PART I

CONSERVING ELECTRIC POWER

An engineer looks at ways to save dollars.

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This article is based in part on "An Engineer Looks at How to Save $ and Conserve Electric Power," a presentation by the author at Metal Treating Institute's Furnaces North America, Las Vegas, Nev., 3-4 April 2002.

Electric power consumption is insidious, because generally it is out of sight and mind, but can be measured easily with power meters and instrumentation. An individual walking through a manufacturing plant can miss equipment operating inefficiently. Figure 1 is such a simplistic example.

Here are two electric lamps, each producing the same number of output lumens. One is a standard 60-watt incandescent lamp, the other a 15-watt compact fluorescent lamp. The initial cost for the fluorescent lamp is slightly less than $20.00. The cost for the incandescent lamp is $0.50. The initial reaction is to reject the fluorescent lamp for high initial cost, but when one analyzes the operating cost over seven years the fluorescent lamp operating cost is about two thirds lower. This does not include maintenance labor and all that is entailed with these costs and downtime.

Fig. 1 — Electric cost comparison based on life-cycle costs.

Costly electric motors

Much more deceptive operating costs apply to electric motors. Many electric motors such as water recirculation pumps for cooling purposes, vacuum pumps, and other types of circulation pumps for oil like those used in quench tanks operate continuously. In Table 1 the cost of running electric motors for different time periods and different size motors is outlined. For example, the cost of operating a 20-hp electric motor continuously is $18,000 per year, somewhat of a staggering revelation to the uninformed. The modern production vacuum furnace utilizes a diffusion pump for producing high vacuum. In Table 2 the operating cost for various size diffusion pumps in commercial operation is listed. A very common diffusion pump is the Varian 20 in. size. This pump operating continuously for one year will cost $5,500 to operate. Since diffusion pumps operate with no noise and would seem benign from an energy absorptive viewpoint, these operating costs again are more or less "out of sight."

The object lesson is to turn off any electric motor or, as in the example the diffusion pump, whenever it's not in operation. One would never leave a home workshop without turning off the lights. However, in our manufacturing plants operators leave the plant everyday with all sorts of motors and pumps operating continuously without a second thought.

Where electric motors cannot be turned off, they can often be controlled with variable frequency drives so that the motors will not be operating at full capacity, but only as required. For example, in a plant water cooling arrangement one may use either one very large water pump or a number of small pumps. Since it is desirable to maintain a constant water pressure throughout the plant, these pumps could feed a pressure regulator where the drive water pumps would operate at more or less full capacity and electric power use. A preferable way is to utilize variable speed drive controls for each water pump in a feedback control loop, based on a preset operating pressure. As the demand for water cooling various pieces of equipment comes online or offline, the variable speed drives will automatically control the water pumps and operate the electric motors at optimum speed, for the lowest possible electric power use (Fig. 2).

Power demand

Every manufacturing plant, small or large, will be provided with an electric power meter by the utility company. Each industrial electric power meter contains a power demand register, which is an independent record of electric power usage over a specific time increment, usually a 15 to 30 minute period. This can be thought of, more or less, as an instantaneous demand peak that is recorded each month. The result is the total kW hours registered is one part of the electric bill, and the second part of the electric bill is made up of the kW electrical power demand (Table 3).

In an ideal situation, the instantaneous electric power demand use would be flat for the month with no demand peaks. A good example might be the continuous operation of electric lighting, such as in a large department store open 24 hours a day. Manufacturing plants are not so fortunate, as large electrical loads are often initiated and disconnected throughout the production day for various results.

Batch type electric furnaces are typical and can produce erratic and major demand peaks — all resulting in exaggerated electric power billing. Such an example is Fig. 3 where four times

Table 3: An Analysis of your Electric Power Bill

Cost per kW hour* = total $ of power bill / kW hours used

Demand or **Load Factor** is usually billed in kW or kVA and is directly related to your % Load Factor, or how well you use your power over time.

kW or **kVA Billing** is usually related to your operating Power Factor and can be thought of as a lack of efficiency.

Both **Demand Billing** and **Power Factor Billing** are really penalties imposed by the power company against your operations.

*usually in ¢ per hour

Table 1. Cost of Running Electric Motors @ $0.10/kWh

Motor HP (application)	KVA*	$/Hour	$/Day	$/Month	$/Year
¼ (shop fan)	0.34	3.4 ¢	.82	30	300
5 (vacuum pump or water pump)	6.0	60 ¢	14.40	521	5,250
10 (vacuum pump or water pump)	11.2	1.12	26.88	821	9,700
20 (water pump or gas fan)	20.8	2.08	49.92	1,520	18,000
30 (water pump or gas fan)	31.2	3.12	74.88	2,281	27,000
50 (water pump or gas fan)	50.4	5.04	121.00	3,680	43,600
100 (quench fan)	98.4	9.84	236.00		
200 (quench fan)	192.0	19.2	461.00		

**kVA rating is based on operating currents (amps). Note: Efficiency of small motors is approx. 60%, increasing to 80% for larger motors, based on 746 watts/hp. Source:* Glover Pocket Reference Book, *October 1996 edition.*

Table 2. Operating Costs for Diffusion Pumps

Size, in. (Power, kW)	$/Hour	$/Day	$/Week	$/Month	$/Year
16 (6.5 avg.)	0.46	11.00	76.00	331.00	3,975.00
20 (9.0 avg.)	0.63	15.00	105.00	458.00	5,500.00
35 (12.0 avg.)	0.84	20.16	141.00	611.00	7,338.00

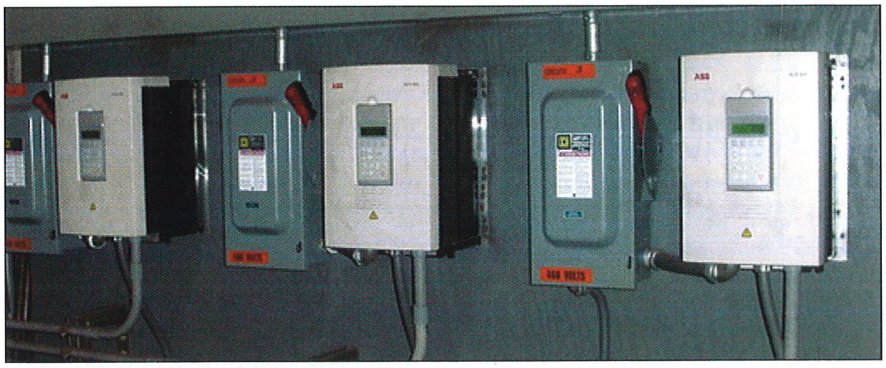

Fig. 2 — Variable speed drives automatically control motors of water pumps to deliver lowest possible electric cost.

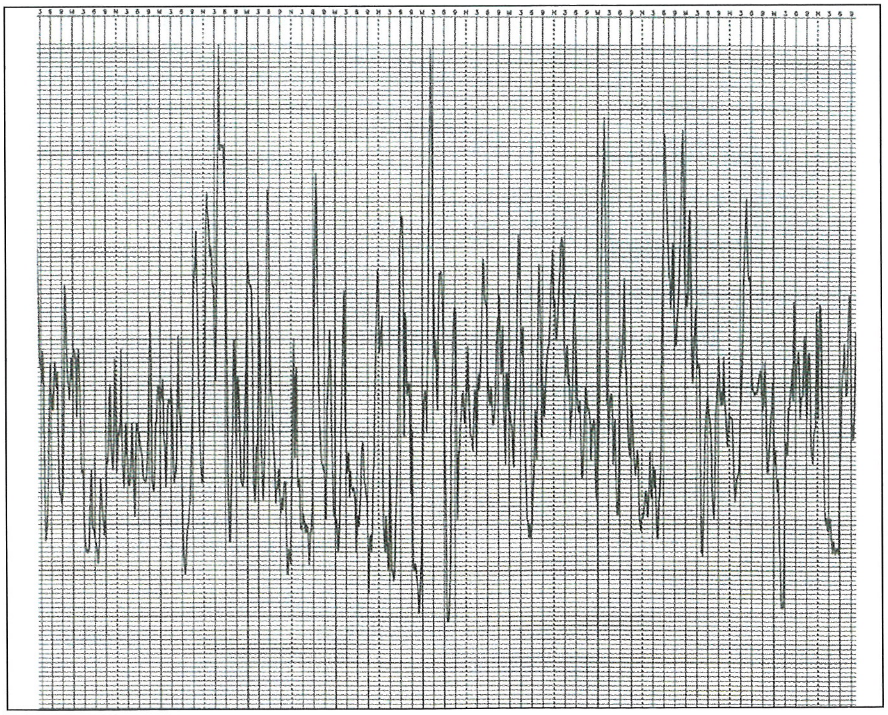

Fig. 3 — One month's power demand displays major peaks, which should be eliminated for significant energy savings.

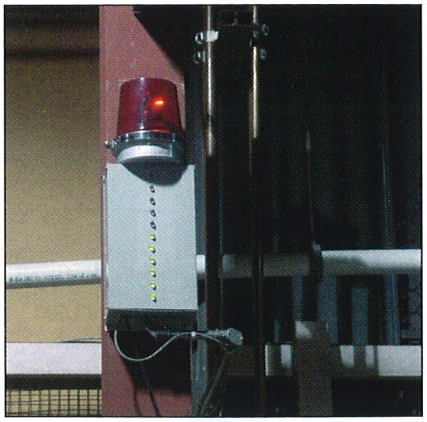

Fig. 4 — Demand monitors can alert operators when to avoid starting equipment during peak periods.

during the month heavy demand occurred. If equipment can be controlled so that these peak demands can be eliminated, major electric power savings are possible. Sometimes this can be accomplished by simply scheduling heavy production cycles to "off peak hours" where some utility companies will not penalize the customer for the demand factor. This is usually during the evening or nighttime hours or on the weekend. Production managers often resist for obvious reasons.

When operation is necessary during daytime and peak demand periods, demand monitors (Fig.4) can serve as an indicator to operators when operating in adverse conditions. When the demand monitor indicates a higher than preset condition, operators can either delay starting a piece of equipment or in some other way attempt to reduce electric demand. At least they have an indication as to what is happening and some corrective action may be taken.

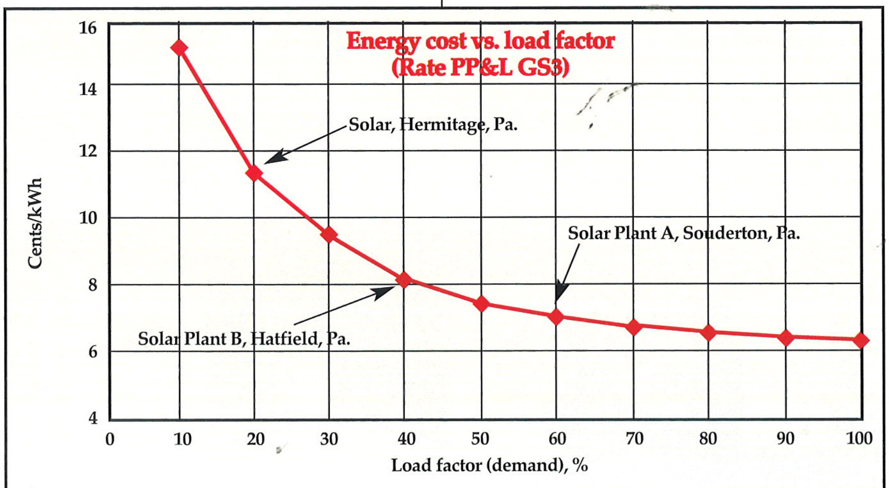

Fig. 5 — Effect of power demand on electric cost is shown for three different plants.

'On-off' offenders

Electric furnaces that operate with "on-off" control using electric contactors are particularly offensive. When calling for heat and in the "on mode" the furnace will call for full power. When temperature reaches the set point, power will be completely turned off. If a number of batch furnaces operate in this mode together, electric power can easily be peaked. A solution to this problem is to replace the electric on-off contactors with silicon controlled rectifier (SCR) power drives. These SCR controllers will provide a proportional power control, eliminating peaked power demand where batches of these furnaces operate together, the economics is considerable and can easily pay for the replacement of the on-off contactor — not to mention the elimination of maintenance of the contactors themselves, due to contact wear and requiring periodic attention.

A compilation of energy costs vs. load factor or the effect of demand is shown for three manufacturing plants (Fig. 5). Plant A operates 24 hours a day 7 days a week around the clock, is well established, and is under reasonably good electric power control. The operating cost for one month is approximately $0.07/kWh. Plant B operates two shifts per day and not weekends; thus the operating costs are somewhat higher at a little more than $0.08/kWh. The Hermitage, Pa. Plant, at the time of this chart, was just coming on line and operating one shift per day during weekdays. For this plant operating costs are $0.115/ kWh due to under utilization of equipment and "power peaking" demand.

With added production and 24 hour a day operation, this situation has reversed. One observation is that in boom economic periods electric operating cost very well may be lower than in slow economic times because of load factor considerations. This is our experience here at Solar Atmospheres, Inc. The conclusion of the matter is that closer observation of electric power demand during lean times can result in significant electric power billing. The utility company is just as anxious as the manufacturing plant to reduce these heavy electric power demands. They are more than interested in cooperating with manufacturing plants to avoid these peak load conditions. They do not want to build more electric power generation any more than manufacturing plants want to pay higher electric power bills.

This article is Part 1 of a two-part article. The second part will deal with the electric power factor and adverse effects on the electric power bill. **HTP**

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