Quantification of the Potential and Benefits of Process Improvements Using Process Energy Optimization Methodologies

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ABSTRACT

Process Energy Optimisation (PEO™) is a new holistic approach that takes both energy and material flows into consideration when improving bottom-line results for industrial facilities. The purpose of Process Energy Optimisation is to maximize production or yield, whilst minimizing costs associated with production, such as energy and water consumption.

Industry is interested in making a profit. This can be achieved through energy efficiency. The benefit to industry can however be increased with PEO™ by taking a holistic and optimised approach by considering both energy and production. PEO™ aims to optimize all resources thus providing better benefits than conventional conservation approaches. This is achieved without compromising on production targets or product quality to simply save energy.

Processing plants tends to operate in a number of efficiency modes for various reasons. These modes of operation depend on a large number of controlled and uncontrolled variables. Each of these variables have an influence on the overall process efficiency. The methodologies developed and used for PEO™ will identify these modes of efficiency. They will also identify trends in the performance of the facility. The PEO™ scoping investigation will quantify the potential and benefits of process improvements based on the operational and system performance already achieved by the plant.

Introduction

The increasing cost of electricity in South Africa in conjunction with the strengthening Rand against foreign currencies is forcing many South African industries to rethink their current operational and production practices. Since electricity is a significant variable cost in production, the industries need to explore strategies to make their operations and production more energy- and thus cost effective.

In some cases the selection of certain tariff structures for large consumers in the industrial sector have caused production at a loss during certain periods of the year, typically the peak periods in the winter months. These winter months are the months of June, July and August. Figure 1 provides a schematic breakdown of the various time-of-use (TOU) periods under the Megaflex tariff structure.

It is common under this tariff structure, which is commonly found in the industrial sector, that the electricity cost can increase by as much as 227% during the winter (high demand season) peak periods when compared to the same periods for the summer (low demand season) [Eskom 2004]. The majority of the industrial sector however continues to produce during these periods due to production- and sale budgets that simply need to be met for local and international markets.

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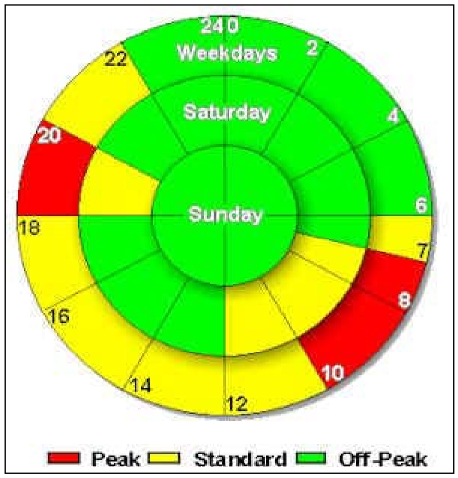
Figure 1. Time of Use Periods



Industry is interested in making a profit. This can be achieved through energy efficiency. The benefit to industry can however be increased with PEO™ by taking a holistic and optimised approach by considering both energy and production. PEO™ aims to optimize all resources thus providing better benefits than conventional conservation approaches. This is achieved without compromising on production targets or product quality to simply save energy.

This article provides a short overview of the Southern African industrial sector and the problems associated with the implementation of energy efficiency and load management in this sector. This paper also briefly describes the rationale behind PEO™ and the stages involved in the implementation of a PEO™ solution. The focus of the paper is however placed on the initial phase of PEO™; namely the scoping investigation.

The methodologies and procedures followed during the scoping investigation is discussed in detail. The data required to perform the PEO™ scoping investigation is discussed and a number of analysis techniques are provided. These methodologies are used to structure the data and key performance indicators in such a manner that trends and operational modes can be recognized. These methodologies are essential in identifying the potential and benefits of process improvements. Actual cases are used to demonstrate the effectiveness of the PEO™ analysis techniques and to demonstrate typical results found on industrial sites.

Energy and the Industrial Sector

The industrial sector accounts for 55% of all energy consumed in Southern Africa [Den Heijer & Grobler 2001]. The industrial sector was also the largest contributor to carbon emissions in Southern Africa, some 67% of total carbon emissions. The closest following sector was the residential sector. It is thus the logical step to focus on the industrial sector in order to achieve the largest impact in terms of energy efficiency, load management and climate change mitigation.

The industrial sector differs drastically from the residential- and commercial sectors because it is driven by certain processes. Unlike the residential and commercial sectors where poor energy management can lead to indoor comfort being compromised, the industrial sector simply can't afford to compromise their process or production. It is consequently very difficult to "sell" energy efficiency and load management when there is even a slight chance that it could influence production in a negative manner. It is for this reason that our approach makes use of a Decision Support System that doesn't take control out of the operator's hands, but rather assist them towards high performance and energy optimised control.

It is thus not possible, and certainly perilous, to consider the utilisation of energy on an industrial plant independent of the most critical key performance indicator, namely production. It is necessary to consider the whole process and not only the energy that it uses. This implies that the focus is not only placed on the efficient use of energy, but also on efficient production. In Southern Africa a large scope exists for process energy optimisation. This can be seen in the oversized systems that are often installed and also in the inefficient control of energy intensive systems.

Rationale behind PEO™

PEO™ has been developed to enhance the value proposition to customers by looking both at energy and material flows through a facility.

- The purpose of Process Energy Optimization (PEO™) is to:
- Maximize yield/production; while
- Minimizing production costs and resource costs like energy and water.

PEO™ is an integrated systems approach with the viewpoint that clients are more interested in profits than simply reducing energy consumption. They should use energy as a tool for making money. Energy usage is therefore not inherently good or bad. Efficiency in the PEO™ contexts is therefore defined as getting what you want in the most efficient way. PEO™ aims to optimize all resources thus providing better benefits than conventional conservation approaches. Finally it never compromises on product quality or production to save energy.

PEO™ has specific applications in complex industrial systems and processes that are inter-related. It is an integration of the theory of constraints, traditional energy management and process improvement practices as well as energy analysis and process diagnostic tools and techniques.

Information and experience gained from over 100 industrial and commercial audits have shown that industrial plants are usually designed quite efficiently for full load conditions, but are becoming more inefficient under part load conditions. Maintaining process stability and ensuring that the plant is operated close to its "sweet spot" for most of the time is therefore of utmost importance.

Processing plants tends to operate at a number of efficiency modes, depending on the input parameters that effect overall performance. The process will stabilize at a certain mode of operation for a period of time. As the input parameters starts to change the plant will keep on performing within this efficiency mode until the parameters have changed such that it force the process to switch to another efficiency mode. All of this still occurs within the operating boundaries set by the operators. Substantial production and energy efficiency benefits can be realized if systems are introduced that maintain process stability within the more efficient modes of operation.

The result of this is that in-house operational staff manage to achieve optimal performance and/or process stability some of the time. PEO™ has been developed to ensure that optimal performance and/or process stability is maintained most of the time, thus ensuring that the performance of the plant is also operating efficiently under part-load conditions.

Project Stages

The stages of any PEO™ project are such that it minimises the risk to the client. A scoping investigation is the first project stage. It is the aim of the scoping investigation to identify the potential for PEO™ and to quantify the potential benefits that exist to the client. Business cases are developed and submitted to the client. The project will not proceed if viable business cases could not be identified to the satisfaction of the client. The project will however proceed to the next phase if the potential do exist. Once the scoping investigation has been successfully completed and focus areas identified, the project will proceed to the next phase.

The next phase of the PEO project is to implement and deploy systems to capture operational and performance data of the plant and its various energy using systems. The project team require approximately 3 months worth of data to perform targeting and monitoring. The purpose of this stage will be to put the data infrastructure in place that would enable the project team to capture the performance- and operational data of the selected production systems. This stage is also associated with the identification of all the relevant operational- and performance parameters. It is these parameters that need to be captured, recorded and logged over a period of three months. Once the data acquisition infrastructure has been implemented and integrated with existing systems, and the parameters are being logged, the project can proceed to the targeting and monitoring stage.

An important part of the targeting and monitoring stage is concerned with the benchmarking of the system performance as it was operated and performing prior to any intervention from the project team. This would assist the project team to quantify the impacts of the project once the Decision Support System has been installed and operational.

Key performance indicators (KPIs) will be developed as part of the benchmarking and targeting exercise. The KPIs will be used to track and evaluate the performance of the affected systems over time.

Targets for the post-implementation performance and operation are also developed during this stage. These parameters will serve as the targets for performance and operation after the implementation of the Decision Support system.

An additional output of this stage will be the development of baselines that will be used to measure and verify (the final stage of the planned project activities) the impact of the project after implementation. These baselines describe the pre-implementation scenario of the system performance and are be compared to the actual post-implementation performance to determine the impact and ultimately the success of the project.

Extensive data mining is performed on the captured data during the engineering and design stage. This is done to identify the factors that are affecting the performance, energy efficiency and load levels of the plant systems. This stage includes a detailed cause analysis of the plant systems and their operation. This detailed cause analysis is done to get a clear understanding of the operation of the plant systems and to determine which factor(s) affect the performance of the systems.

The information and results obtained from the data mining and the cause analysis is used to engineer the solutions needed to ensure that the plant systems are be operated and controlled at its optimum efficiency levels. This include the development of models using rule based, fundamental laws, artificial intelligence, neural networks as well as regression procedures and techniques. The identified operational and technical constraints of the systems is then incorporated into the engineered solutions

The software of the Decision Support System (DSS) is designed and developed during this stage. The design and development is based on the engineering solutions developed during the engineering and design stage.

The DSS is tested extensively during this stage and all testing will be conducted in an “offline” mode of operation. Methods of integrating the DSS with the existing SCADA system on the furnace will also be developed during this stage.

The Decision Support System will be installed once the offline testing of the previous stage have delivered satisfactory results. Once installed, the DSS will be deployed to the production systems. This deployment of the DSS will also be coupled with its integration with the SCADA system. It will firstly be deployed offline for testing and evaluation purposes.

Deployment will be followed by a commissioning process and performance assessment. The first part of the commissioning stage will be to activate the DSS at which time it is again subjected to extensive testing and evaluation. This stage will also be characterised with the fine-tuning of the DSS and its operation. The purpose of the performance assessment will be to assess whether the project performs as intended.

A continuous measurement and verification process is put in place to track and evaluate the performance of the DSS over time. The baselines that were developed as part of the targeting and monitoring stage are used to quantify the true impact of the project.

Scoping Investigation

The purpose of the PEO™ scoping investigation is to quantify the potential and benefits of process improvements based on the operational and system performance already achieved by the plant.

This initial stage is a critical for PEO™ since it identifies the focus areas for the PEO™ project stages to follow and it determines the business case for the client.

A scoping investigation was recently completed for a large ferrochrome producing plant in South Africa. The ferrochrome plant had a number of large furnaces and ancillary systems operating for 24-hours of the day. The plant also operated under Eskom’s Megaflex tariff structure The discussion and case study results that follow in this article are applicable to this plant.

The project team had to identify and quantify the potential for load management and energy efficiency, as well as process efficiency during the scoping investigation. We needed to identify the potential to reduce energy consumption per tonne of production, as well as the energy cost per tonne of production. It secondly served to identify the areas on which focus should be placed to obtain the greatest results process energy optimisation in a cost effective manner.

The scoping investigation was conducted in a number of stages which included the following:

- Walk-through audit of plant;
- Interviews with plant maintenance and operational personnel;
- Implementation of a data acquisition system integrated with current plant systems;
- Identification of focus areas;
- Performance analysis;
- Benchmarking of plant key performance indicators;
- Identification of no-cost and low-cost opportunities in load management and energy efficiency;
- Identification of energy efficiency and load management opportunities; and
- Quantification of the potential impacts and cost savings with load management and energy efficiency.

A number of no-cost and low-cost opportunities for process energy optimisation were identified as a result of the scoping investigation. The majority of these opportunities were concerned with scheduling activities on the ancillary systems to the main energy using system. As the name implies, these opportunities have little or no costs associated with their implementation. Unfortunately they will also result in minor reductions in the electricity consumption, -demand or -cost.

The largest potential for electricity cost reductions and production optimisation was however identified in the areas of load management and energy efficiency on the furnaces themselves.

Data Requirements

Industrial electricity use is often concerned with complex processes that have a high level of interaction and dependability between systems and process stages. It is thus critical to assess the complete process to determine the interactions and set requirements that exist in order to gain a holistic understanding of the plant, its process and the flow of energy.

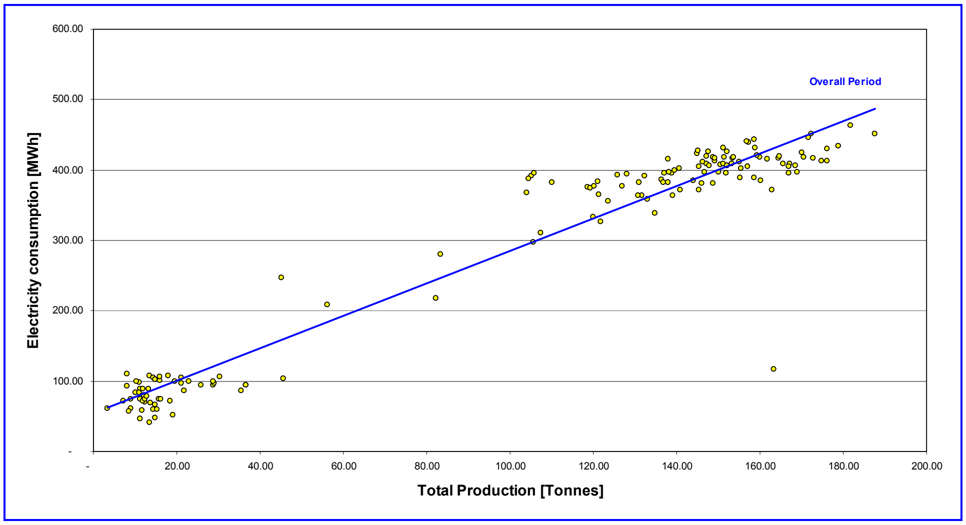
Processing plants tends to operate in a number of efficiency modes for various reasons. These modes of operation depend on a large number of controlled and uncontrolled variables. Each of these variables have an influence on the overall process efficiency. The methodologies developed and used for PEO™ will identify these modes of efficiency. They will also identify trends in the performance of the facility.

Large quantities of data are required to perform a PEO™ scoping investigation. This data typically consist of production data of some sort and energy usage that is linked to the production data. This data could thus consist of production and energy consumption data for a single furnace.

Analysis Methodologies

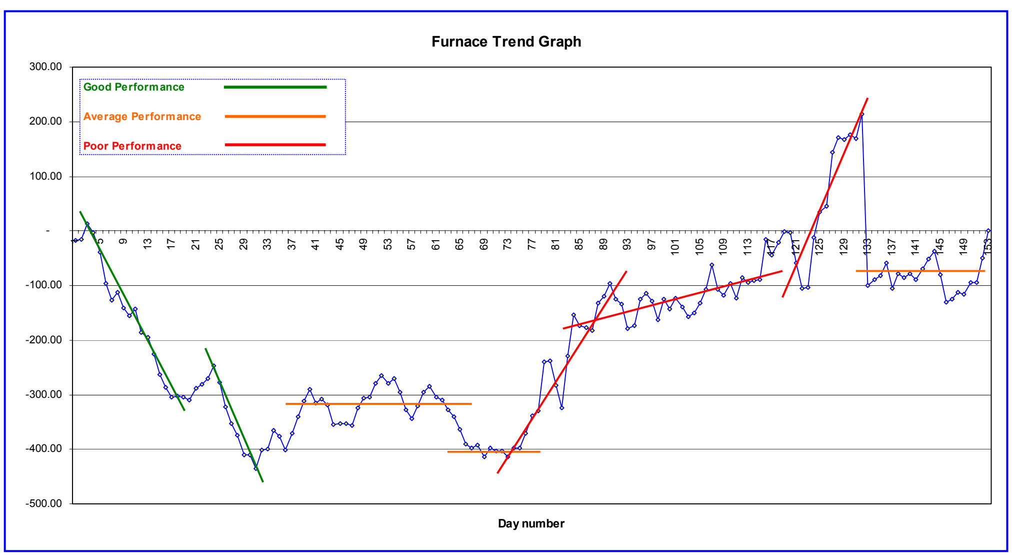
The first step is to establish the relationship between the energy use and the production data. Consider figure 2 that shows the electricity consumption per time interval against the production per time interval. It can clearly be seen that there are two very distinct modes of operation present for this furnace.

Figure 2. Energy Use versus Production



The next step is to look at the operational trends that exist for the furnace over extended periods of time. Figure 3 shows such a trend graph. Periods of good performance, average performance and poor performance can be identified from this graph. It is important to mention that all the mentions performance modes are achieved under current operational conditions, without any intervention by the project team. These modes have also been sustained over extended periods of time.

Figure 3. Operational Trend Graph for a Furnace



This is an important graph since it allows the project team to identify the various mode of operation, the rate at which transfer from one mode to next mode take place, and where in the operational history of the system in happened. This provided boundary of operation for the cause analysis stages that follow in the PEO™ project.

Typical Results: Load Management

The ferrochrome producing industry in South Africa is energy intensive due to the fact that it utilise large electric arc furnaces and substantial quantities of electricity to produce their product. The steadily rising cost of electricity caused one of Southern Africa's primary ferrochrome producing plants to take action to identify potential actions to reduce their production cost through the more efficient use of electricity. A scoping investigation was consequently performed to quantify the potential impacts of process energy optimisation.

In the area of load management the scoping investigation needed to determine whether it was possible to "shift" production, and consequently energy use, out of the peak periods (07:00 to 10:00 and 18:00 to 20:00 during weekdays).

Figure 4 (on the following page) provides the total plant load for five days. When considering the total load of the plant, it could be seen that there was a substantial level of variance in the load. This could mainly be attributed to the numerous furnaces being operated during the daily production cycles. The various furnaces thus formed the focal point for load management.

Figure 4. Typical Daily Total Electricity Profile for Plant

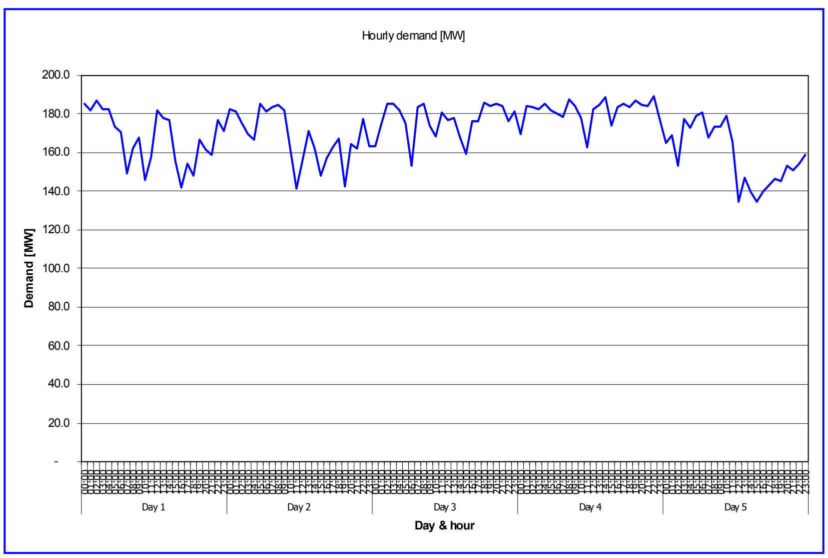


Figure 5 shows the typical daily load on a single furnace. Effective load management required that the energy demand be reduced during the peak periods (indicated on Figure 5) without affecting overall production in any negative manner. The production thus had to remain unchanged or increase over the same period. An analysis was made of the production, operation and energy use of each furnace. The analysis subsequently showed that the furnaces could be controlled in such a manner that the production could be reduced during the peak hours and made up in the standard and off-peak hours of each day.

Figure 5. Typical Daily Load Profile for a Single Furnace

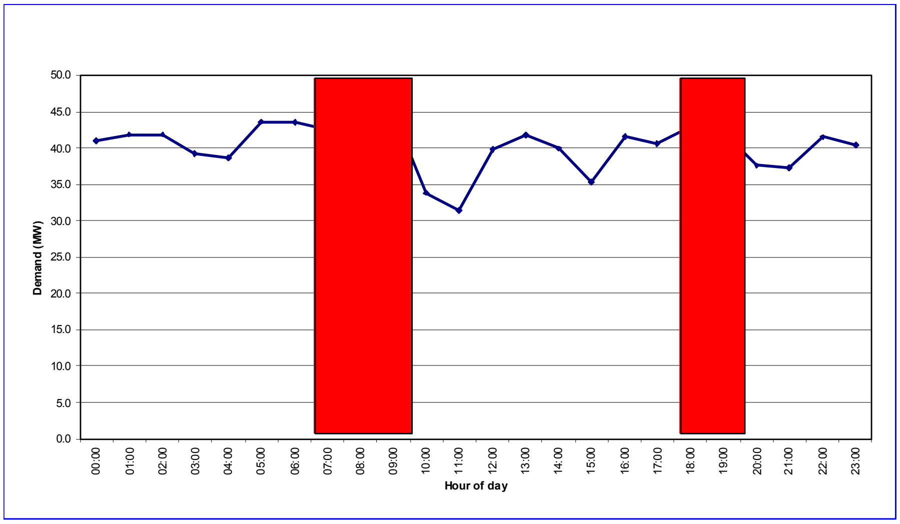
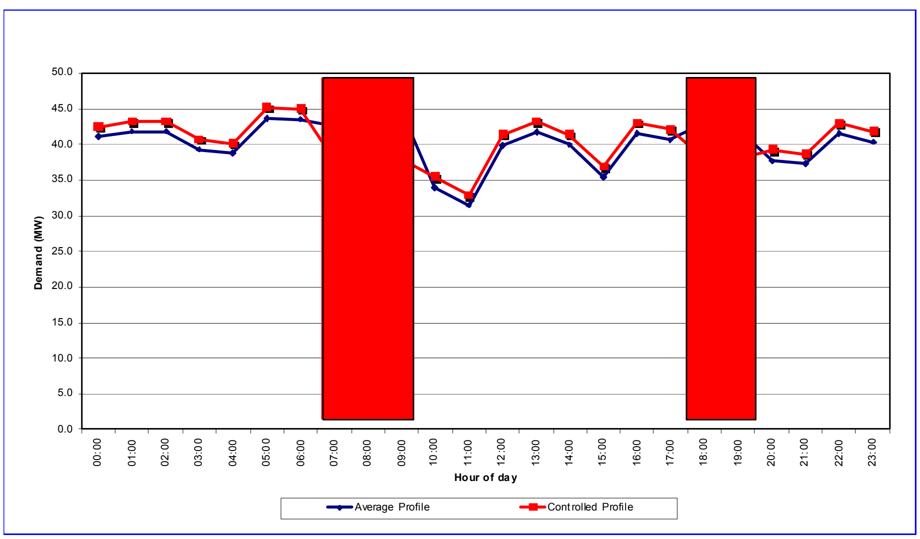


Figure 6 shows that the furnace didn't need to be switched off, but could continue to produce during the peak hours, but only at an average minimum level that is already being achieved for a limited number of times under the current production and operation strategy. The load management savings could however be increased if active control was done to the minimum of the minimum operational level during the peak hours.

Figure 6. Typical Daily Load Profile for Single Furnace with Controlled Profile



This analysis was repeated for all the furnaces. It was determined from the scoping investigation that the plant could potentially save between R1,8-million (control to average minimum load) and R3,7-million (control to minimum minimum load) per year through effective load management, depending of the level of control strategy acceptable under the production strategy. This was equivalent to between \$257,000 and \$529,000 per year.

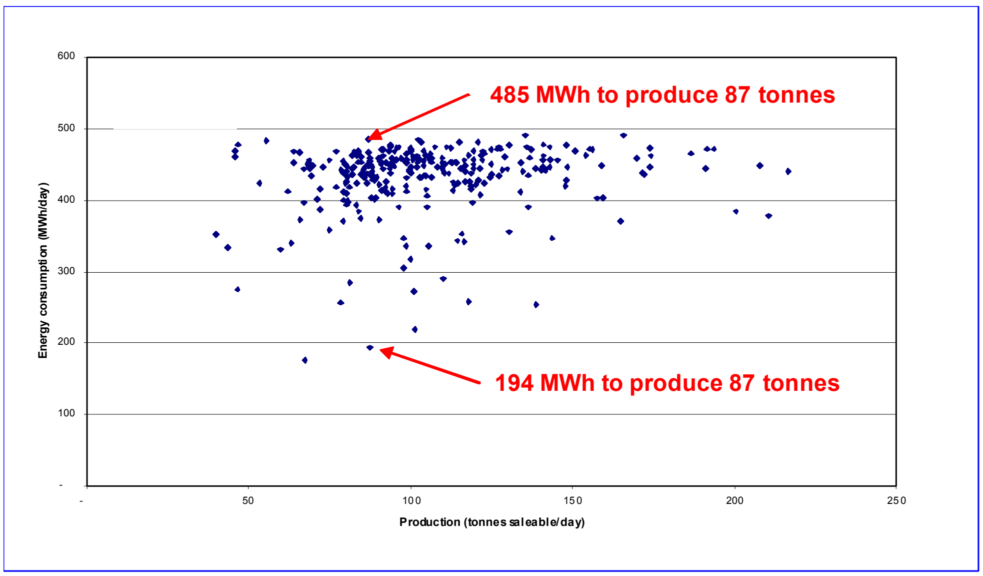
Substantial benefits could thus be obtained from effective load management on the various furnaces through PEO™.

Typical Results: Energy Efficiency

The next stage of the performance and energy optimisation scoping investigation was to quantify the potential impacts that could be obtained from increased energy efficiency on the furnaces. Consider Figure 7 (on the next page) where the daily energy consumption (MWh/day) is plotted to the corresponding daily production over a certain period of time. Figure 7 shows this relationship only for a single furnace. It can clearly be seen that there exist a very weak relationship between the daily energy consumption and the corresponding daily electricity consumption, which can be seen from the substantial scatter of the data.

To illustrate the point, consider the two days indicated on Figure 7 that have the same production figures, namely 87 tonnes of product for the day. Now consider their electricity consumption figures. The one day used 485 MWh to produce the 87 tonnes. The second day used only 194 MWh to produce the same quantity of tonnes. Something was clearly not in order with the operation of the furnace.

Figure 7. Daily Energy Consumption against Production for a Single Furnace



The scoping investigation needed to quantify the potential impacts that could be achieved if the performance could be optimised and for which the above trends could be eliminated. When considering the key performance indicator of MWh/tonne produced, it was determined that the energy consumption per tonne of production could be reduced by 15% on average for all the furnaces if effective control systems and PEO™ Decision Support Systems were integrated into the process to achieve energy efficient production.

The furnaces would thus consume less energy to produce the same amount of tonnes. A total energy consumption saving of 181,000 MWh could be realised at a cost saving of R 22,6-million per year (equivalent to $ 3,2-million per year).

It is important to note that the plant is already achieving efficient production, but only ale to sustain it over limited time periods. PEO™ will however assist plant operators and managers to sustain this efficient mode of production over longer periods of time and at more frequent intervals, thus most of the time.

If successfully implemented, the above impacts would increase the competitiveness of the plant in the international- and domestic market. It will also make a substantial contribution to the demand-side management efforts of the local electricity industry.

Summary

A holistic approach towards energy efficiency and production is needed to obtain maximum bottom-line results in industry. These outcomes must both be considered to obtain an optimised result of maximised production or yield, whilst minimising the costs associated wit production (such as energy consumption). Process energy optimisation takes this approach and sets targets for plant operation, production and energy use which it is already achieving, but not currently able to sustain.

The scoping investigation into performance and energy optimisation for a Southern African ferrochrome plant showed that there exist substantial benefits to produce under an energy efficient mode of operation.

The largest potential for performance and energy optimisation was identified for load management and energy efficiency on the plant's furnaces. The plant could potentially save between R1,8-million and R3,7-million per year through effective load management, depending of the level of control acceptable under the production strategy.

Energy efficiency with the assistance of Decision Support Systems on the plant and its furnaces could reduce its electricity consumption with up to 181,000 MWh per year, which could result in cost savings of to R22-million per year.

References

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