ELECTRICAL DEMAND CONTROL

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ABSTRACT

Almost every building owner or manager is interested in controlling electrical costs. Since the HVAC system is a large user of electricity, this article will discuss what can be done in the HVAC system to influence parts of the utility bill.

INTRODUCTION

A utility bill consists of four major parts:

1. Usage - the user's actual consumption of energy measured in kilowatt-hours (kwh). This charge represents the cost of fuel converted to energy.
2. Fuel adjustment charge - the charge that utilities are allowed to make for seasonal changes in the cost of fuel.
3. Demand charge - the premium rate charged for the user's highest period of electrical consumption. The demand interval is usually 15 minutes. This charge is representative of the investment necessary to meet the user's maximum power requirement and figures prominently in electrical costs.
4. Power factor - the difference between apparent power and actual power. Simply stated, it is the extra current needed to magnetize motors and other inductive devices. This magnetizing current does not appear on watt-hour meters so it is measured separately and prorated as an additional charge.

DEMAND

Demand is measured by a pulse generator installed in the watt-hour meter. The pulse generator makes and breaks a contact at a rate proportional to energy usage or kwh. Each closing and opening, or pulse, represents a set amount of watt-hours. These pulses are accumulated over the demand interval. The number of pulses times the pulse factor divided by the demand interval yields the demand.

$$\frac{100 \text{ pulses} \times 0.7 \text{ kwh/pulse}}{0.25 \text{ hour}} = 280 \text{ kw}$$

The demand charge is usually based on the highest demand measured during the billing period. Fixed interval or synchronous interval means the pulses are accumulated during fixed or time-defined intervals. The interval is initiated by a synchronization pulse occurring every 15 minutes or other defined time period. The term "sliding window" simply means the demand can occur during any consecutive 15 or 30 minutes. No synchronization pulse is required to initiate the interval with sliding window demand measurements.

While increased demand during a demand peak places an added burden on the utility, increased demand during off peak periods allows the utility to produce a large portion of the annual load with more efficient generating equipment. To encourage off peak usage, a utility may offer time of day rates. Time of day rates charge a premium during periods of high demand (on peak) and offer reduced rates during periods of low demand (off peak). The charge may be based on demand, usage or both.

Utilities meet increased demand during peaks with gas or diesel peaking plants. These generators are designed to come on line quickly and seldom obtain the efficiency of larger base load plants. To cover the cost of peaking capacity that lies idle for extended periods, utilities may invoke a minimum billing demand. A minimum billing demand is based on a percentage of the highest demand during the year or season. For example, take a recorded demand in January of 890 kw. The recorded demand the previous August was 1450 kw. The January demand charge is based on 1305 kw (90 percent of 1450 kw).

Power factor and demand, while generating additional cost to the user, do not provide any user benefit. They are simply user inefficiencies. By improving power factor or reducing demand, the cost of energy can be reduced without any loss of benefits.

Power factor can be improved by simply adding capacitors to the user's electrical system. Reducing the user's demand requires careful analysis of the electrical equipment and its function. Several approaches to power demand control can be developed. Some may require significant capital investment or changes in the user's utilization of power.

COPING WITH DEMAND

Utilities cope with increased demand by employing one or more of three major strategies:

1. Alternate source
2. Storage
3. Demand limiting.

Alternate sources include large diesel generators, gas turbines or simply purchasing power from utilities that have an excess. While some research continues with storage batteries, their use has been limited to telephone systems and computer rooms during power outages. Some utilities store generating potential in large hydro reservoirs. These reservoirs are replenished naturally by watershed or ground water, or artificially by using off peak power to pump water back into the reservoir. Utilities have employed demand limiting for a number of years. Customers are offered a rebate for reducing their usage during peaks. When the utility needs to shed demand, a radio signal is sent to turn off one or more elements in the customer's electric water heater or other standby electric equipment.

Current demand charges have enticed more and more users to resort to the same strategies. The execution is varied to meet the needs of the user. For example, hospitals use emergency generating equipment as an alternate source to trim demand during peaks. Since air conditioning may be the culprit, demand can be reduced by applying these same strategies to the refrigeration load.

The use of absorption cooling equipment has diminished due to escalating fuel cost. However, as an alternate source to trim demand peaks due to refrigeration, the absorption market persists. A second advantage of absorption equipment and associated auxiliaries is that they do not place a large burden on emergency generating equipment. This allows the continuance of critical refrigeration during power outages. Cogeneration is another example of an alternate power source.

Thermal storage found acceptance decades ago as a means to reduce the installed cost of air conditioning systems with highly variable loads. Today's demand charges have revived the concept. Thermal storage uses large volumes of water or ice in central or modular packages to store refrigeration produced during off peak periods for later use during periods of peak demand. Thermal storage systems can be placed in two general classifications--partial storage and total storage. Partial storage trims the peak refrigeration load only and requires some chiller operation during demand peaks. The storage volumes are manageable and the demand savings are attractive. Total storage systems must produce the entire daytime refrigeration load the evening before. No chiller operation is allowed during the daytime period. Total storage systems require enormous volumes of thermal storage and are usually attractive only where time of day rates are available.

DEMAND LIMITING

One of the most active areas of power demand control is demand limiting or load shedding. This concept involves measuring the demand and turning equipment off following a prescribed order or set of priorities. This task is especially well suited for microcomputers.

Demand limiting programs use one of three algorithms to limit demand:

1. Deadband
2. Ideal rate
3. Predictive.

These methods are easier to comprehend if we first understand the time/pulse relation of demand monitoring. This can be represented by a plot of usage (kwh) versus time as shown in Figure 1. The horizontal axis is time. The microcomputer can serve as timekeeper. The vertical axis is usage. Pulses from the watt-hour meter will indicate usage. This plot shows one demand interval. The upper limit is the demand limit we wish not to exceed. Given a demand limit of 900 kw, a pulse factor of 0.6966 kwh/pulse and a demand interval of 15 minutes, the allowable number of pulses per demand interval, i.e., the number of squares on Figure 1, can be determined:

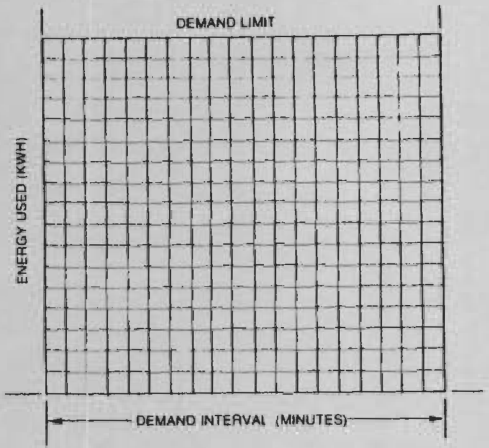

Figure 1. One Demand Interval Showing Usage (kwh) vs. Time

$$\frac{900 \text{ kw} \times 0.25 \text{ hour}}{0.6966 \text{ kwh/pulse}} = 323 \text{ pulses}$$

If the demand limiter allows no more than 323 pulses in any 15-minute period, the demand limit will be maintained. The simplest method of limiting demand would be to let all equipment in the building operate until 323 pulses are counted. If the elapsed time is 15 minutes or more, no action is required. If the elapsed time is less than 15 minutes, all equipment must be turned off for the remainder of the demand interval. Obviously this is not desired by the user, the utility or equipment manufacturers. To provide more stable control, separate shed and restore boundaries are established as shown in Figure 2. This allows action before the pulse limit is reached. In the area between the shed and restore lines, no demand limiting action takes place, hence the term deadband control.

If the number of allowable pulses is divided by the demand interval, an ideal rate is determined. In our example, the ideal rate is 21.4 pulses per minute or 2.803 seconds per pulse.

$$\frac{323 \text{ pulses}}{15 \text{ minutes}} = 21.4 \text{ pulses/minute}$$

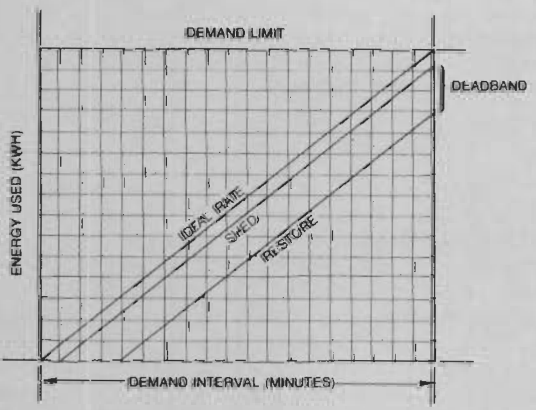

Figure 2. Demand Shed and Restore Boundaries

If the pulses are shorter than 2.8 seconds, demand must be shed. If the pulses are longer than 2.8 seconds, there is allowable margin to start or restore loads that have been shed. The ideal rate method allows a more rapid response and is sometimes referred to as the instantaneous method, since action is not lost while in the deadband, Figure 3.

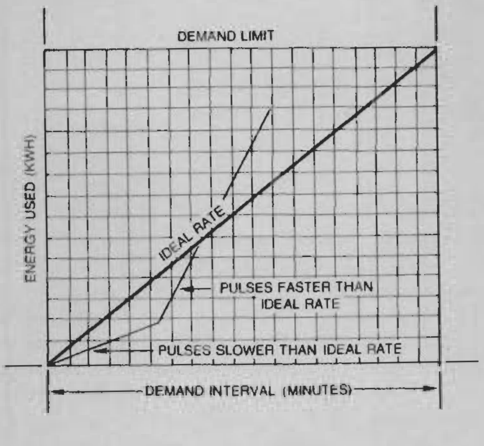

Figure 3. Ideal Demand Rate Curve

Both the deadband and ideal rate methods can determine when loads must be shed. However, they cannot establish the quantity of load that must be shed. Trial and error allows these nonhistorical methods to find a solution. When demand must be shed, a priority or set group of loads is shed. The algorithm then waits a period of time called the action period. If the demand returns to acceptable limits during the action period, no further adjustment is required. The proper length of time for the action period depends on the application. If the action period is too long, the demand limiter may not be able to maintain the limit when the demand is erratic. If the action period is too short the demand limiter may panic and unnecessarily shed higher priority loads.

The advent of more intelligent microprocessor-based, demand limiters presents the opportunity for more stable demand control. Predictive demand control uses a brief period of recent history to predict the near future.

This extrapolation, Figure 4, allows the algorithm to determine the actual kilowatts of load that must be shed to maintain the demand limit. The resulting control is stable, allowing more off time for lower priority loads and avoids the unnecessary shedding of higher priority loads.

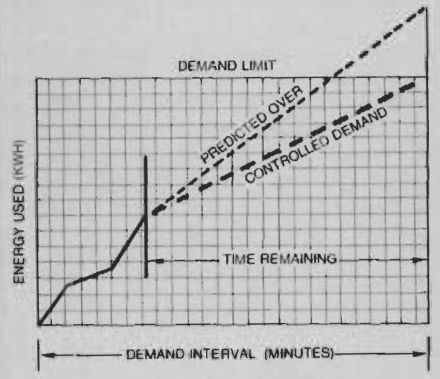

Figure 4. Algorithm-controlled Demand Shedding

APPLICATION OF DEMAND LIMITING

How is the demand limiter safely applied to air conditioning equipment? The least objectionable method is to limit the amount of refrigeration load sent to the compressor. However in chilled water systems, the reduction in compressor load is not immediate. Cycling air handlers may cause objectionable changes in sound power levels in the occupied space. Frequent starts of large air handlers can be traumatic to motors, belts, drives and fan wheels. Limiting the capacity of centrifugal chillers is accomplished by simply reducing refrigerant flow by partially closing the inlet vanes. The kw reduction is immediate, sound levels in the air conditioned space do not change and, most importantly, equipment start/stops are avoided. Most centrifugal chillers are installed with manual demand limiting systems. Interfacing this equipment with demand limiters is relati be limited relatively simple. With unitary equipment the by simply energizing the compressor unloaders. Again equipment start/stops are avoided.

Smaller packaged equipment such as small rooftops and incremental units do not provide a method for compressor unloading. The compressor must be turned off to reduce the refrigeration. Fortunately these smaller compressors are designed for cyclic duty. Due to their close proximity to occupied spaces, fan cycling should be avoided. Air conditioning systems employing these smaller packages in larger buildings display an increased need for demand limiting. As building zone size is reduced, total installed tonnage increases due to inversity. Each compressor is cycled by a space thermostat. There is no control system to limit the number of compressors running at any given time. This situation can be compounded by night setback time clocks. The cost of applying demand limiting to a larger number of units can be significantly reduced by grouping compressors. These compressor groups should be established by priority, not by thermal zone.

Faced with nuclear regulation, environmental constraints and the high cost of capital, utilities are providing users major incentives to reduce their electric demand. Today's engineering challenge is to design HVAC systems that can easily curb their appetite for power without taxing comfort or equipment life.