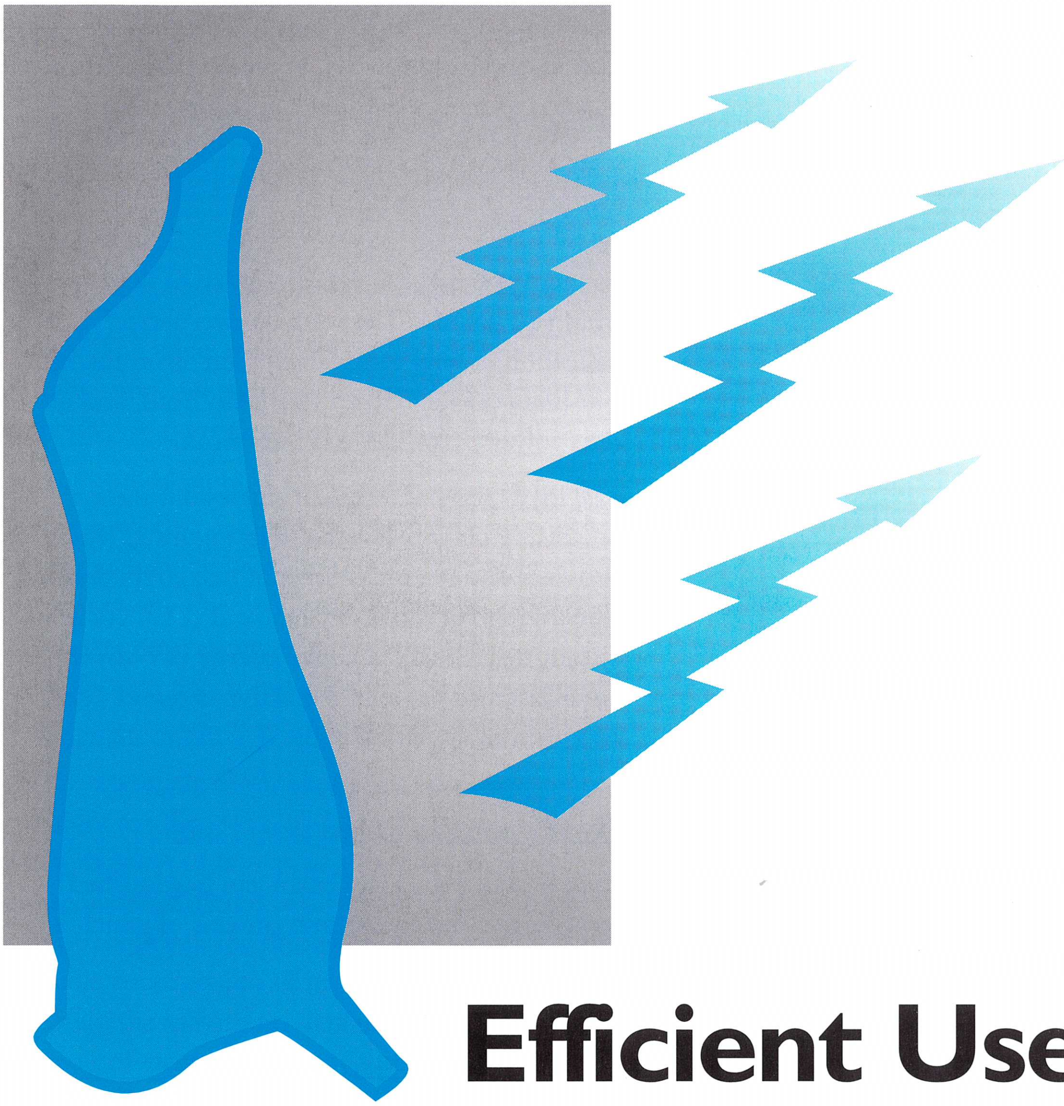

Efficient Use of Electrical Power

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Meat Research Corporation

AMT
AUSTRALIAN MEAT TECHNOLOGY

The meat processing industry depends on electrical power for essential operations, such as refrigeration and rendering. The demands from these operations are such that of the three services – water, fuel and electrical power – the cost of electrical power is the greatest, generally contributing more than 50 percent of the cost of all services.

The Importance of Efficiency in the Use of Electrical Power

Unlike most other services used in production, electricity is invisible, which makes spotting waste difficult. Efficiency in the use of electrical power is often not the highest priority from a production perspective. However, cost savings may be achieved with little or no impact on operations. At the same time, changes to processes or technology may impact on electrical power costs.

Achieving energy efficiency requires an understanding of:

- the essentials of tariffs;
- the characteristics of installed load; and
- specific cost-saving measures, not related to plant performance.

Energy management is inherently a continuous, repeated process of identifying areas of concern, measuring existing energy costs, setting energy and cost-saving targets, and implementing the required changes. This process has important benefits, apart from the obvious cost savings. It will result in a growing awareness of the importance of the cost of energy, which will permit accurate product costing. Knowing when and where energy is being used, and to what effect, is a crucial step towards professional management of assets.

Tariffs

Electrical power tariffs are generally made up of two components: energy and demand. These two components are aimed at recovering the cost of supplying the energy to the consumer. The energy component reflects the cost of generation of the energy, while the demand charge reflects the cost of infrastructure to bring the energy to the consumer. Demand is measured in active (kW) or apparent (kVA) demand, depending on the tariff. Energy is always measured in kW-hours. The cost of energy may vary during the day, in which case reference is made to time-related, or time-of-use tariffs.

The concept of apparent (kVA) demand is a bit like beer: the golden liquid (active power) is the useful part, while the froth (reactive power) does not add value, and the total (apparent demand) is what you pay for. The term "power factor" is an indication of how much froth there is on the beer – at unity power factor there is no froth, and at zero power factor, there is only froth.

The load curve of a typical single-shift meat processing plant is illustrated in Figure 1, which also demonstrates the concept of maximum demand. The average of the active demand (kW) curve is directly related to the active energy (kWh), while the maximum value of the active demand (kW) over the billing period is the maximum demand.

Characteristics of Installed Load

Each installed load in a plant can be classified according to the production process of which it is

FIGURE 1 Typical weekly load curve

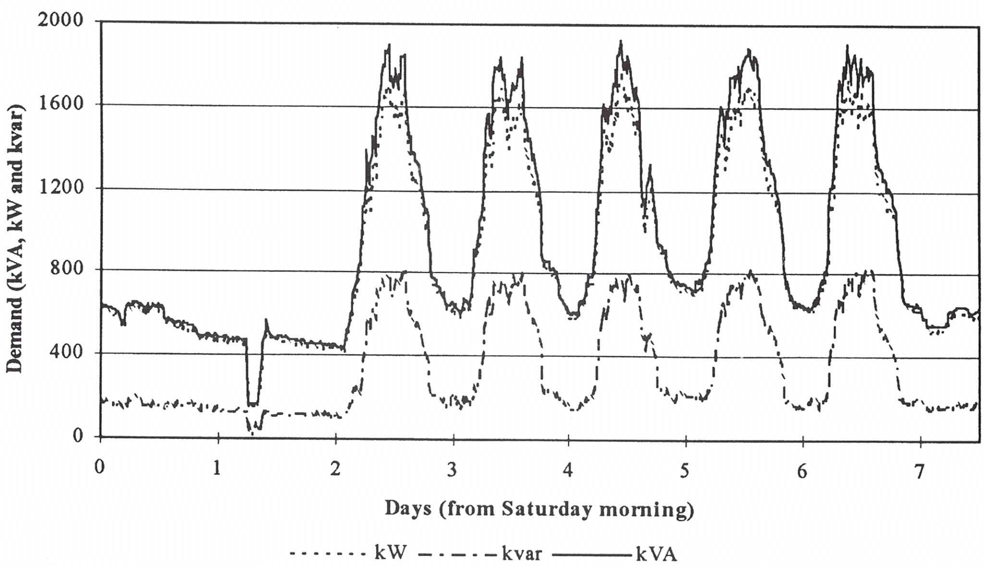


TABLE 1 Individual load characteristics

Load	Power factor	Load cycle	Size
Lighting	Fluorescent: 0.9 - 1.0 High-pressure sodium, metal-halide: 0.8	Constant load during shift hours	At least 16 - 20 W/m^2 of surface area, depending on application and luminaire
Air-conditioning/ ventilation	Mainly induction machines for fans and compressors: 0.7 - 0.8	Peaky load during shift hours	Varies from marginal kW to hundreds of kW
Refrigeration	Mainly induction machines: 0.7 - 0.8	Very peaky load during shift hours	Varies from marginal kW to several MW
Motor loads	Mainly induction machines for hand tools, saws, hoists, water pumps and presses: 0.7 - 0.8	Very peaky load during shift hours	Varies from marginal kW to several hundred kW

a part. The table above indicates one such classification. All the loads in the plant add up to the total, or aggregate, load of the plant.

At the individual load level, it is important to realise how electrical power is utilised and which measures may be taken to reduce the power consumption. The problems of thermal insulation of refrigeration equipment, loss of cooled air though open doors and windows, illumination of unused space and oversized motors are common.

At the aggregate level, important factors to consider are the overall load factor of the plant (an indication of how peaky the load is, and consequently whether maximum demand costs can be reduced), the timing of peak loads, and the possible coordination of process blocks to reduce, not only the maximum demand costs, but also the amount of electrical power consumed during periods of high cost in a time-of-use tariff.

Cost-saving Measures

There are opportunities for specific cost-saving measures, not related to plant performance, and two examples are:

Selection of lights In a medium-sized warehouse area, the selection of fewer, more expensive but more energy-efficient lowbay – instead of highbay – luminaires, can achieve the same illuminance. The associated saving on electrical power use could be up to 35%, which would result in an annual saving in power costs of close to $11 000.

Correct sizing of electric motors A 100 kW motor is used to drive a mechanical load of 25 kW in a plant with an apparent (kVA) demand tariff. At this load level, the motor power factor is 0.4, and the electricity demand drawn by the motor is 62.6 kVA.

Consider, now, the same load with a 30 kW motor. The full-load power factor of this motor is 0.85, and the demand is 29.4 kVA. The difference of 33.2kVA (62.6-29.4), which would have been added to the energy account monthly at a cost of $9.6/kVA, would be equivalent to an annual cost saving of $3812.

An additional effect of this unnecessary demand is that the higher current required to supply the higher demand increases the copper losses in the cabling, resulting in the need for larger cables and transformers. Copper losses, called I^2R losses, have the effect of a hidden, constant drain of energy, much like a leaky pipe.

Guidelines to Efficient Electrical Power Use

With the introduction of Quality Assurance programs, many abattoirs have process monitoring systems in place which will provide information on performance indicators, such as steam, electricity or other utilities used per carcase, load factor and load diversity.

The three basic strategies of electrical power management are: operational efficiency, demand control and load scheduling.

Operational efficiency aims at identifying loads that are wasteful in power consumption, such as lighting where it is not required, inefficient lighting; or loads which result in unnecessary demand charges, such as motors that are too large. Correct design avoids these problems. Payback periods generally vary between one and two years.

When purchasing power-intensive equipment, such as transformers, motors and compressors, consideration should be given to the inclusion of a performance contract with the supplier, based on the cost of energy losses. In this way, the purchase price incorporates the cost of at least some of the losses of new equipment.

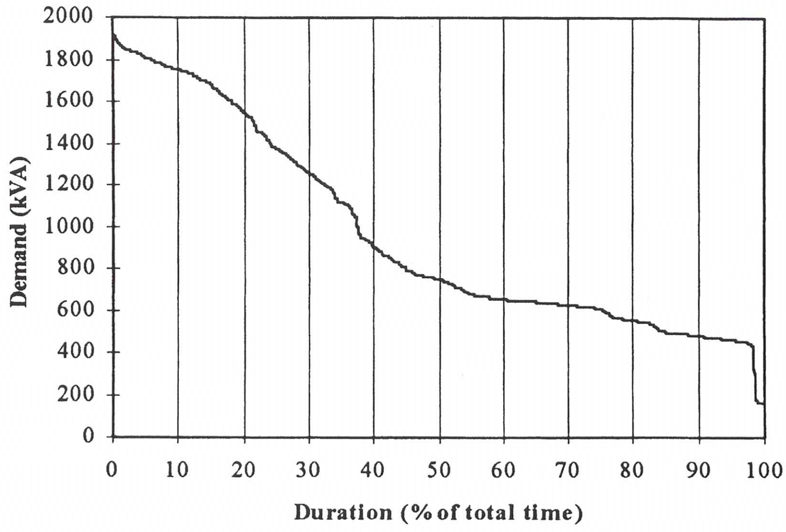
The concept of correct design includes the optimal design of plant reticulation. This means that the substation and switchboard cabling should be designed to minimise cable length or, more precisely, the amount of copper required. This will lower cable costs, and will also reduce the I^2R losses in the cabling. Consideration must be given to back-feeding in the event of cable or switchboard faults.

Demand control focuses on the reduction of demand charges by monitoring consumption on-line, and shedding load when a demand target is expected to be exceeded. It works well in, and is only recommended for, plants with spare capacity or flexible operations which will not be hampered by load shedding. Generally, it is an inexpensive solution which is easy to install and operate. Payback periods are generally less than six months.

Consider a plant with a 150 kW chiller. The chiller is capable of maintaining temperature within acceptable limits after loss of power for at least 15 minutes. The plant has a maximum demand of 1780 kW, based on an integration period of 30 minutes. Analysis shows that the chiller runs at the time of maximum demand.

A demand controller is installed which monitors the plant's overall demand and predicts the expected demand during each period. When the demand target is predicted to be exceeded, the controller sheds load – in this case the chiller. Assuming a demand charge of $9.6/kW, the monthly demand charge is reduced by $720, resulting in a saving of $8640 per annum. *Provided the chiller has sufficient thermal capacity*, this saving will have no impact on plant operation.

FIGURE 2 Load duration curve



A load duration curve, such as shown in Figure 2, is useful in identifying the extent to which demand control can achieve savings. The figure, based on the load profile presented in Figure 1, shows that the demand exceeds 1800 kVA for only 5% of the total time.

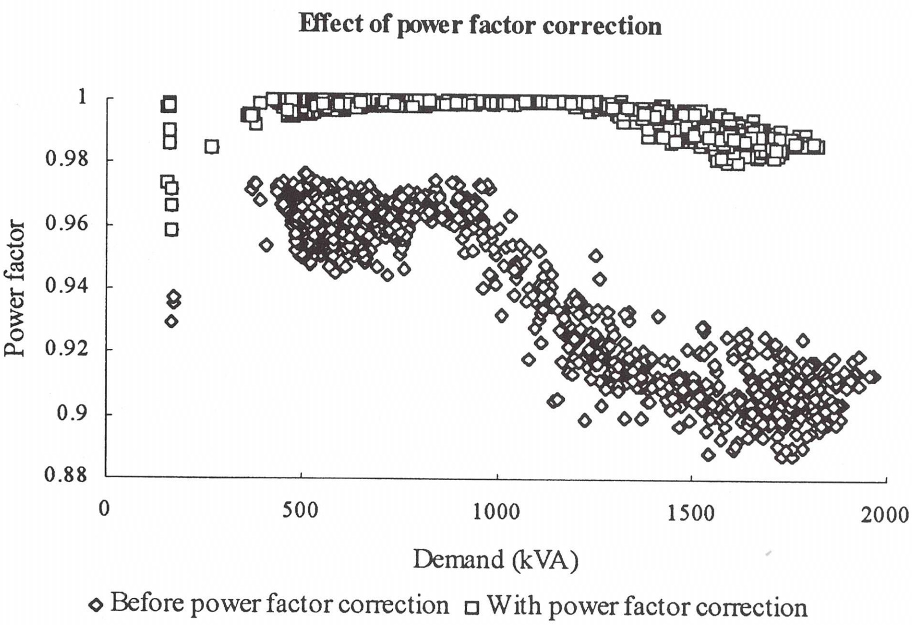
Load scheduling is applicable to time-of-use related tariffs as well as tariffs with a demand component. It works on the principle that flexible operation allows for changes in timing of loads – moving energy-intensive tasks into times when energy costs are lower – and reduces the load factor of the plant and, therefore, the demand charges. Two requirements must be met before very significant savings can be made: a flexible labour force, and flexible processing systems. Payback periods depend on the cost and extent of process changes, and can range from less than a month to several years.

Demand control includes **reactive power compensation**, or power factor correction. If electrical power charges are based on an apparent (kVA) demand tariff, installing reactive power compensation equipment will reduce the demand charge. This equipment generates some or all of the reactive power that is absorbed by electrical loads in the plant, reducing the amount drawn from the supplier. Power factor correction can be applied to individual or total loads.

A maximum demand of 1200 kVA at a power factor of 0.8 can be improved to a demand of 1000 kVA at 0.96 power factor. This is done by installing 440 kvar of reactive power compensation. A payback period of less than one year is possible, with a saving of $23 000 per year (assuming $9.6/kVA).

The benefit of ensuring that the power factor is corrected optimally is indicated in **Figure 3**. In the example illustrated the plant has a power factor of 0.91 at the time of maximum demand. Correcting to 0.982 at the time of maximum demand will result in a reduction in kVA demand from 2000 kVA to 1750 kVA, with a payback period of approximately 18 months.

FIGURE 3 Demand and power factor



Quality of Supply

Changes in technology, working hours, process and plant layouts, may all be required in order to improve the efficiency of electrical power use. Apart from the obvious impact on human resources, these power-saving measures can have additional, easily overlooked effects on the electricity reticulation of the plant. These all fall into the wide area of power quality, or quality of supply.

Supply quality refers to the extent to which the power, as monitored at the point of supply to the consumer, deviates from the rated voltage and frequency, termed 'distortion'. It describes steady-state phenomena such as harmonics, under and over voltage, and unbalance, as well as transient effects, such as voltage surges, dips and impulses. It also includes distortion brought about by actions of the consumer, and distortion to which the consumer made no contribution but which adversely affects equipment in his/her plant.

Consideration of the impact of loads on power quality is important for practical and regulatory reasons. Poor power quality can be very costly when it results in damage to equipment and loss of production. The power utility may also require correction of deleterious effects when distortion caused by equipment in the plant exceeds limits defined in Australian Standard AS.2279, Disturbances in Mains Supply Networks, Parts 2 and 4.

Two examples of unfavourable impacts on power quality are:

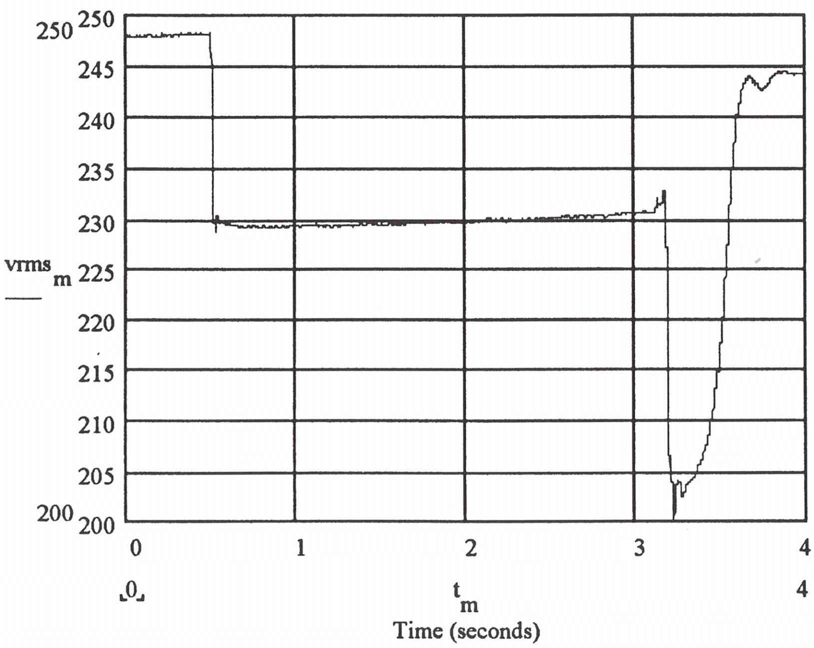
Variable-speed motors
A plant supplied from a 2 MVA transformer fed from a weak rural supply, has a resulting fault level of 27 MVA at the 440V busbar, and has 1 MVA of power factor correction installed. A direct-on-line starter for a motor is replaced with a variable-voltage, variable-frequency drive due to the improved starting and speed-control features offered by such a drive. However, this drive generates significant fifth harmonic current, which is amplified in the resonant circuit formed by the power factor correction equipment and the supply impedance. The power factor equipment was not designed for the harmonic voltages and currents and needs to be replaced.

Should the power factor correction equipment be damaged and disconnected, the cost of replacement will include the equipment cost, as well as the loss of savings brought about by the power factor correction. Designing power factor correction equipment in a plant with power quality problems is a complex task which should be entrusted to qualified professionals.

Motor starting Consider a plant situated in a rural area with a supply fault level of 70 MVA, and supplied through a 2 MVA 11kV/440V transformer. A motor in the refrigeration plant rated at 300 kW will cause a short-term voltage dip of close to 7% in the plant, and close to 2.5% on the 11 kV system. This may result in control-circuit malfunction and, depending on the number of 'start' cycles per day, it may also be regarded as causing excessive irritation to other consumers connected to the same 11 kV supply.

The problem may be aggravated by incorrect timing of the start-up sequence. The effect of a large motor starting by means of an autotransformer, which allows a lower initial voltage applied to the motor, is indicated in **Figure 4**. Once the machine is near full speed, the autotransformer is bridged out, allowing full line voltage to be applied to the motor. (The motor was not at full speed when the transfer was made, resulting in a voltage depression of 17% – sufficiently large to cause malfunction of metal-halide lights in the plant).

FIGURE 4 Motor-starting voltage depression



The important issue arising from these supply disturbances is the fact that other consumers may be affected by your activities.

Checklist

The following points form the basis of a checklist which will assist in the process of achieving greater efficiency in the use of electrical power:

- **General plant management**
  - *Comprehensive list of all loads:* This should include function, location, rating, running load, load curve (timing of load), feeder cable size, reference to maintenance schedule, and a reference to an as-built drawing number.
  - *Plant maintenance schedule:* This includes the actual maintenance carried out, as well as the planned maintenance, and should indicate the cost incurred in each event.
- **Power costs**
  - *Existing tariff:* The prevailing tariff, as described in the supply contract, should be readily available and understood. Tariff options available to the industry and trends in the supply industry must be noted.
  - *Records of supply costs:* Comprehensive records of past utility bills should be kept and reviewed at least twice a year. These should be seen in relation to other production costs.
  - *Allocation of costs:* The total cost of electricity should be allocated to departments and, within each department, to each process. This allocation should be driven downward until the contribution of each load is known and can be reconciled with the load schedule.
- **Strategy**
  - *Identify areas of concern:* List specific areas in the plant where improvements can be made to power factor, maximum demand, and energy losses. Consider alternative tariffs and load scheduling.
  - *Quantify present power costs:* Express in each of these areas the actual power cost, and determine the impact on the total power account. This information should be available from the load schedule and cost allocation processes.

- *Co-generation/outage strategy:* Integrate the plant's emergency or disaster planning with the possibilities of using co-generation for maximum demand control.
- *Set targets:* Set realistic targets for savings in each area. Take into account the cost of implementing savings measures, the possible impact on operations, and long-term effects on maintenance and equipment replacement.
- *Implement:* Prioritise identified savings to address most significant improvements first. Determine feasible implementation deadlines.

- **Repeat from the top!**

Additional information

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