DEMAND CONTROL STRATEGIES DURING LOAD STEP CHANGES

WHITE PAPER #33

Demand charges on your electric bill are based on the highest average 15-minute power draw. This paper provides tips to lower demand charges that come from short-term loads.

Energy management isn't always about energy, but it is always about dollars. For some customers, demand charges dominate the bill, especially when large demands occur for short periods of time. When short-term demands are increasing demand charges, this is a prompt for demand control. Methods vary but the point is to lower short-term demands – usually by 'spreading out' the energy use over time, smoothing out the usage pattern.

The generator analogy

Short-term loads raise demand charges. A good way to think of demand charges is renting a generator for a month. The size of unit you rent is based on the max power output you need at one time. Refer to **Figure 1**. If you can do the job without the 'spikes', you can get by with a smaller unit and lower rental fee. If the load cannot be smoothed, you'll need rent larger unit even though it is idling most of the time.

> Concept: When multiple days are viewed on a graph, large short-term load have the appearance of 'spikes'. This makes them easy to spot as potential preventable expense, but remember they are in minutes, not seconds – in fact smallest interval of data we record for billing is 5-minutes.

The electric utility company provides large generators we all share and the maximum 15-minute demand each customer draws from the system sets their demand charge (the 'generator rental' fee). This is further divided into on-peak and off-peak, but the concept is the same: *Your electric bill will be less - sometimes a lot less - if you can avoid short-term large peak demands.* For most businesses, electric demand goes up when the business is open and down at night, and the middle-size generator shown in **Figure 1** would be a good value other than the short-term large demand loads. The goal of this paper is to give you ways to avoid renting the big one…and lower your demand cost.

> Concept: this is not about 'inrush current': While it is true that motor power required to start a motor is quite high, this demand only lasts a few *seconds* and the demand value used for billing is the highest average 15-*minutes*. The short-term loads referred to are ones that last a few minutes or an hour.

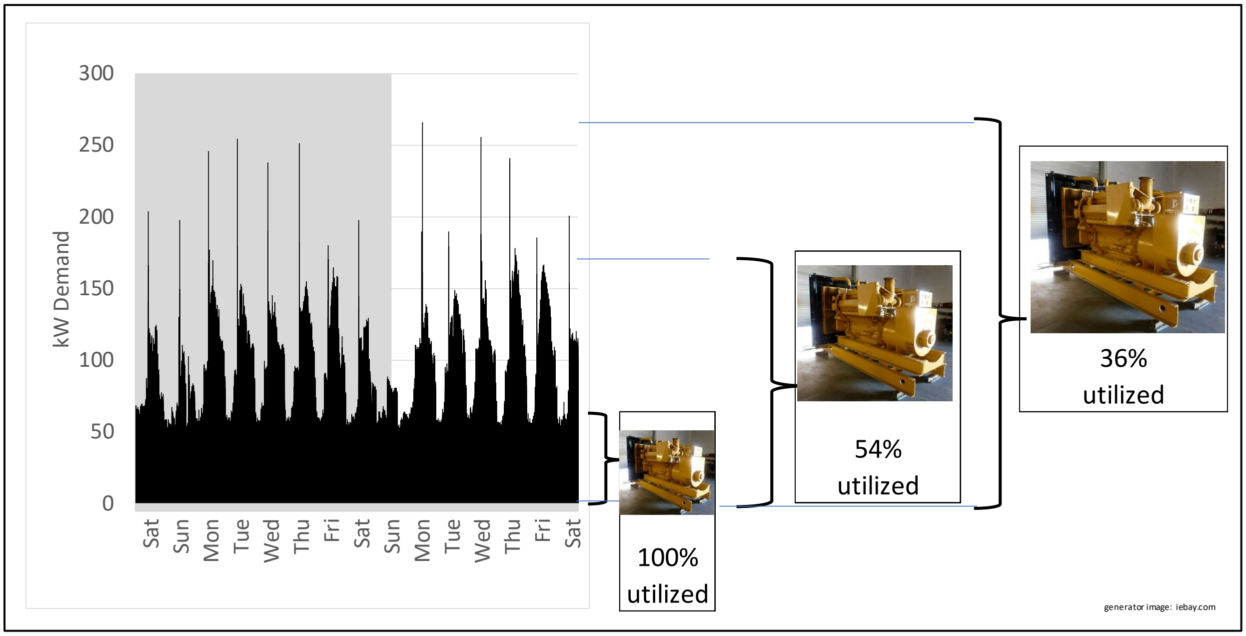


Figure 1 Generator Size Increase and Utilization Decrease from Short-Term Demand

Demand Cost is a Big Part of the Electric Bill

For customers on a demand rate, the electric cost is divided into pieces in order to be representative of the utility cost of service. Fixed costs of the electric utility are recovered with demand charges, and most of that comes from on-peak demand since the peak time loads require machines and cable sizes used only during peak time, however demand expense on bills can also include off-peak demand and minimum demand, both discussed below. Combined, demand charges are commonly 60% of the total electric bill and can be 70% or more where load factor is low (**Figure 1**, using the jumbo generator because of occasional short-term loads).

Concept; for most customers, the largest single line item on their bill is on-peak demand

Power Factor

Our present bill structure embeds power factor charges in demand charges. This has some basis since low power factor does impact infrastructure size and raises fixed costs, however power factor charges have nothing to do with spike loads and cures for low power factor are unrelated to this paper. Power factor explanations, causes, and cures are discussed separately in a white paper under the same name.

Concept: demand charges include power factor charges and can be reduced by improving low power factor conditions in the facility. This usually requires investment in power factor correction equipment, making it a capital consideration vs. short-term high demand loads that can often be treated effectively using existing controls as an operational change.

Energy vs. Power

Energy does work. For conventional generation, energy use and fuel use are tightly related. Pieces of the bill related to energy are based on kW***h***. One kilowatt-hour of energy use can come from 1 kW over 1-hour, 1/2 kW over 2-hours, 4-kW over 15 minutes….same work, just more or less time involved. 'Power' is about how fast the work gets done; power is associated with equipment size and cost.

> Concept: for a given amount of work, if it can be allowed to occur over a longer period of time, the rate of energy use….the demand….. will be less. Hold onto this thought.

On Peak and Off Peak

Per-kW demand charges are higher on-peak than off-peak. Our rate design collects most of the demand related cost for machines and other fixed cost from on-peak rates. We charge for off-peak demand only to the extent it is larger than on-peak demand. For most customers, the off-peak charge is small or even zero. For example, say an *off*-peak demand is measured at 750 kW and *on*-peak highest demand is 500 kW – here, the off peak value is 250 kW higher; then, the on-peak charge would be based on 500 kW and the off-peak charge would be based on 250 kW. For normal, smooth uses that occur during a business day, this explains why very often the off-peak demand charge is zero or close to it.

> Concept: moving large spike loads to off-peak does lower the demand rate, but the charge will not be zero. The amount of kW that is over the on-peak kW is then the basis of the off-peak demand charge.

Ratchet Charge

Shown on bills as 'minimum demand charges', these are another cost of short-term high demands. This is best explained by way of example. Say, one month the largest demand of the year occurs and it is significantly higher than all the other months. If the max demand for all months except this one is 500 kW and this year it is 1000 kw, a lingering charge for the next 12 months will be on the bill. Current rates set a bar at 68% of this high value and with that, any month for the next year that has a demand less than 680 kW would have a minimum demand charge equal to the amount it is below the 680 kW value. So, if 6 months after the 1000 kW big demand event, if the highest demand that month is 500 kW, there will be the usual demand charges PLUS 180 kW minimum demand charge, billed at the off-peak rate.

> Concept: Extremely large 15-minute power demands, even if off-peak, can create additional demand charges for the next 12 months.

Look for 'Spikes' with Interval Data

Look at your demand profile. Only a few customers have private meters to watch demand patterns real time – but all demand customers have access to the utility data portal, where they can see the demand patterns. The load profile data will show kW demand in 5- or 15-minute intervals a week at a time on the screen and up to a month of raw data if downloading. Guess what you will be looking for? If you answered 'spikes' you are correct.

If you see large demands that are short duration, equate that to a sizeable business cost that you are interested in reducing or eliminating. Even if you can't completely eliminate them, we encourage you to study the patterns and make sure the energy and demand expense is no higher than it needs to be. Refer to our other resources for cost saving suggestions. Some require capital investment, but many are O/M and those savings go straight to the bottom line.

Concept: Demand savings are proportional to the reduction in the size of the 'spike'.

Step Change as Cause

A change in operating set point is a 'step change' in what is expected from the heater. When moving to occupied setting, the equipment capacity controls see the step change as a big load to tackle or more exactly it sees it is way off set point and needs to step on it, to catch up. The machine's natural response to the step change automatically by going to full output, where it stays until it starts to catch up and then slowly tapers off. This load response has a very tell-tale signature appearance you can spot in the interval demand charts, as shown in **Figure 2**. You may have to spread out the chart, so an hour's time is an inch or more on the chart to see it. The time it takes to catch up and level out from a step change varies by the size of the machine vs. the size of the step change but it won't catch up in a minute. It might be at full output for an hour, or half hour and in the process may have unwittingly set the billing peak demand for the month.

Concept: the spike followed by slow tapering off is the signature of a step change. The look is very patterned once you are used to looking for it.

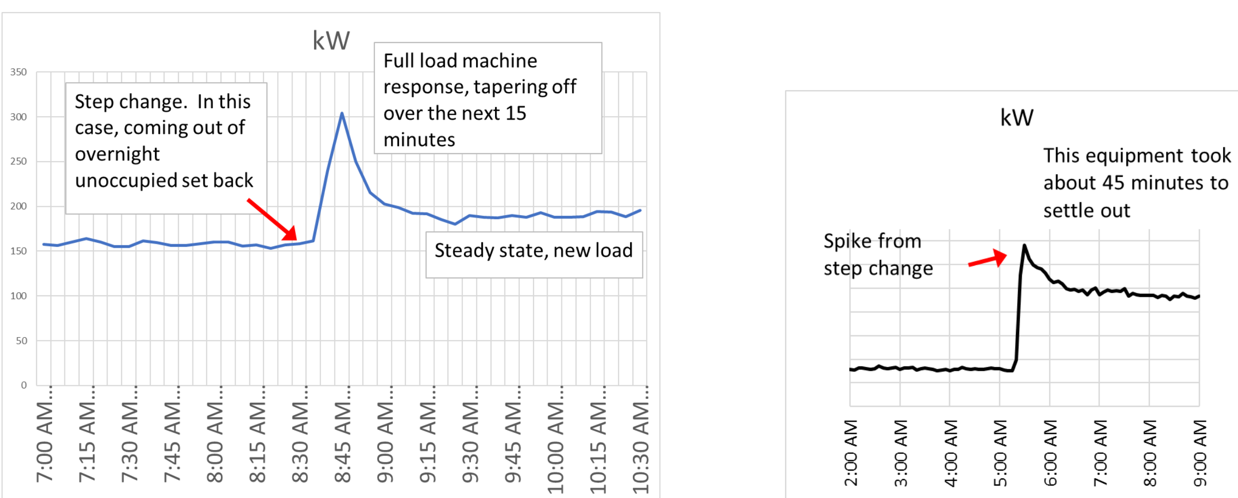


Figure 2 Step Change Examples and kW Demand Machine Response

What You Can Do to Reduce Demand Charges from Step Change 'Spikes' – Grab the Reins

An example will illustrate reducing demand charges by smoothing out short term 'spike' loads. Once the concept is planted in your mind, you can adapt it to different scenarios.

Concept: It's all about learning to live with a smaller generator while still getting the job done.

Consider a building that is electrically heated and has been set back to a low temperature over the weekend.

- Applies equally to heat pumps, and air conditioning as it does to electric heat.
- Applies equally to any standby mode or period moving to active mode as it does to 'Monday morning'
- Applies equally to an array of small items operated simultaneously as it does to single large equipment item.
- Applies equally to heating or cooling a tank of water as it does to heat or cool a building.

Remembering that the energy required for the step change to the building or process is the same whether it occurs in 15 minutes or 2 hours, but the rate of energy use….power…..kW…..size of rented generator…. is higher when asked to the job in less time. With that in mind, the strategy for avoiding a spike during a step change (from unoccupied-to-occupied or standby-to-active state) is to **plan for it and let it take time.** This is done by a combination of predicting how much sooner it needs to be started to end up warm at the right time… and using load limiting control during that time.

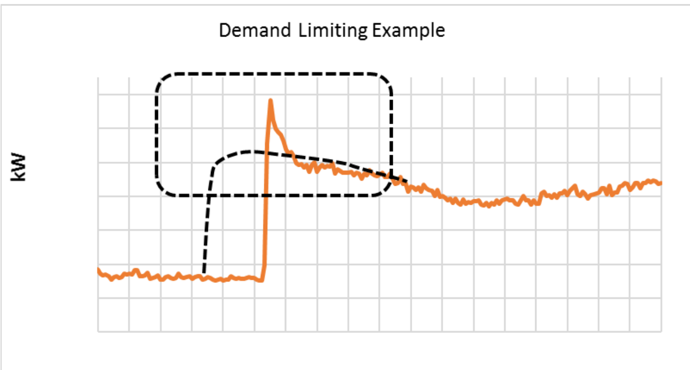
Load limiting control tells the machine (heater, cooler, compressor, etc.) *not* to go to full load. It's like pulling back on the reins, not letting it do what it wants to do. Maybe limit the load to 40% and let it take 2.5x as long as it would if allowed to go to 100% load. Planning, patience, savings.

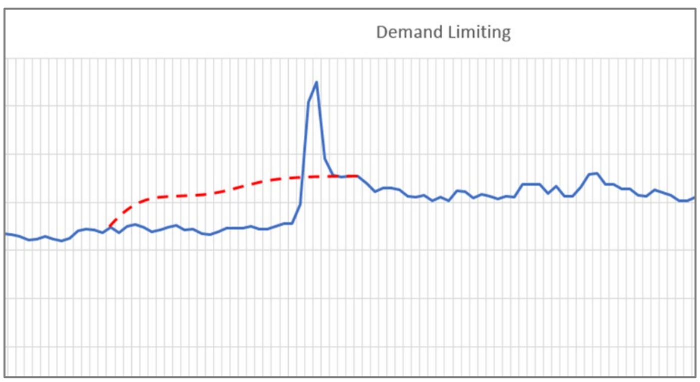
Samples of this concept are shown in **Figure 3**. Exact details of control strategy you would employ will vary according to your business and equipment involved. For example, a step change in a critical manufacturing step may not tolerate delay at all in which case the spike is unavoidable. Also, the '40%' starting spot needs a control watch dog and may need to be increased in 10% increments if it is not enough and would never catch up – process comes first, this only adds economy to the operation. It will work nicely in most cases if you can spend the time initially to get tuned.

Notes:

- The presumption is the availability of 'off time' to make this slow graceful ramp in demand vs. heavy demand. Sometimes in process work, step changes must be dealt with immediately and hard response from equipment is part of doing business. Only use our money-saving suggestions when your business mission allows it.
- Automation is key since a high demand 'even one time' sets the bill for the month.

- It does take an additional amount of control adjustment and shepherding until it is doing what you want; it also takes machines that will accept a load limit command. In the case of single large machines, this method requires some way for the machine to be told to not go above a certain electrical demand point; in the case of multiple small units that are only on-off, the same thing can be accomplished by adjusting start times so that one group gets to start first and the next group does not start until the first group has achieved the new setting and has resumed normal cycling / average loading vs. flat out operation all together.





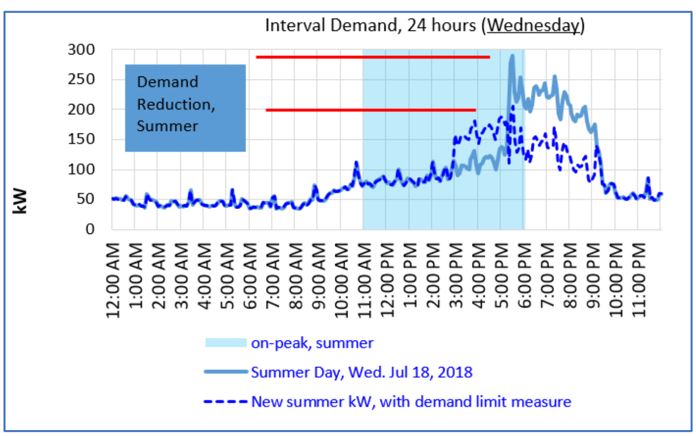


Figure 3. Demand Limit Control Examples Showing Short Term Demand ('Spike') Reduction

Note the areas under the curve are the same for the avoided spike and the new pattern. Energy use is the same, just more time allowed.

Top: Electric heat, morning warmup. Savings from reduced off peak demand and ongoing minimum demand charges

Middle: Electric chiller for comfort cooling entering occupied period.

Lower: An array of packaged roof top units that serve assembly areas in a church, kept off for energy savings and started only when events are about to start.

Additional Strategies for Demand Control – O/M (not capital expense)

- Monitor demand regularly using interval data. You know the building better than anyone and can find opportunities based on expertise.
- Spread out process loads to avoid 'load stacking', such as not starting large load A unless large load B is off or move an electrically intensive process to a different shift to spread out the electric use. Sometimes this causes delays that create problems, sometimes it's just a planning change and doable with some thought. Note that the savings only stick on the bill if the reductions are consistent.
- Where electric heat is used, start in groups and don't start the next group until the first group has caught up and is cycling.
- Voluntarily turning things off or down during peak times. This can be automated and may also be part of a demand reduction (DR) program. These measures are often noticeable to the facility such as dimming lights or allowing interior temperatures to drift, so they are not transparent to business operations (not for everyone).
- Some heat pump systems that use electric resistance backup heat can set a morning peak if they are set back too deeply. Investigate inhibiting the electric heat (takes longer without it) or avoid deep setbacks if you find them all coming on together.
- Packaged VAV rooftop units that have gas morning warmup with electric heat in the VAV boxes can easily set a morning peak when handing off the heating duty at occupied time; this can be smoothed by overheating the spaces beyond the occupied setting and letting them 'coast' down to normal temperature with heaters cycling as they take over, vs. all on for the first half hour.
- Insulate and cover electrically heated tanks and keep them from cooling off between shifts, avoiding large warm-up loads.

Additional Strategies for Demand Control – Capital Measures

Noted for completeness, but outside the scope of this paper

- More efficient equipment…..same output for less input. Applies to lighting, cooling, air compressors, or any major equipment load. Generally considered as energy-saving since the savings occur for hundreds or thousands of hours, but also reduce demand charges when their lowered demand is coincident with the highest demand period of the month and the reduction is persistent
- Fuel switching. When replacing equipment, selecting options that do the job without all the electricity such as natural gas heat, process ovens, humidifiers, evaporative cooling.
- Thermal storage. Leveling the daytime peaks using thermal storage that produces and stores a cold material at night for use during the day.
- Batteries for load leveling. Discharge batteries automatically in peak times.

- Onsite generation. Emission and life cycle cost consideration.
- Onsite solar PV. Non-dispatchable for demand since all it takes is 'one cloudy day' to negate the savings that depend on persistent performance the full month. Expect very good on-peak energy contribution but poor on peak demand savings unless combined with batteries.

Summary

Demand charges dominate most business electric bills.

This paper discussed one form of self-help for demand cost control - treating short-term large demands that stem from the 'catch up' responses called step changes, such as coming out of unoccupied mode, going from idle to event mode, coming out of hibernation mode. The general solution is a combination of load limiting of large loads or an array of small loads, with early start. For heating and cooling equipment, extra time is needed but the energy use is the same.

For customers that already have a robust automatic control system, adding some demand control logic can produce savings with no capital outlay other than time. Manual solutions are possible, but automation is usually more successful because the utility demand savings require the benefit to be e persistent.

For controls to work, equipment must listen. Equipment with built-in 'load limiting' features are an enabler for demand limit control.   A useful business strategy when selecting or replacing equipment is to consider demand limiting capabilities for chillers, heaters, fans, lights so they make it easy to implement demand limiting control.

Each facility and process is unique and the operator's expertise can find other ways to reduce demand charges and reduce utility expense in general. Sometimes just a habit change is all it takes. Interval data is an excellent tool for spotting errant demand patterns and focusing efforts and can be found on the utility customer portal at no charge.