the opportunities for Australian industry?**

Systems optimisation is likely to be beneficial in operations with the following characteristics:

- **Energy consumption and prices vary with time**
  Opportunities for cost-reduction are greatest when both energy consumption and prices vary over time, which is common in process industries and open energy market environments. Typically, the overall cost reduction can be 2–5% of the total energy cost.

- **Dynamic and complex processing environment**
  Systems optimisation has the ability to continuously interpret various inputs and autonomously optimise the process set points based on these inputs. In a dynamic and complex processing environment, this level of optimisation simply cannot be achieved through manual human input and as such, systems optimisation provides a viable solution.

- **Highly variable process**
  In the case that a process deviates considerably from the set point, it often has to be operated well below the system constraints, such as warning or alarm thresholds. This is to ensure that the process doesn’t deviate to the point that it exceeds the constraints and produces undesirable outcomes. Operating with such a safety factor leads to a system operating inefficiently and well below its capabilities. Systems optimisation has the ability to stabilise the process and operate the system closer to the constraints, resulting in increased efficiency and output.

Currently available ‘closed loop’ energy optimisation programs and implementation projects have focused on the power generation industry, cement, petrochemical, steel making, and the pulp and paper industry. There have been a number of installations in the power industry in the USA, Europe and Japan. Several large engineering firms have developed optimisation systems that can be deployed on top of existing process-control systems.

In a power-generation application utilising a turbine-generator arrangement, systems optimisation can assist in better meeting generating targets through avoiding over generation and under generation, minimising gas or steam flow per unit of output by operating the system closer to the constraints, and limiting the reliance on human input, which decreases variability. Systems optimisation can also be applied in combined cycle gas turbine (CCGT) installations and co-generation applications.
Cement manufacturing benefits from systems optimisation by achieving a better quality product and increased energy efficiency, whilst at the same time increasing throughput. A key constraint in cement production is the pre-calciner temperature. Stabilising this input with system optimisation leads to steady kiln operation and higher clinker quality, which is the cement product prior to being milled\(^6\).

In Australia, systems have been successfully installed at cement production facilities and an alumina refinery. There have also been a number of systems installed on large industrial facilities with onsite power generation capacity, with the aim to optimise the generation of power relative to its consumption by activities undertaken onsite. Most large commercial buildings have a building management system (BMS) with the capability to optimise performance, but these are often under-utilised.

Most industrial processes currently have real-time monitoring and control system of some description in place. In some cases, the upgrade to real-time systems energy optimisation may not require a complete replacement of existing systems. Indeed, most supervisory control and data acquisition (SCADA), distributed control system (DCS) or programmable logic controller (PLC) systems are capable of running energy optimisation strategies and algorithms, but have not been designed with this as the primary purpose.

**Current technologies**

A process control system uses a system of instruments (or sensors) and devices to measure and change process parameters. These devices include equipment such as control valves and variable speed drives (VSDs) that make physical changes to the process by modulating pumps, fans, conveyors and other equipment.

The signals from instruments are typically read by a DCS or PLC, which applies logic and algorithms to translate the information coming in from the instruments into control instructions that are applied to the valves, motors and other actuators.

A SCADA system typically provides a human-machine interface to the DCS, allowing plant operators to visually observe the state of the process. It displays alarms or warnings, and provides an interface for operators to make manual adjustments or changes to the plant.

A ‘systems optimiser’, such as a multi-variable control system or an expert system, can provide another level of sophistication and automation through the application of broader real-time rules and algorithms. The goal of optimisation is to reduce process variability by bringing all aspects of the process in the plant to an optimal collection of set points. These are usually optimal in the economic sense, for example they may include maximum feed rate, lowest possible burning zone temperature or exact flame oxygen levels.

The first step involved in the optimisation process is the prediction of the state of the system at some future point in time. This is achieved through a variety of techniques that are collectively known as model predictive control (MPC). The process control system then modifies the set points of the process to achieve the desired optimal state.

A wide range of systems optimisation technologies and techniques are available, and there are many possible variations. This optimal control sits above the DCS/SCADA/PLC and adjusts the set points that the DCS/SCADA/PLC implements. The results of the changes are then fed back to the optimiser and the calculations are repeated. This process is illustrated in Figure 2.
The key operational characteristics for currently available real-time systems optimisation technology are described below.

- **Data historian capabilities**
  Systems optimisation servers collect and store data continuously from the process control system. This provides the process configuration data, along with keeping historical logs, system error logs and system audit logs. The system settings are matched to the performance outcomes in the data historian in order to allow the system to learn from previous performance in a feedback loop configuration.

- **Consistent and ongoing analyses of the process performance parameters**
  In order to realise the optimal operating conditions, current systems optimisation technology employs various control techniques, which may include a combination of fuzzy logic, mathematical functions, Boolean logic, neuro-fuzzy and MPC. Fuzzy logic is employed to allow computation of the ‘soft’ inputs where human intuition is otherwise required. Neuro-fuzzy control has the ability to learn the relationships between key process variables and utilize this knowledge to predict outputs in the future based on the provided inputs. MPC utilises predefined algorithms to determine the state of the process based on the provided inputs and predicts the future values of the critical process parameters. The algorithms are developed by modeling of the process, and in doing so the future values can be optimised.

- **Autonomous optimisation control**
  After the optimal process set points have been identified, autonomous implementation is required to further reduce the requirement for human input. The ability of the personnel controlling the process to evaluate the current operating point, determine the optimal settings and then implement those changes, requires much more time than an automatic system.
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This time-lag can result in extended sub-optimal performance, and the dependence on inconsistent operator judgment can result in sub-optimal decisions.

- **Requirement for a lower level process control system**
  Systems optimisation has the capability to define optimal operating set points; however a lower level process control system is required to implement the set point adjustments. Industrial processing facilities will generally have a lower level process control system installed, such as a DCS, SCADA or PLC.

- **User interface with remote access**
  A user interface is important for monitoring the performance of the process and being able to measure the increases in efficiency as a result of implementing real-time system optimisation. The user interface can be accessed via personal computers in various locations around the industrial facility or building with internet access. The user interface is critical to illustrating the benefits of systems optimisation and providing process engineers with outcomes that can be clearly presented to senior management and even shareholders, to substantiate the investment.

Many companies already have the technical capability to optimise processes, but this has not been fully realised. For example, most industrial facilities have automatic data historians connected to integrated PLC, DCS or SCADA networks. These plant information systems provide the basic underpinning for any type of systems optimisation. They enable information from all instruments and equipment in the plant to be collected, stored and processed.

External inputs can also be stored on the same platform such as manual inputs from the laboratory or automatic assays fed into the system by automatic laboratory equipment. Other information about the process, such as set points, is also stored. Once this architecture is in place, the various forms of process systems optimisation can be layered on top of the plant information systems.

**Different approaches to systems optimisation**

Optimisation can be applied to various degrees depending on the level of automation:

- **Manual or offline open loop systems optimisation** where the optimisation is undertaken by human operators. Set points are determined based on past plant data and the new set points are then manually entered into the process control system.

- **Online open loop systems optimisation**, which use an MPC system to complete calculations in order to determine future behaviour of the process. The operator then makes set point changes if deemed appropriate. The delays inherent in the human decision making process and the level of experience of the user may adversely affect the system outcome. However, system efficiency will continue to improve over time as operators gain experience and implement continuous improvements to the system and the user interfaces.

- **Autonomous systems optimisation** provides the highest level of automation and it is referred to as **closed loop real-time optimisation**. Process control inputs are determined from real-time data and anticipated outcomes derived from the MPC models and algorithms. The set points are then adjusted automatically to achieve the desired outcomes.
Each company profiled in these case studies demonstrates a different aspect of systems optimisation (Figure 3). The three examples help to illustrate the spectrum of approaches that can be taken by companies seeking to learn from these experiences.

Figure 3: Different approaches to systems optimisation.
Case Study 1

Simplot Australia Pty Ltd:
Moving from a static energy use model to a systems optimisation model

About Simplot Australia

Simplot Australia is a wholly owned subsidiary of US-based J.R. Simplot Company, a privately held food and agri-business corporation based in Boise, Idaho. It has manufacturing facilities in Tasmania, Victoria and New South Wales, annual turnover of around $1.6 billion and approximately 2,500 employees (2012 figures).

This case study focuses on Simplot’s plant in Devonport, Tasmania, which produces frozen vegetables under the Birds Eye and Edgell brands. The key processing elements are product receiving, product washing and preparation, product blanching, freezing and storage, product packaging and storage and dispatch.

The electrical energy use of the site is over 18,000 MWh each year, about 70% of which is used in the refrigeration and freezer tunnels. The natural gas use is about 40,000 GJ per year and mainly in the form of steam from a boiler for blanching products before freezing and hot water generation for CIP (Cleaning in Process) and other general cleaning activities.

Simplot Australia Pty Ltd

Why the project was initiated

Simplot has been actively pursuing savings in energy use through increased energy management for many years. Around 2008 Simplot decided to invest in a more dynamic data collection and monitoring system to improve energy management at its Devonport facility. This was driven by several converging factors:

- The introduction of the Federal Government’s Energy Efficiency Opportunities Program provided impetus to focus on energy savings
- There was an unprecedented increase in energy prices
- Simplot head office introduced its global ‘25 in 10’ program – a target to reduce energy intensity (energy use per tonne of production) by 25% over a 10-year period from base year 2008.

Figure 4: Simplot facility in Devonport, Tasmania. Courtesy Simplot Australia Pty Ltd.

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When Simplot conducted its EEO energy assessments, it identified a wide range of energy performance improvement projects, which started a coordinated drive to save energy costs and build the systems required to sustain these savings.

A key area for development was energy metering and monitoring to measure, plan, carry out and assess energy saving activities. This was followed by an optimisation project for the refrigeration system.

Data and control systems at Simplot

The Simplot SCADA system (Figure 5) consists of a user interface and PLCs for data collection and control. All processes are controlled by a local PLC, which is supervised by a central computer system. Data is stored on a historian, which is programmed to store data for long periods of time and to create reports for production and energy use.

![Figure 5: Screen shot of real-time data acquisition for refrigeration condenser operation at Simplot Devonport.](image)

How systems optimisation was implemented

Improved metering

The first step was to improve metering. Prior to 2008 the only data being collected was from meters on incoming energy and a couple of the main switchboards. These meters were read and manually recorded each month. There was very little analysis of the data, which was primarily used as an input to financial reports.

Simplot decided to invest in a metering system that would improve its ability to understand and improve energy performance. More data was needed to understand where energy was being consumed across the site and where there might be opportunities to improve efficiency.

Many of the major energy using sites in the Simplot group created energy metering plans, with funds allocated to allow the meters to be implemented and integrated into the site SCADA.
Data on energy and material flows is now collected online and compiled into daily, weekly and monthly reports on energy use and energy intensity.

Electricity meters were installed on all key equipment including refrigeration compressors, main electrical supply transformers and switchboards for production lines, and air compressors. In addition to the electrical metering, the plant installed a range of flow meters for compressed air, water and steam flow measurement.

The next step was to use this data to start modelling processes, and to redistribute meters to allow closer monitoring of energy use. The metering system then provided detailed coverage of all main energy users and allowed energy efficiency KPIs (key performance indicators) to be created for many of the key production processes and energy equipment.

The cost of the metering equipment and installation was more than $100,000. The project received strong corporate support despite the fact that the anticipated future energy savings could not be quantified. The business case was not directly financial; it was based on the fact that metering would be an ‘enabler’ for future savings.

**Integration of data into the SCADA system**

The SCADA system was improved by programming the PLCs to collect energy use information, and with optimal control algorithms for the refrigeration systems to minimise energy use.

Energy use trends were configured to allow operators to view real-time energy use, and the historian was programmed to collect daily energy and production data to create energy KPIs for all key processes.

Daily, weekly and monthly energy reports are utilised in site meetings to track and identify energy use issues. The ability to see plant energy performance at key production process and energy system levels allows for quicker identification of energy waste and opportunities for improving energy use.

> ‘You don’t want to know next month when your energy bills come in that you’re not using energy efficiently. You want to know right now so that you can do something about it. If you know that the carrot line isn’t running efficiently energy-wise, then the shift manager and the maintenance team can go in and find out why and fix it, or at least be able to explain why it’s happening.’

Graham Bryant, National Environment Manager, Simplot Australia

**Optimising the refrigeration system**

Refrigeration has been a focus for energy efficiency due to the high cost of electricity and the need to have high equipment and process availability during vegetable processing seasons. The refrigeration control systems are now highly advanced, using algorithms to maximise energy efficiency and refrigeration capacity.

Previously the compressors often worked at only part-load, which resulted in unnecessary energy consumption. The key projects that have led to improved energy performance are the installation of a Variable Speed Drive (VSD) on a key compressor to improve efficiency at part-load, and the introduction of variable head pressure control (VHPC) to take advantage of ambient conditions. The logic has also been programmed to stage the operation of the compressors based on plant load. Compressor selection is optimised to maximise energy performance while operating with the variable loads of between one and four freezer tunnels. This is a form of systems optimisation.
VHPC aims to optimise the head pressure (refrigerant condensing pressure) of a refrigeration plant at any given time to match ambient conditions and plant load. To ensure that the system can run at optimum head pressure, the speed of the condenser fans is determined by the control logic based on the ambient conditions, thereby specifying the head pressure. To equip the logic to recognise the ambient conditions in order to provide appropriate instructions, temperature and humidity sensors need to be installed, and the logic programmed appropriately based on the month of the year.

The new refrigeration control system was implemented in 2009-10. The implementation of the VHPC required the installation of VSDs on all condenser fans so that the logic can directly specify the speed of the fans, reducing power consumption. When head pressure is optimised, the combined power consumption of the refrigeration compressors and the condenser fans is minimised. The power savings range from a few percentages to over 10% depending on the ambient conditions. The largest percentage savings are generally made during the cooler months when the condensing pressure or head pressure can be reduced further than in summer conditions.

The VHPC optimal control algorithm was designed and implemented by external parties and site engineers took over after the initial programming. Some improvement in performance was noticed; however, there was no immediate focus on tuning or maximising the performance of these control systems.

This changed when there was a major failure in the electrical distribution system, which caused two of the high stage compressors to become unavailable. This occurred during peak production of frozen peas, which is the most vulnerable product. Peas need to be processed within four to five hours of being picked or they lose their freshness. Without two of the compressors there was insufficient freezing capacity to process the peas at planned production throughputs. To further exacerbate this problem, the electrical system failure required a new transformer, which had a six-week delivery time. There was a need to immediately find extra capacity in the refrigeration system to ensure that all of the peas could be processed.

Simplot site engineers decided to review the control systems to see if the control strategies could be adjusted to achieve the desired refrigeration capacity without the use of the two compressors. After a series of adjustments, the refrigeration capacity was found to ensure uninterrupted processing. A key factor in the ability to increase refrigeration capacity was the implementation of VHPC, which allowed the condenser fans to be run at high loads to lower discharge pressures and thus increase refrigeration capacity.

The ability to access real-time energy use information for each refrigeration compressor and condenser fan and the transformer supplies allowed the engineers to quickly access the electrical load distribution and thus find a solution to the refrigeration capacity issue without overloading the remaining transformers.
Benefits achieved to date

The Devonport plant has reduced energy intensity by 20% over the last few years and this has resulted in significant cost savings each year. The overall saving can be attributed to equipment upgrades as well as systems optimisation. The improved data collection system has helped to shift the focus from reporting to monitoring for improvement. Daily plant meetings monitor performance over the previous 24 hours and look for discrepancies.

Changes to the refrigeration control system, including the installation of VSDs and the VHPC, may have reduced refrigeration energy use by up to 10%. More significantly, the installation of the VHPC allowed the Devonport facility to continue operating despite the loss of two compressors. This avoided the potential loss of up to one third of the season’s pea production.

Even after the replacement of the transformer, the plant often operates without the need for two of the compressors during the summer peak processing season. The energy savings continue to accrue from optimal control, however the major benefit of improved control is the reduction of risk due to the improved flexibility and redundancy available to cope with any production situation.

Next steps

Driven by the benefits already achieved from improved data collection systems, the next stage of development is to provide online energy performance indicators by combining production and energy use information in real time in the SCADA system. This will allow operators to see directly how each production line is performing from an energy intensity point of view.

It will also enable forecast modelling to be undertaken based on typical plant operations over a seven-day period, rather than maximum demand. Operators will be able to monitor actual energy use compared to forecast energy use, and to take action immediately if there are any discrepancies.
Case Study 2

AngloGold Ashanti Australia Ltd:
Optimising existing data and control systems to improve energy efficiency

About AngloGold Ashanti

AngloGold Ashanti is a gold exploration, mining and marketing company headquartered in Johannesburg, South Africa, with operations and projects on four continents.

In Australia AngloGold own the Sunrise Dam gold mine near Laverton, Western Australia, which has been in operation since 1995. The mine began with open pit operations, and in 2003 commenced underground mining. The processing plant at Sunrise Dam is typical of many gold mining operations, consisting of crushing and grinding processes, and carbon-in-leach (CIL) technology to recover gold. The mine employed approximately 500 people and consumed 2.69 PJ of energy in 2011-12. Approximately 80% of energy is from gas and 20% from diesel.

Why the project was initiated

Systems optimisation was initially considered by AngloGold as a means to improve productivity by reducing downtime in the milling and crushing plant (Figure 10). The objective of the project was to improve throughput by maximising the productivity of the plant.

Figure 8: Sunrise Dam gold mine. Karl Schoemaker/AngloGold Ashanti Australia Ltd.

Figure 9: Processing plant at AngloGold’s Sunrise Dam gold mine. Karl Schoemaker/AngloGold Ashanti Australia Ltd.

Why the project was initiated

Systems optimisation was initially considered by AngloGold as a means to improve productivity by reducing downtime in the milling and crushing plant (Figure 10). The objective of the project was to improve throughput by maximising the productivity of the plant.
The team sought to increase production by finding the optimum processing rate, and sustaining that rate as much as possible by eliminating causes of downtime or process bottlenecks.

The project was not labelled as an energy efficiency initiative because it was entirely focussed on improving production, productivity and profitability. Increasing throughput inevitably improves energy efficiency, but this was a benefit rather than a driver for change.

The project received additional impetus from a number of energy efficiency initiatives. The process engineering team at Sunrise Dam conducted an energy management study in 2007, in part to meet the requirements of the Australian Government’s Energy Efficiency Opportunities program.

One of the findings from this study was that a significant amount of data had been collected by the existing systems at the plant, but it had never been analysed to identify opportunities for improvement. The SCADA system was already in place but it was underutilised. This prompted the process engineering team to conduct a ‘stocktake’ of what could be done with its existing control system.

**Data and control systems at AngloGold Ashanti**

The processing circuit at Sunrise Dam is controlled by a PLC. A SCADA system provides the human-machine interface, with a mimic of the plant and display of key performance measurements (Figure 11). An objective of the optimisation project was to improve the control logic running in the PLCs to minimise the amount of manual intervention required by the operational staff.

Operating data is collected by a data historian, which continually interrogates the SCADA system and stores operating data and faults in an SQL (structured query language) database. The SQL database can be accessed by many different software packages, and by multiple users simultaneously. Easy access to high quality data enables much of the optimisation opportunities to be identified and evaluated.
Sunrise Dam has upgraded its historian regularly over the years. The purpose of the upgrades was not for functionality but rather to keep current with the technical support packages offered by service providers.

Figure 11: A screen shot from AngloGold Ashanti’s SCADA system

**How systems optimisation was implemented**

**Taking stock of existing data and control systems**

Before looking at any equipment upgrades, the engineers first investigated how they could unlock the potential of the operating equipment that was already installed.

The existing control systems and operating methodologies were designed to avoid out of control events or unstable events, and were working reasonably well in this regard. However, the plant was avoiding these unstable events by running well below the capability of the equipment.

Many of the operating costs of the processing plants are fixed regardless of throughput, while other parts of the process become more efficient at higher levels of utilisation. Maximising the throughput of the plant lowers the energy consumption cost per tonne. Increasing the throughput results in an increase in power demand, but the overall energy intensity improves, resulting in an improvement in profitability.

The project team investigated options to minimise the amount of idling time in crushing and milling equipment, and the time that equipment spent operating outside its ideal speed or throughput range. They also investigated instances when the circuit became unstable to gain a better understanding of the constraints and limitations of the plant.

For example, if the feed supplying ore into the mill stopped but the mill continued to operate, then the mill would still draw a substantial amount of power while adding to wear and tear on the milling balls. One area of optimisation was to ensure that the mill only ran when sufficient feed was supplied. Other problems can occur if the mill is optimised to run at a certain
throughput and the throughput is increased, resulting in an overload. This may require the circuit to be stopped while the overload is rectified, resulting in a net loss of productivity.

Before making any changes to the control system, the project team developed a full understanding of the ideal operating range for each part of the circuit. The project team looked for other events that caused faults and downtime, and these were fixed first.

**Implementing systems optimisation**

All systems optimisation upgrades were implemented through changes to the logic and control algorithms of the PLCs.

Prior to implementation the initiative was given a high profile and actively promoted by the processing manager at Sunrise Dam. It was regularly discussed in production meetings, and became a part of the performance evaluation process. The process manager for each area of the plant was responsible for identifying opportunities, developing the business case, implementing opportunities and measuring the results with SCADA.

Optimisation projects were scoped and budgeted, and then ranked based on payback period and production improvement. Once approved, external contractors were engaged to implement the programming changes.

**Training operators**

As new control system upgrades were implemented, it was important to minimise manual intervention by the plant operators. Systems were put in place to monitor how often control loops were in automatic mode, and to log times when the plant was switched to manual control.

A training program for plant operators was introduced to support the changes. Under the old system operators regularly had to intervene in the process to make changes, often prompted by warnings or alarms from the SCADA system. The training focused on how to use the data in the control system to be proactive rather than reactive.

Operators were still able to take manual control of the system at any time, and were instructed to do so if they felt the need to switch off the automatic control system. They were also asked to make a note of the reason why they had to switch out of automatic mode, so that the process engineers could understand what the limitations of the automatic control system were, and which issues to address next.

**Benefits achieved to date**

The operators now proactively use the control system to keep the plant working within defined operational parameters. The benefits achieved to date include:

- fewer maintenance events (less downtime)
- increased throughput
- improved energy efficiency
- reduced unit costs.

**Reduced maintenance and downtime**

Increased stability in the processing circuit has resulted in less damage and therefore fewer unplanned maintenance events. This in turn has improved throughput and energy efficiency. Under the new system it is clear when efficiency is starting to move away from the optimum band or power range, and the operators can investigate and either make adjustments or schedule machine maintenance.

Savings have been realised through the development and operation of a list of normal operating parameters and operating bands for the plant. The plant operators now work to
keep the plant within the specified envelope and as a result energy savings have been achieved.

**Improved crusher operation**

The crusher is now controlled within a power band, as defined by the ore being fed to the ROM (run of mine) pad. This mode of operation has reduced energy consumption through the crushing circuit by reducing the amount of recirculating load in the circuit. In the past, recirculating load has meant that energy is wasted ‘crushing out’, where the circuit is run with no fresh feed being added. This project has also resulted in a steadier operation of the crushing circuit, which allowed optimisation to be completed in downstream operations. The estimated energy saving for this project is approximately 50 GJ/year.

**Mill optimisation**

The efficiency of the milling circuit has also been increased through improved process control. Grind surveys are being regularly undertaken to ensure the mill is operating effectively. The overall aim is to reduce incidences when a ‘grind out’ is required. This occurs when the mill is overloaded and must be operated with no fresh feed being added, to remove some of the load from inside the mill.

**Next steps**

Having optimised the processing plant, AngloGold engineers are now looking at upstream processes, prior to the crushing circuit. The objective is to understand what causes the crushing circuit to stop, and how the running time of the crushing circuit can be maximized. This requires the use of reliable techniques to examine how improvements in operating conditions and maintenance programs can improve running time and minimize downtime.

The mining process that delivers ore to the crushing circuit has become another upstream area of focus. Engineers are looking at how they can improve the quality and consistency of material that is presented to the crushing circuit. With the transition to underground mining and the associated changes in ore, this aspect of overall mine optimisation becomes more critical.

The lessons learned about systems optimisation at Sunrise Dam will be applied to the company’s new Tropicana mine near Kalgoorlie (WA), and to mines in Colombia.

Left: The crushing and grinding circuit at Sunrise Dam.  
Right: The onsite power house at Sunrise Dam.  
Karl Schoemaker/AngloGold Ashanti Australia Ltd.
Case Study 3

Worsley Alumina:
Achieving quantifiable business benefits through systems optimisation

About Worsley Alumina

Worsley Alumina is a joint venture bauxite mining and alumina refining project between BHP Billiton (86%), Japan Alumina Associates (10%) and Sojitz Alumina (4%). Based in the south-west of Western Australia, operations include a bauxite mine in Boddington, alumina refinery near Collie and port operations in Bunbury. Worsley employs about 2000 permanent employees and contractors.

The refinery commenced operations in 1984 and has undergone several expansion over the years, including a major expansion completed in 2012. The current annual production capacity of the plant is 4.6 million tonnes of alumina per annum. It used 36.5 PJ of energy in 2011-12.

Why the project was initiated

Worsley Alumina began implementing its Advanced Process Management system in 2004. At that time the refinery had been in operation for 20 years, and the engineers were given the mandate to set the plant up for the next 30 years. A high priority was the implementation of multi-variable controls (MVC) throughout the plant. This sought to combine the deep, latent understanding of the process, held by the plant engineers and operators, with the intelligent use of modern control systems, with the aim of improving profitability (Figure 12).
Data and control systems at Worsley Alumina

The Worsley Alumina refinery is comprised of several processes with complex and multivariable interactions between them. The plant is controlled by a DCS. This provides the human-machine interface, and is networked, enabling the integrated data management and control system access to all plant processes.

Operating data is stored and managed by a data historian. This system allows engineers to access historical data that can be used to analyse past performance, improve their understanding of the system characteristics and performance, model system changes, and substantiate business cases for further modifications.

MVC is a popular technology for advanced process control, usually deployed on a supervisory control computer, which identifies important independent and dependent process variables and the dynamic relationships between them. It uses algorithms to control multiple variables simultaneously.

Figure 12: Worsley Alumina Refinery approach to system optimisation

Figure 13: Screen shot of real-time data acquisition for spent liquor system at Worsley Alumina
How systems optimisation was implemented

The implementation of systems optimisation technologies was a major project, and it was broken into several discrete stages to evaluate the costs, benefits and risks. The project team combined in-house engineers, vendor engineers, and third party engineering consultants.

Mandate from senior management

The business case that was presented to management went beyond the financial costs and benefits. After many years of successful operation, senior managers and plant operators had to be convinced that the process could be managed in this new way. One way that implementation risk was overcome was by ensuring that the automatic MVC control application could be switched off by the plant operators at any time. This safety measure allowed plant operators to restore manual control when required.

At the time that the project commenced, systems optimisation was not widespread in the alumina industry. The Worsley Alumina engineers also leveraged off the successful deployment of MVC in other industries, such as the oil and gas industry, where MVC has been established as a reliable way of achieving greater plant efficiency.

The engineers also engaged with the vendors of MVC and systems optimisation technologies to help evaluate the feasibility of the project, and explain how risks would be managed. The benefits of systems optimisation were sold to management on the basis of attractive payback periods and comprehensive risk management.

Front end study

With a mandate from senior management to develop the full feasibility of an MVC implementation, the project team began a front end study. This study was a standard process from the vendor that had been selected to supply the MVC system. The process engineers set out the terms and specifications of the front-end study at the start of the process, and then fully interrogated and questioned the findings, providing feedback on changes until they were satisfied with the results. This created a sense of ownership all the way through the process.

Implementation

Following the completion of the front end study, the project team received approval from senior management to proceed.

The engineers began by designing an MVC system for spent liquor temperature control. To characterise the process, they had to operate it ways that had not been done before. They took it closer to its upper and lower limits, left it under automatic control, and monitored the process to see how the different variables interacted to influence temperature. Operators still had the ability to switch off control if anything went out of bounds. Data from the system characterisation process was analysed in detail, and used to develop rigorous models and simulations which became the basis for the design of the MVC system.

The Worsley Alumina refinery is a complex planting comprising many different processes, as shown in Figure 14. After the first MVC process was implemented and shown to be successful, other ideas for applications were developed in other parts of the plant. This increased comfort with the system as it evolved.
A large component of the budget was engineering labour. Consultants and contractors were based on-site for the duration of the project. Locating the consultants on-site, full-time, was deemed to be critical to the success of the project.

After the successful implementation of each MVC system the consultants could then be scaled back to be on-site only when required, typically for 2-3 week periods to help with specific changes.

For the first applications the team did not introduce any new instruments; using only existing plant and equipment. Then, after seven or eight applications, management felt comfortable enough to approve instrumentation and actuator upgrades.

Once the project had been approved and a budget had been allocated for implementation, it took about six months to implement each MVC for an individual process. Worsley found that the development of MVC is a specialised skill, and external specialist contractors were used throughout each implementation.

**Benefits achieved to date**

Improved process control has allowed Worsley Alumina to increase yield at the refinery with an associated improvement in energy efficiency. This has been achieved by reducing process variability and downtime.

Before the MVC was implemented, plant operators had to micro-manage the process using frequent manual adjustments and interventions. One of the key benefits of the MVC is that the process variability was dramatically reduced. The MVC is capable of much finer and faster system control than plant operators manually adjusting the process.

Once the system had been implemented, the refinery observed ‘orders of magnitude’ reductions in the number of operator interventions (Figure 15). This reduces operator workload, and operator error. The MVC is now controlling the process more than 98% of the time.
Reduced maintenance costs and improved reliability

The MVC dramatically improved system stability, resulting in a dramatic reduction in planned maintenance activities. An example is the seed pump changes (Figure 16), which were changed regularly prior to the implementation of the MVC. The MVC improved system stability, which reduced the number of starts and stops on the seed pump, resulting in a marked improvement in reliability and a reduction in the number of change-outs.

Increased productivity and energy efficiency

The benefits from implementing the spent liquor MVC had a payback period of 7 months. The MVC allowed the spent liquor temperature to be controlled within a much tighter band around the set-point (see Figure 17). From an energy perspective, the higher the spent liquor temperature up to a target temperature, the less steam and hence energy that is required to meet temperature targets. However, if the spent liquor temperature is above target, energy will be rejected from the system.
This improved system stability allowed the engineers to increase the set point closer to the maximum temperature because of greater confidence in the ability of the system to control to that set point. The MVC was able to respond to disturbances and changes much better and faster than hands-on operators could, allowing a reduction of the safety margin between the process set-point and the warning or alarm threshold, resulting in an energy efficiency improvement.

The energy efficiency benefit of projects is estimated in terms of the additional tonnes of alumina that could be produced each year. The expected benefit of MVCs was equal to an additional 500 tonne of alumina produced per year, but the actual benefit was over 3,000 tonnes.

**Next steps**

Some of the MVC equipment has only just come on line. A priority will be to go through the data to make sure that it is as accurate as possible. This is essential to ensure that the project team can measure the benefits of any improvement.

Based on the success of the project to date, Worsley engineers are planning to install MVCs on all processes within the refinery. They will also install an optimisation package on the new cogeneration power station.

There is also now a very substantial data history on the plant, going back over ten years, which will be analysed in greater detail. This is expected to yield new insights into the potential application of the new control system and more opportunities for improvement.

**Lessons learned**

**Before you invest in expensive control systems, look at what you already have**

The three companies profiled in this case study show some of the ways that process control can be improved without a large up-front investment. AngloGold Ashanti improved its process control by changing the logic and control algorithms of the PLCs. Operators are now able to use the systems optimisation calculations to keep the plant within its ideal operating range.
Prepare a persuasive business case

Considerable analysis and evaluation must be undertaken to present a business case to senior management. This includes whole-of-business costs and benefits, including:

- quantifiable financial benefits expressed as total cost savings, simple payback and/or net present value
- other benefits such as product quality or occupational health and safety.

A commitment from senior management through to the process operators is essential to effectively implement systems optimisation. However, true systems optimisation technology has only been introduced to Australia in the last 10-15 years, and its implementation has been limited. A persuasive business case is therefore required in order to secure senior management commitment. Evaluation of the costs and benefits of installing such a system and how these are presented to the stakeholders is important.

Costs that should be considered include:

- **Third party systems optimisation engineering consultants**
  Due to the high level of expertise required to effectively implement systems optimisation and the extensive time required to undertake the front end engineering design study, third party engineering consultants may be required.

- **Systems optimisation vendor engineering design**
  The selected systems optimisation vendor will often deploy their own engineering staff to work with the engineering consultants and client’s engineering personnel in order to adapt their technology to suit the client’s requirements.

- **Internal engineering staff contribution**
  The engineering staff on site will need to be involved in the development of the systems optimisation design, the installation and the subsequent monitoring.

- **Systems optimisation technology and installation**
  The systems optimisation software and hardware supplied by the selected vendor will form part of the initial investment outlay. Generally, the vendor will provide their own specialised electrical contractors to conduct the site installation and commissioning, which will be a significant part of the overall investment cost.

- **Instrumentation and sensors**
  Depending on the complexity of the existing process control system, the introduction of new sensors and actuators may be required in order to realise the full potential of the systems optimisation technology. However, it may be easier to minimise the introduction of new sensors and actuators initially to simplify the installation. This will decrease set-up costs and make it easier to gain support from management until the benefits can be clearly demonstrated.

- **Personnel training**
  The process engineers and operators that will be involved with the systems optimisation will require training to understand how it works, how to utilise the interface, and how to continually develop and refine the process modeling to maximise results.

The business case also needs to show how systems optimisation will be integrated with existing processes and how any potential risks will be mitigated. The introduction of new technologies is often met with a healthy amount of caution and scepticism, and risk assessment and mitigation is an important component of any major control system change or
upgrade. Actions to address some of the perceived risks associated with system optimisation projects are outlined below.

- **Manual control override**
  A key perceived risk associated with systems optimisation is that due to the autonomous nature of this type of control, the process operator may not be able to intervene if the process is operating outside of its accepted maximum or minimum constraints. However, systems optimisation technology can be designed to allow human intervention at any stage as a safety precaution.

- **Return on investment**
  A level of caution will generally be taken due to the possibility that the investment in systems optimisation will not produce the expected results and associated return on investment. This is generally mitigated by thoroughly investigating the costs and benefits, and engaging an experienced team of consultants and suppliers. Case studies could be provided of similar facilities that have achieved the anticipated outcomes of systems optimisation.

- **System characterisation**
  There is a risk of incorrectly characterising or modeling a process. During the development of the systems optimisation modeling it is essential to simulate the process in order to ascertain the optimal outcomes prior to actual implementation. This iterative approach will mitigate the risks associated with incorrect system characterisation.

- **Ongoing costs**
  Subsequent to the conclusion of the implementation and commissioning stage, there is a risk that there will be ongoing costs due to a requirement for continued assistance and technical support from the vendor. Such support includes software upgrades and annual licensing costs, training of personnel and de-bugging of the system after installation. Clearly defining the expected outcomes and the level of support from the vendor in the contractual documents will mitigate this risk.

- **Process operators**
  The autonomous nature of real-time systems optimisation can be a barrier to the development and training of less experienced process operators and engineers in terms of their understanding of controlling a process. Training simulation can be provided to allow them to understand the process and gain confidence in the system’s ability to control critical processes and react appropriately to disturbances.

**Undertake a staged implementation process**

It may be wise to limit the scope initially, for example by implementing systems optimisation on only one process or aspect of an industrial facility. This minimises the initial investment costs and the project can be utilised as a pilot to demonstrate the potential benefits.

An external specialist may be required to undertake a front-end engineering design study. Internal process engineering staff will define their own objectives for the project and it is then the responsibility of the specialist to work in concert with the client to design and develop the system in line with these objectives. Throughout the design and development stage various systems optimisation technology vendors should be included in discussions to ascertain the capabilities of the currently available technology.

Some companies may not need to use an external specialist. Worsley Alumina required consultants to be involved at a very early stage, but AngloGold Ashanti developed the
opportunity and business case for systems optimisation themselves. They only brought in external contractors to implement code changes in the PLCs.

Once the system has been specified, the preferred vendor appointed, and the equipment procured, the installation and commissioning stage can take a number of months to realise the full potential of the optimised process. During this time the vendor engineers will work with the client to develop and fine-tune the process models, through prioritisation of hard constraints and further definition of soft sensors. The process operator and engineers will also undergo an intensive learning process to understand how to effectively utilise the systems optimisation technology.

Ensure you have access to the required skills

While all three companies managed the systems optimisation process using in-house engineers, they also found it most cost effective to use external contractors to implement the software and hardware changes required. In-house engineers at Worsley Alumina have learned much about MVC and real-time optimisation, but are not planning to build-up the full suite of specialised skills in-house.

Worsley Alumina also expects to continue using consultants when deploying MVC to a new part of the plant. However, the internal knowledge of costs and benefits of systems optimisation technologies is continuously being improved and refined, leading to identification and evaluation of better opportunities.

Simplot found that they only started to achieve the full benefits of optimisation after they’d employed an experienced process engineer. This brought more of the knowledge and expertise in-house and helped to build ownership of the new system.

‘For this to be successful, you have to have the skills in-house. Contractors are important, but once they leave they take the knowledge with them. It’s also a matter of ownership. If you have someone on staff they will always be thinking about opportunities to improve the system.’

Graham Bryant, National Environment Manager, Simplot Australia

Manage the learning process

The introduction of greater automation can be challenging for both process engineers and operators, who may feel that they’ve lost some control over the process. A staged implementation process will help to address this by allowing the team to identify and address any difficulties as they arise. It will also help to build internal support. Once the liquor project had been implemented at Worsley Alumina, operators understood what MVC could do and started to look at other potential targets. Operators need to be able to restore manual control when required, in the same way that the ‘cruise control’ function in a vehicle operates.

At AngloGold Ashanti the new process control system also met with some resistance. Some people were amenable to a greater use of automatic controls, while others thought that humans could run the plant better than an automatic control system. However, as operators became more accustomed to the capabilities of the control system, they were less likely to intervene. It was important to let the control system manage the process and observe the results, so that it could continue to be improved. Operators were asked not to switch out of automatic mode unless there was an alarm. By letting the system run, and then observing the results, engineers could determine whether they could run processes closer to their operating limits. Once the operators learned to trust the PLCs to safely operate the plant, the number of operator interventions, and the number of alarms, dropped off significantly.
Maintain operator proficiency

Following implementation of systems optimisation, operators may start to lose the ‘feel’ for the process. The only way operators can learn the process is by changing the system and seeing what happens, but with increasing automation more of this knowledge is embedded in the system. This is a risk because operators need to manage the process if the system goes down for any reason.

To address this problem Worsley Alumina has set up training simulators for two of its processes. Simulation allows operators to understand the process and gain confidence in the system’s ability to control critical processes and react appropriately to disturbances.

‘Real-time systems optimisation is like the cruise control function in a car. A sensor monitors the car’s speed and feeds this information to a controller that adjusts the throttle to maintain the desired speed. For example, when the car goes uphill, the speed drops back and the throttle position changes to increase engine power and the speed of the car. However, the driver can always take back control if necessary.’

Angelo D’Agostino, Senior Process Control Engineer, Worsley Alumina

Conclusion

The benefits of systems optimisation go beyond energy efficiency. Real-time optimisation can achieve significant improvements in productivity by allowing the process control system to adapt to changing conditions (both internal and external) in real time.

There are many different ways to implement an optimisation process, depending on the type of business and the primary objectives of the project. The case studies presented here demonstrate that it can be undertaken with varying levels of automation. It can be implemented at relatively low cost, for example by repogramming an existing process control system. In large and complex manufacturing environments there may be a strong business case for optimisation, which can justify a more substantial investment in software and equipment.

There are challenges involved in implementation, but these can be overcome. The case study companies managed risks by staging the implementation process to fine tune the process and to build support from managers and operators.

Systems optimisation will become increasingly important in Australia and globally as companies seek to reduce costs and remain competitive. At least two of the companies profiled in this case study implemented systems optimisation in response to an unprecedented increase in energy prices.

Compliance drivers like the Energy Efficiency Opportunities Program encourage companies to develop a deeper understanding of their energy use in order to identify efficiency improvements. Systems optimisation takes this process to a higher level of sophistication and effectiveness.

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