Module 5: Energy Assessment – Demand Analysis

Learning Objectives

After completing this module, you will be able to
- Obtain an electrical demand profile, interpret it, and identify possible EMOs;
- Identify opportunities for power factor correction.

5.1 Introduction

The demand charge is often a significant component of the electricity bill. Effective demand management offers substantial savings opportunities. The demand profile discussed in this Section and the load inventory detailed in Module 6 are tools that may be employed in assessing and managing electricity demand.

The demand profile for a facility, building, service entrance, or any user of electricity is simply a record of the power supplied at any point in time. Its purpose is to provide detailed information about how the facility, or separately metered portion of the facility, uses energy. It is, in essence, the "electrical fingerprint" of the facility. To the electrical energy auditor, the demand profile is an extremely useful tool in tracking energy use.

The simplest demand profile would be a series of manual utility meter demand readings recorded monthly, daily, or hourly, (if possible, more frequently). Monthly demand is shown on the utility bills of monthly billed customers. The particular time interval used will depend on what the information in the demand profile is to be used for. Table 5.1.is a sample of a manually recorded hourly demand profile.

Table 5.1: Manual (Tabular) Demand Profile

Hour	kW	Hour	kW	Hour	kW
1:00 am	45	9:00 am	120	5:00 PM	110
2:00 am	47	10:00 am	122	6:00 PM	82
3:00 am	43	11:00 am	121	7:00 PM	60
4:00 am	46	12:00 PM	100	8:00 PM	61
5:00 am	45	1:00 PM	124	9:00 PM	63
6:00 am	62	2:00 PM	135	10:00 PM	61
7:00 am	69	3:00 PM	120	11:00 PM	65
8:00 am	95	4:00 PM	123	12:00 PM	50

Another representation of the tabulation of demand readings shown in Table 5.1 would be a graph similar to that shown in Figure 5.1. This method of presentation facilitates comparison of the relative demand levels throughout the day, and a quick identification of the hours of peak power demand along with start-up and shut-down characteristics.

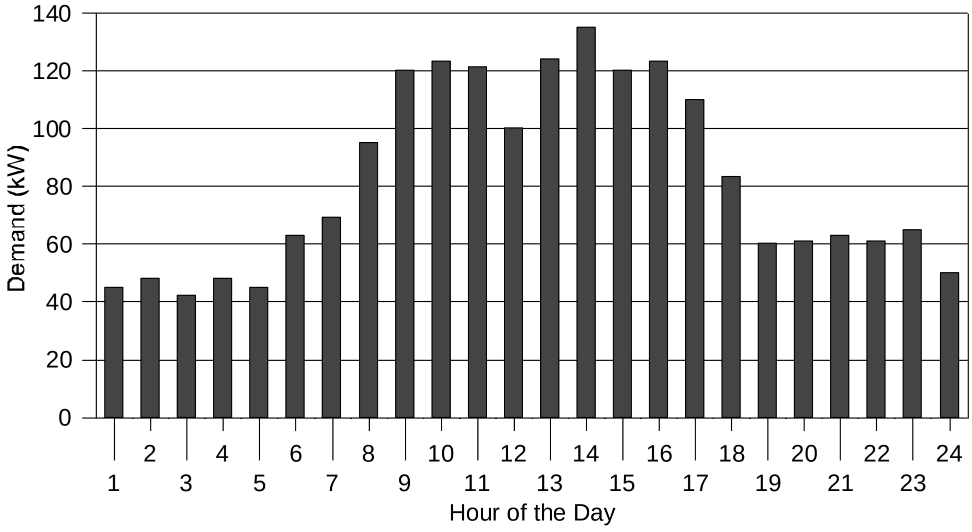


Figure 5.1: Graphical Demand Profile

The most commonly used form of the demand profile is similar to that illustrated in Figure 5.2. The profile covers a period of approximately 24 hours; lightly more than 24 hours is better than less. The power demand appears on the vertical axis, while the time, in hours, appears on the horizontal axis.

A recording power meter was used to generate this demand profile. Readings are generally recorded automatically, less than one minute apart. In some cases, the readings may be adjusted by the recording instrument to match those that would be taken from the utility meter.

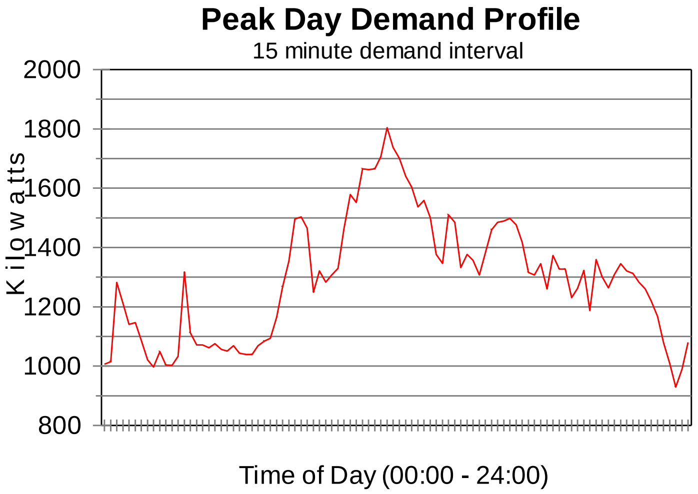


Figure 5.2: 15 minute Interval Demand Profile

The profile shown in Figure 5.2 contains real power information measured in kilowatts (kW). More sophisticated recording power meters are capable of recording kilowatts (kW), kilovolt-amps (kVA), power factor and three phase voltage and current. Comparing Figures 5.1 and 5.2 shows clearly the advantage of using a recording power meter. Significantly more detail is available, although the hour by hour profile remains a valuable starting point.

A great deal of useful information may be derived from the demand profile:

Table 5.2: Information Derived from the Demand Profile

Information	Description
Peak Demand	The time, magnitude and duration of the peak demand period or periods may be determined.
Night Load	The demand present at night (or during unoccupied hours) is clearly identified.
Start-Up	The effect of operation start-up(s) upon demand and the peak demand may be determined.
Shut-Down	The amount of load turned off at shut-down may be identified. This should equal the start-up increment.
Weather Effects	The effect of weather conditions upon the demand for electricity can be identified from day to night (with changing temperature), and from season to season by comparing demand profiles in each season.
Loads that Cycle	The duty cycle of many loads can usually be seen on the demand profile. This can be compared to what is expected.
Interactions	Interactions between systems may be evident—for example, the increased demand for electric heat when ventilation dampers are opened.
Occupancy Effects	Often the occupancy schedule for a facility is reflected in the demand profile; if it is not, this could identify control problems.
Problem Areas	A short-cycling compressor is usually easy to spot from the demand profile.

The information that may be found in the demand profile is not limited to that mentioned above; these are some of the most obvious items. Profiling not only the facility as a whole, but also departments or sections, will allow the development of detailed knowledge of the facility's power consumption habits.

5.2 Obtaining a Demand Profile

A service entrance demand profile can be obtained in a number of ways, some of which have been discussed previously. This section outlines a number of methods along with the strengths and weaknesses of each.

The demand profiling methods that can provide useful information to the electrical auditor include:

- Periodic utility meter readings.
- Recording clip-on ammeter measurements.
- Basic recording power meter.
- Multi-channel recording power meters.
- A Facility energy management or SCADA system.
- A dedicated monitoring system.

While the first method above is the cheapest and simplest to implement, the data it produces is limited. At the other end of the spectrum, the multi-channel recorders are expensive and complex to use, but yield a wealth of information—from real power to power quality.

Whatever technique is used, it is important that the demand profile be measured at a time when the operation of the facility is typical and, if at all possible, the peak demand is equal to the peak demand as registered by the utility meter for the current billing period. This is important since the overall objective in measuring the load profile is to identify which loads contribute to the maximum or billed peak demand.

5.2.1 Periodic Meter Readings

Usually recorded hourly, this method requires a meter that is accessible for readings. The major limitations of this manual method are its limited time resolution (forcing the interpreter to "guess" about the load in between readings) and its labour intensity (although it might be a good student assignment). The advantages of this method are its simplicity, freedom from capital cost outlay, and the fact that readings match exactly the utility's readings. Attaining this match becomes an issue for the other methods.

5.2.1.1 Recording Clip-on Ammeter

A recording ammeter is a single or three phase ammeter connected to a device that will store readings periodically. It may be installed on a facility's incoming service conductors to record current draw over time. The data acquired may then be combined with the system voltage and a power factor to yield an estimated demand reading.

The recording device may be a computerized unit but is usually a strip chart recorder of some description. The recorder is simply connected to an output plug on the clip-on ammeter which looks similar to an Amprobe(TM) unit. Figure 5.3 illustrates the set-up for a single phase measurement.

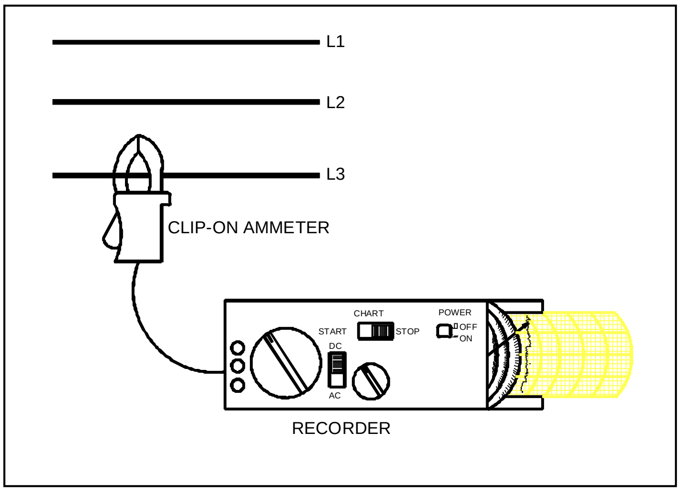


Figure 5.3: Recording Ammeter Set-up

Step 1 Obtain a recording ammeter capable of being installed on the service conductor in the subject facility. This will require an electrician for selection and installation of the equipment. Ensure that the current capacity of the unit is appropriate for the facility.

If the facility is served by three phase power, a three phase meter is advisable. Alternatively, if the loads present in the facility are predominantly three phase, or it is known that the phase currents are balanced reasonably, a single phase meter connected to a representative phase would be a reasonable alternative.

Step 2 Select a typical period, and have the recording ammeter installed and the voltage and power factor measured. For a three phase service, measure each of the phase to phase voltages and take an average.

Step 3 Remove the recording equipment, and retrieve the demand profile—either on a paper strip chart, or via software that reads the data from the recording module and prints a graph.

Step 4 Convert the values of current that you read from the graph of the demand profile to kVA or kW as required:

For kW and single phase: ***kW = Amps x Volts x PF ÷ 1000***
For kW and three phase: : ***kW = Amps x Volts x PF x 1.73 ÷ 1000***
For kVA and three phase: : ***kVA = Amps x Volts x 1.73 ÷ 1000***

The most significant limitation of this method is that it does not measure real power (kW) or reactive power (kVA). Instead, it makes the assumption that the current is proportional to the power. This is only true when two conditions exist:

1. The voltage at the service entrance is always constant—the error introduced if it is not, will depend directly on the voltage variation. This is a reasonable assumption given the normally expected voltage variation.

2. The power factor is constant at all demand levels. This assumption is questionable. The only way to test this assumption is to measure the power factor by the method described above at various demands, say 25%, 50%, 75% and 100% of the peak demand. If there is a dramatic change in power factor, the accuracy of this method becomes questionable.

5.2.1.2 Basic and Multi-Channel Recording Power Meters

These methods of measuring the demand profile are virtually the same except that the basic method would normally only record one value such as kilowatts (kW) or kVA, whereas the multi-channel method could record kW, kVA, phase current, voltage, overall power factor and possibly more.

The recording power meter measures current and voltage simultaneously on up to three phases and calculates electronically kW, kVA and power factor. A recording device such as a magnetic tape, paper chart recorder or microprocessor based data logger stores all information for later use. A typical installation is shown in Figure 5.4.

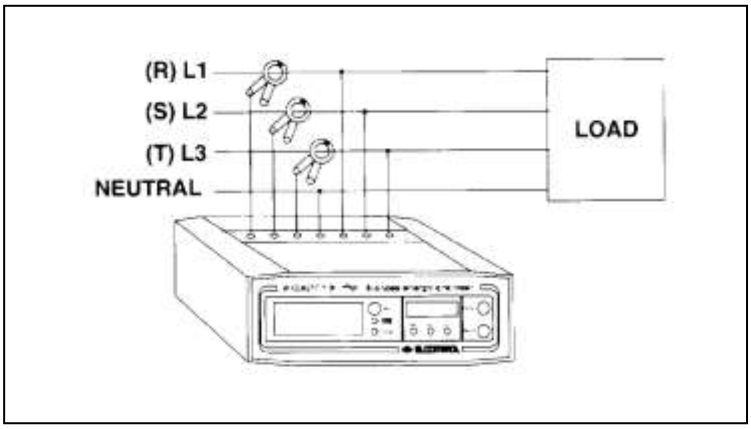


Figure 5.4: Elcontrol ™ Recording Power Meter Set-up

When using a recording power meter, it is highly advisable to follow carefully the manufacturer's instructions for use. The following steps outline the general procedure to be followed:

Step 1 Obtain a recording power meter capable of being installed on the service conductor in the subject facility. This will require an electrician for selection and installation of equipment. Ensure that the maximum power that may be measured by the meter is not exceeded by the expected peak demand. If the facility is served by three phase power, a three phase meter is advisable. Alternatively, a single phase meter connected to a representative phase would be a reasonable substitute.

Step 2 Select a 24-hour period during which the load is typical and have the meter installed for this period.

Step 3 Remove the recording equipment, and retrieve the demand profile, either on a paper strip chart, or via software that reads the data from the recording module and prints a graph.

When using demand profile results measured by a recording power meter or ammeter, it is important to remember that the power meter takes a large number of readings per minute. The meter is capable of registering very fast changes in power demand; Utility meters are not. The standard utility meter averages the demand over the previous 15 minute period. Some models of power meter will perform an average; others will not. Interpretation of the demand profile (Section 5.3) should take this into consideration.

Sample monthly and peak day profiles generated with a recording power meter are shown in Figures 5.2 and 5.5; these profiles were generated from 15 minute average data.

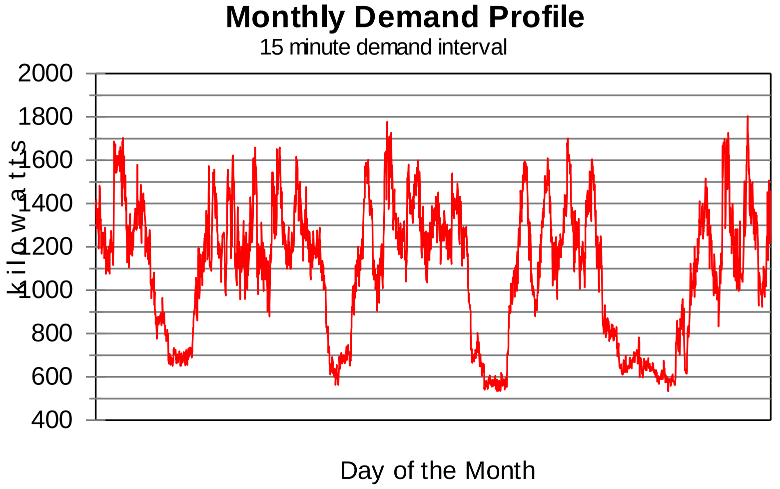


Figure 5.5: 15 Minute Interval Demand Profile

5.3 Interpreting the Demand Profile

The demand profile is the electrical "fingerprint" of a facility's electrical consumption patterns. Key information may be obtained by reading or interpreting the profile, loads that operate continuously and could be shut down, loads that contribute unnecessarily to the peak demand, or possibly loads that are operating abnormally and require maintenance.

Many electrical loads leave behind very distinct fingerprints as they operate. By recognizing the patterns associated with each component, it is possible to identify the contribution of various loads to the overall demand profile.

Interpreting a demand profile is not just science; there's a bit of interpretative art involved, too. Good knowledge of the facility, its loads, operational patterns, and the examples in this section should be a good beginning for the development of that art.

Step 1 Did the peak occur when it was expected and was it equal to that taken from the utility invoice? Was the night load greater than, less than, or equal to what was expected? Did the facility shut down and start-up as anticipated?

Step 2 It is useful to begin with a list or inventory of electrical loads within a facility.

Step 3 Study the demand profile and circle or make a note of all the significant occurrences, such as:

- abrupt changes in demand
- the top three peak demands
- repeated patterns
- flat sections
- dips during peak periods
- minimum demand level

This is only a partial list; each and every demand profile will be different. Mark anything that looks significant.

Step 4 Mark along the time scale the time of day when significant operational events occur. Such events would include:

- start-up and shut-down
- coffee breaks
- lunch hour
- shift changes
- notable events (operation of a certain process)

The purpose here is to spot some correlation between the features noted in Step 3, and work patterns in the facility.

Step 5 Annotate your demand profile to indicate known events. Make a copy of this profile and circulate to others who may be able to assist you in explaining the patterns.

5.3.1 Opportunities for Savings in the Demand Profile

Often, many opportunities for savings can be found in the Demand Profile. The following are typical examples of savings opportunities:

- A peak demand that is significantly higher than the remainder of the profile for a short amount of time is an opportunity for demand reduction by scheduling.
- A high night load in a facility without night operations presents an opportunity for energy savings through better control or possibly time clocks.
- Loads that cycle on/off frequently during unoccupied periods suggests that possibly they could be shutdown completely.
- High demands during breaks in a production operation or insignificant drops at break times suggests that equipment idling may be costly--consider shutdown.

- Make sure that systems are not starting up before they are needed and shutting down after the need has past. Even 1/2 hour per day can save a significant amount if the load is high.

- Peak demand periods at start-up times suggests an opportunity for staged start-up to avoid the peak.

- If the billed demand peak is not evident on a typical demand profile, this suggests that the load (or loads) which determine the demand may not be necessary (if they only operate once in a while). Consider scheduling these loads. Also check the billing history to see if the demand peak is consistent.

- A large load that cycles frequently may result in a higher peak demand and a lower utilization efficiency than a smaller machine running continuously. Consider the use of smaller staged units or machines. Such a strategy may also reduce maintenance since machine start/stop results in increased wear and tear.

- Short cycling loads are a clue to potential maintenance savings and failure prevention.

5.3.2 Power Factor Correction Savings Opportunities

For customers billed on kVA demand there is an opportunity to reduce the peak or maximum kVA demand by increasing your power factor. As defined in Module 3, power factor is the ratio of real power in kilowatts (kW) to the apparent power in kilovoltamps (kVA). With the application of a capacitor or bank of capacitors it is possible to reduce the kVA demand while maintaining the real power consumption, the kW demand.

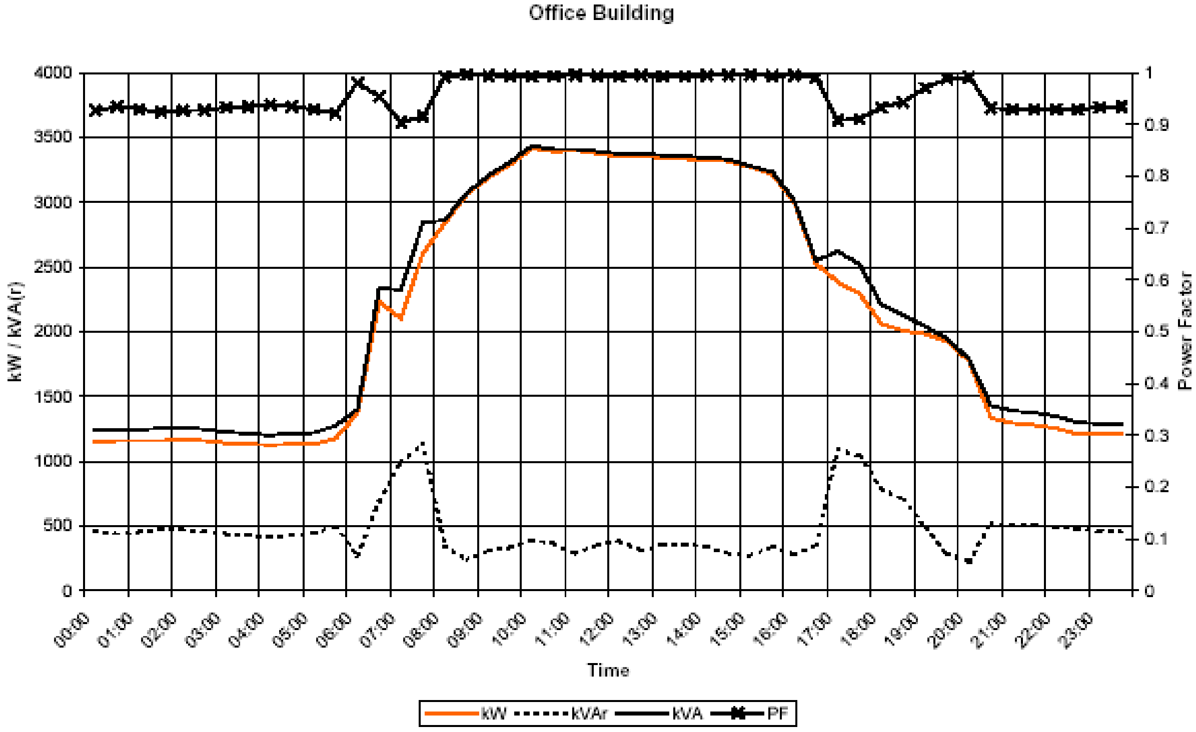
- **Correct power factor**
  In practice it is only the on-peak power factor that really is of concern from the perspective of demand costs.

- **Correct power factor at service entrance**
  This can be done with the addition of a fixed capacitor bank provided that the load and power factor are constant. Otherwise a variable bank (one that adjusts itself to the load and power factor) will be required.

- **Correct power factor in the distribution system**
  When large banks of loads are switched as a unit within the distribution system, installing capacitors at the point of switching may be an advantage. This has an added secondary benefit in that it may also free up current carrying capacity within the distribution system.

- **Correct point-of-use power factor**
  When a large number of motors start/stop frequently or are only partly loaded, it may be operationally advantageous to install power factor correction capacitors at the point-of-use (i.e. at the motor). In this manner the correction capacitors are brought on-line with the motor and removed as the motor is stopped.

Worksheet 5-1 Demand Profile Analysis



Questions:

1) **What operational practices explain this profile—describe the routine that gives rise to this demand/PF pattern.**

2) **What potential savings opportunities arise from this profile?**