Technical Note:

An innovative technique for minimizing operational costs of end-user groups in a production environment

by C.J. Alberts*, M.W. von Wielligh*, and G.J. Delport†

Synopsis

The perception exists in many organizations that, once an energy management system is employed, there need not be any further adjustments to such a system. This is not true, as the field of energy management is a dynamic field, and constant feedback and adjustments are needed to enhance the efficiency of a system to the point that substantial pay-back can be obtained. It is stressed that for any energy management system to be successful, careful planning should permeate through the organization, from the top level decision-makers to the workplace. This paper describes a dynamic technique by which energy management strategies can be evaluated by viewing the effects of the strategies on the organization as a whole.

Introduction

The mines in South Africa are large consumers of electricity. In 1985, 27 per cent of South Africa's national electrical energy sales went to the mining industry[1]. This figure decreased to 22.6 per cent in 1993. However, the total national demand increased during this period. It is evident from these figures that least-cost energy planning and energy management is a necessity in the mining sector of South Africa.

Energy management and energy management systems:

- cannot be a one-man show
- cannot be self-maintaining
- require continuous effort, innovative ideas, and education
- require equipment modifications[2].

In the past decade, electricity was sold on a constant rate tariff. Then schemes such as time-of-day metering, peak-demand penalties, and volume discounts were introduced. These schemes recognise that the production costs of electricity vary according to both long-term and short-term factors. Electricity, as a commodity, is very much subject to economic concepts of supply and demand.

Keywords: energy management, cost function, real-time-pricing (RTP), systems modelling

A more desirable pricing scheme for electricity would allow for a variable sale price that depends on the spot price of power at any instant in time. This type of pricing scheme has been given the name Real-time Pricing (RTP). The RTP tariff allows the price of electricity to reflect variable production costs. Consumers may elect to modify their use of electricity during peak conditions, thereby reducing peak demand and minimizing the cost of electricity, and taking control of usage patterns and resultant costs[3].

In South Africa, as with the rest of the world, manufacturing industries are going through a period of major of change. Many organizations are currently searching for competitiveness through business process re-engineering, which focuses on removing non-value-adding activities from the organization. As manufacturing contributes to a high proportion of production costs, systems need to be in place to eliminate waste, continuously improve production processes, and increase resource utilization[4].

New electricity tariffs, like RTP, are envisaged for the future, hence the need for a real-time energy model. Such a model should be able to read outside inputs, calculate load profiles, log historical data, make adjustments to certain loads, minimize the operational cost, and interface with various control centres to influence the operational decisions.

The aim of this paper is to describe an innovative technique by which time-varying energy tariffs can be implemented in a production environment.

Systems modelling

It is stressed that in order to study the energy system on a production unit effectively, it is necessary to categorise the production unit into different sub-systems.

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In order to determine any potential cost saving, for example a new energy tariff , it is necessary to simulate the production unit as a whole with regard to the necessary 'What-If' scenarios. It is therefore necessary that detailed system configurations be compiled for each sub-system.

A building-block concept will be used to model each sub-system. Figure 1 is a representation of a simple model developed for a subsystem.

This simple model needs to be expanded for each different sub-system as the requirements differ for each model. The inputs and outputs of a typical sub-system that need to be studied is shown in Figure 2.

The development of the cost function will be discussed, as well as its importance to the modelling process.

Cost function

Energy models are powerful tools for studying energy problems. In practice, the only means of constructing a large-scale model is by the careful integration of separate mathematical descriptions of components of the overall system. This mathematical description will be referred to as the cost function.

The cost function is situated in the process block, as viewed in Figure 1. This cost function will include all the cost options to be considered in determining the various outputs.

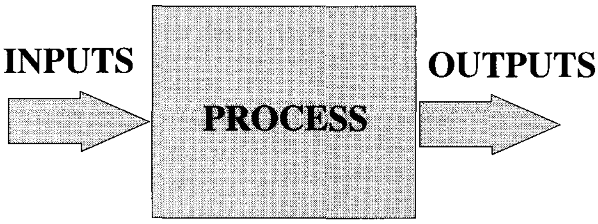

Figure 1—Example of a simple model

The total cost of operating and maintaining the production unit can be calculated by adding all the various sub-system costs together. The total cost of operations of the production unit per hour, Cr, is given by the relationship in equation [1]:

$$Cr = \sum_{n=1}^{k} C_{sn} \qquad [1]$$

where: $n = 1,2,\ldots, k$

k = the number of sub-systems.

The factors $C_{s1},\ldots,C_{sn}$, represent the different costs for each sub-system in the production unit.

Each sub-system cost, C_{sn}, comprises the different costs as described by equation [2]:

$$C_{sn}/h = (C_{pn} + C_{mn} + C_{en} + C_{cn}), \qquad [2\}$$

where n = sub-system number

C_{pn} = production cost

C_{mn} = maintenance cost

C_{en} = external factors cost

C_{cn} = capital cost.

The reason for developing a cost function is to supply the manager with a powerful mathematical tool to simulate various conditions, in order to produce the most economically sound strategy to manage a plant or a process.

Coefficient technique

When computing the different cost factors, as described in equation [2], it is necessary to find a correlation between inputs and production. For example, there might be a linear relationship between production and energy consumption. Thus, the cost of energy for a time slot can be computed by multiplying the production, energy tariff, and an appropriate coefficient together. The problem at hand is finding this

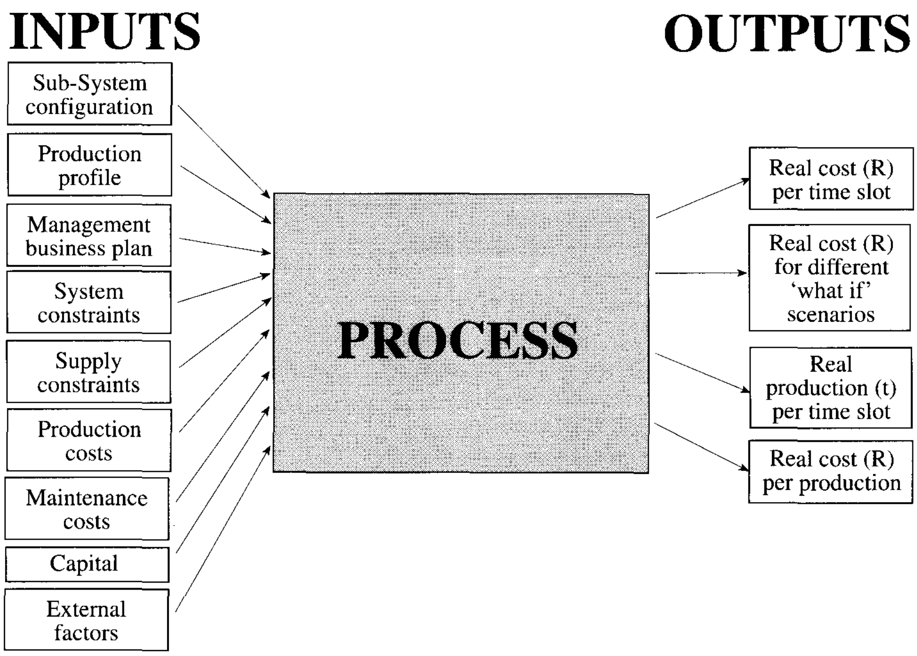

Figure 2—Inputs and outputs of typical subsystem

coefficient. The most accurate and also the easiest method by which such a coefficient can be found is by using data sampled from the actual production environment.

Equation [3] shows an example of how a coefficient or a cost factor can be computed for a cost function.

$$\text{Cost per hour} = \text{(tariff)(production rate)(coefficient)}$$
$$= \left(\frac{1}{100}\right) \bullet \left[T_e\left(\frac{c}{kWh}\right)\right] \bullet \left[P\left(\frac{t}{h}\right)\right] \bullet C_e \qquad [3]$$

Where C_e = an energy cost factor.
Installed capacity multiplied by kW delivery y production, where production might be a rate of tons per hour or litres per second, for example:

$$x[\mathrm{kW}] \quad \Leftrightarrow y\left[\frac{\mathrm{t}}{\mathrm{h}}\right]$$
$$x[\mathrm{kW}] \quad = C_e \bullet y\left[\frac{\mathrm{t}}{\mathrm{h}}\right].$$
$$\text{Therefore } C_e = \frac{x}{y}\left[\frac{\mathrm{kWh}}{\mathrm{t}}\right].$$

If no linear relationship exists between inputs and production, two routes may be taken. Firstly a coefficient can be computed for each state of production (if relevant), or the non-linear relationship can be found by the use of curve fitting.

These coefficients must be computed for each input to the cost function. Equation [4] shows an example of a complete cost function.

$$\text{Cost} = \begin{bmatrix} \left(T_e \times P \times C_{px}\right) + \left(T_{md} \times C_{md}\right) \\ +\left(C_{mp} \times P\right) + C_{man} \end{bmatrix} \qquad [4]$$

where: C_{px} = energy coefficient
C_{md} = maximum demand coefficient
C_{mp} = maintenance coefficient
C_{man} = labour cost coefficient.

This function takes into account energy, as well as maintenance and labour costs. It should be noted that each production environment will have its own cost function and relevant inputs.

By producing cost functions for the various subsystems of a large system, the total cost of production can easily be calculated using computer technology. 'What-if' exercises can then be done without much effort. This type of technique will make the search for the optimal point of operations very easy.

Case Studies

These examples show how the technique can be used for optimization purposes.

Figure 3 describes the flow of data in the model, showing the logical flow of data between the input matrix and the output matrix. The input matrix represents certain variables, relevant to each time unit, as described by the cost function. These variables form the real-time inputs to the cost function, which will then produce real-time outputs (the output matrix).

The case studies represent a fictitious production plant with an installed production capacity of 500 t/h. Modelling of the plant yields the cost function shown in equation [5].

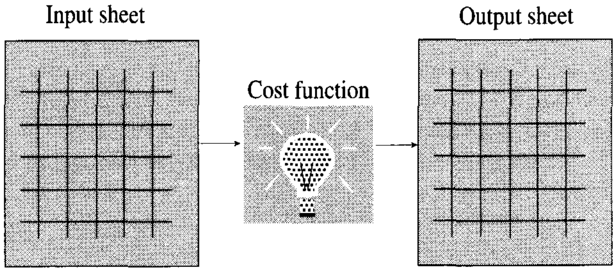

Figure 3—Flow of data between matrices

$$\text{Cost per hour} = \begin{bmatrix} \left(T_e \times P \times 0,04\right) + \left(T_{md} \times 2,7\right) \\ +(26 \times P) + 106 \end{bmatrix}. \qquad [5]$$

The input and output matrices will be represented graphically. Only the variable inputs will be shown by the input graphs. The output graphs show the operational cost, maintenance cost, and the total production cost.

Case Study 1

Figure 4 shows the production schedule and energy tariff (Eskom MEGAFLEX) of a typical scheduled production day. As already discussed, the constant inputs will not be shown, but clearly these influence the output graph.

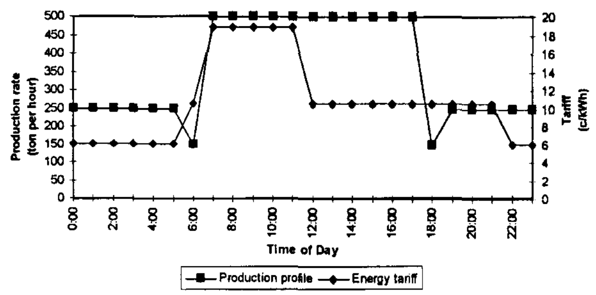

Figure 4—Case Study 1: variable inputs

The data relevant to the graph is:

Total production for the day	8550 t
Average operational cost	R0,834
Total cost of day's production	R7127

Figure 5 shows the output graph relevant to the input variables (Figure 4).

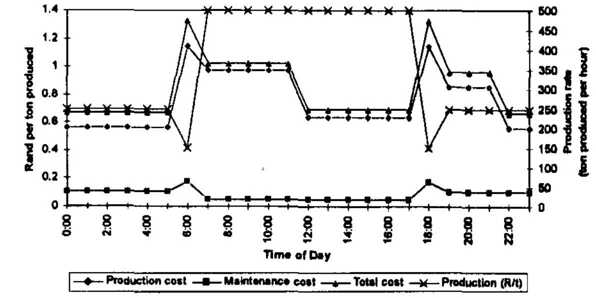

Figure 5—Case study 1: output graph

Case Study 2

Figure 6 shows an altered production schedule. When this schedule is compared with that of case study 1, it is clear that production is increased during the night. This is done to take advantage of the lower electricity tariffs during the night.

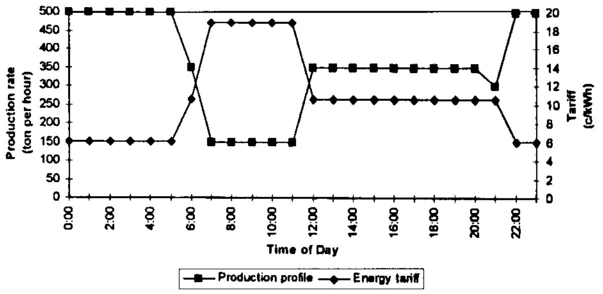

Figure 6—Case study 2: variable inputs

Figure 7 shows the output graph relevant to the input variables (Figure 6). The data relevant to the graph is:

Total production for the day	8550 t
Average production cost	R0,723
Total cost of day's production	R6184

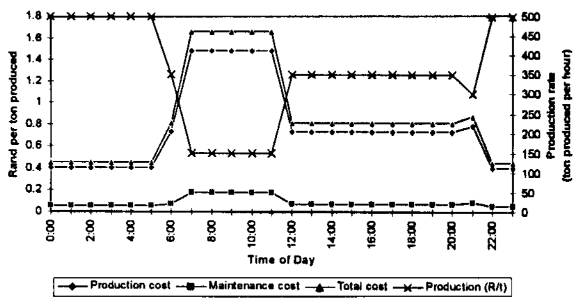

Figure 7—Case study 2: output graph

The results show that profit can be increased by shifting production to low-energy-cost time slots. This is not new, but illustrates how easy it is to assess operational costs by using the developed cost function.

Case Study 3

Just examining the effect of production shifts on energy cost alone is short-sighted. The cost function should display the effect of an alteration on the financial results as a whole. This case study will illustrate how excessive production above design capacity can increase maintenance costs, although the energy cost decreases because of better energy tariffs. The cost function at hand consists of a two-part maintenance cost: scheduled maintenance and unplanned maintenance. Excessive production can cause unplanned maintenance and downtimes that will have a negative effect on operational costs.

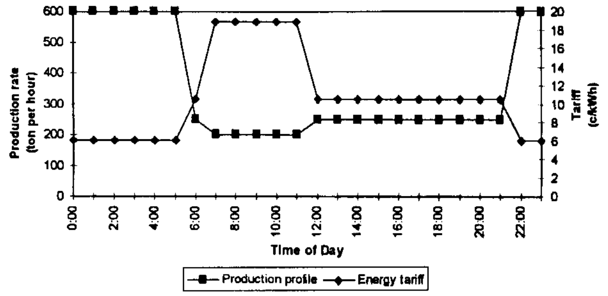

Figure 8—Case study 3: variable inputs

Figure 8 shows a production schedule where maximum utilization is made of lower energy tariffs, by drastically shifted production schedules.

Figure 9 shows the output graph relevant to the input variables (8). It should be apparent that the ratio of production costs to production output worsens when production decreases (see Figure 9, between 07:00 and 11:00). One of the main reasons for this, is that utilization of resources reduces. (A worker needs to be paid, if he is active or not.) The data relevant to the graph is:

Total production for the day	8550 t
Average production cost	R3,06
Total cost of day's production	R26123

Although most of the production takes place during times when electricity is cheap, owing to high maintenance costs, the overall cost is much higher than that for the two previous case studies. The higher maintenance cost is caused by unplanned maintenance. This happens due to the fact that, in an attempt to produce the maximum when electricity is cheap, installed capacity is exceeded and breakdowns induced. These breakdowns may also be due to scheduled maintenance not being adhered to.

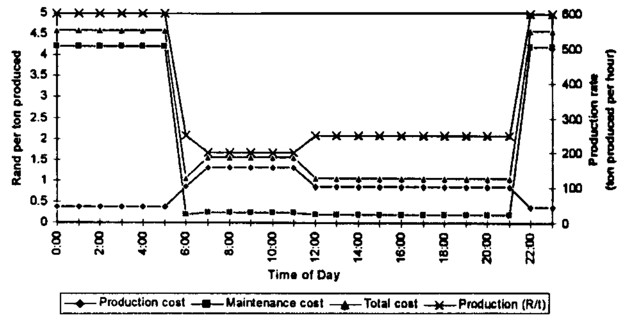

Figure 9—Case study 3: output graph

Interpretation of the results

An evaluation of the relevant data from the three case studies shows that case study 2 has the most financially sound outputs. Table 1 shows a comparison of the case study outputs.

Case study 1 is negatively influenced by the fact that production takes place while electricity costs are high.

Case study 3 is negatively influenced by high maintenance costs due to breakdowns. This is a perfect example of why the cost function should take all possible expenses into account.

Case study 2 is the best option, since the required production is achieved with the lowest total production cost.

Table I

Comparison of case studies

Item	Case study 1	Case study 2	Case study 3
Total production, t	8550	8550	8550
Average production cost, R/t	0,834	0,723	3,06
Total cost for day, R	7127	6184	26123

Summary and conclusions

This article has discussed the development of a comprehensive cost function that takes into account all the factors that influence the total cost of operation.

The function presents the user with a means of quickly and easily computing finances of production units, with a spreadsheet or by the use of a computer program calculating real-time results from real-time inputs.

This technique, will become extremely useful with the implementation of real-time electricity pricing, in cases where production schedules differs from day to day.

Before any capital investment is made in a new system, this system should be tested. There is no easier way than this type of simulation to test planned capital investment, and then weigh the investment up against the return on investment.

Nomenclature

C_T = Total operating cost of the end-user group in rands per hour
C_{sn} = The different operational cost of each sub-system
C_{pn} = Production cost
C_{mn} = Maintenance cost
C_{en} = External cost factor
C_{cn} = Capital cost factor
C_e = Energy cost factor
C_{md} = Maximum demand cost coefficient
C_{mp} = Maintenance coefficient
C_{px} = Energy coefficient
C_{man} = Labour cost coefficient
T_{md} = Maximum demand cost (tariff) (rands per kW)
T_e = Energy cost (tariff) (cents per kW)
P = Tonnage exceeding maximum design tonnage

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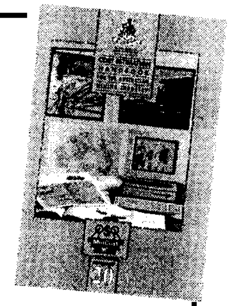

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Water quality and reclamation management in mining using bactericides

V. Rastogi*

Surfactant-based bactericides are able to control acid formation in sulfidic materials such as pyrite and sulfidic ores, thereby helping to abate acid rock drainage. Bactericides are used in the following two ways: as periodic or continuous spray treatments for the prevention of acidification of material actively handled and moved and in controlled-release form for reclamation.

Site-specific bactericide treatments are designed for active sites and reclamation. Results from two active coal refuse sites show that acid production can be reduced by 88% or more. Results from reclaimed sites show that bactericide treatment can be more effective than the addition of alkaline materials such as limestone and can reduce acid production from 3,500 to <30 ppm. The controlled-release-pellets treatment outlasts the life of the pellets, as shown by a study of a site now 10 years old. A single treatment sets up a change in site microbiology to replace acid-producing Thiobacillus ferrooxidans bacteria with heterotrophic bacteria and creates a stable site without the need for further treatments. A secondary beneficial effect of bactericides is on revegetation, and biomass from treated areas is almost 10 times that from areas not treated with bactericide. Depending on the application, bactericide treatment can be cost effective upfront and certainly long-term, compared to the perpetual water treatment that could be required, even after productive use of the site is completed. ◆

* *President, MVTechnologies, Inc., Akron, Ohio, USA.*

Blue Swallow Working Group*

The Blue Swallow Natural Heritage Site just outside the village of Kaapsehoop in Mpumalanga, is under threat by a proposed gold mining company called, ironically, the Blue Swallow Exploration and Mining CC.

Partners in the Blue Swallow Exploration and Mining CC, Paul Czajowski and John Joubert, have submitted a proposal to the Department of Mineral and Energy Affairs to reopen an underground mine, their proposed name for which is the Blue Swallow Gold Mine. The mine was closed in 1952 after two years of operation due to metallurgical difficulties in treating the ore. Their 'pre-feasibility study' includes plans to conduct alluvial or open-cast-mining.

The current area for which they are making application to conduct prospecting and which they hope to mine, includes six of the most important Blue Swallow nests, which would be destroyed by the proposed activity. For the past ten years there have been between nine and 12 active breeding pairs in the Natural Heritage Site each year. The Natural Heritage Site contains the highest breeding density of Blue Swallows in South Africa and Swaziland. At time of writing a decision on the proposal had yet to be made. If mining in this sensitive habitat, specifically set aside for the conservation of the Blue Swallow and its habitat, is allowed, the only Blue Swallows likely to survive would be the Blue Swallow Exploration and Mining CC and the Blue Swallow Gold Mine. The EWT has made a submission to the Minister of Environmental Affairs and Tourism, Dr Pallo Jordan, urging him to intervene and prevent this from happening. ◆

* *Courtesy of the Endangered Wild Life Trust.*

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