



BEYOND
SMART CITIES

**ELECTRICAL POWER SYSTEMS - CEM
REFRESHER TRAINING**

KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
FOR ENERGY MANAGEMENT AND EFFICIENCY PROFESSIONALS

ENERGY MANAGEMENT SPECIALIST
BEYOND SMART CITIES

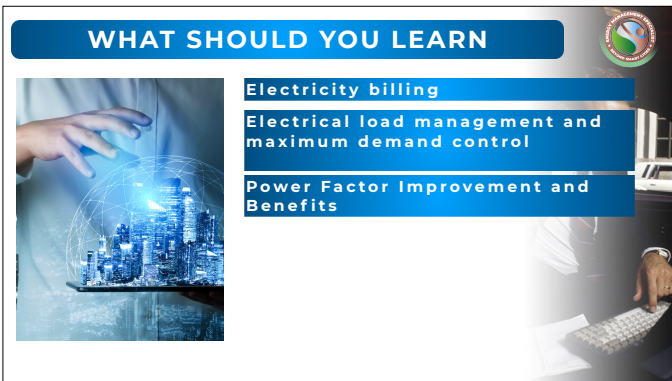


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**ELECTRIC POWER SUPPLY SYSTEMS- 2
FOR ENERGY PROFESSIONALS**

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WHAT SHOULD YOU LEARN

Electricity billing

**Electrical load management and
maximum demand control**

**Power Factor Improvement and
Benefits**

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ELECTRICITY BILLING

The electricity billing by utilities for medium & large enterprises, in High Tension (HT) category, is often done on two-part tariff structure, i.e. one part for capacity (or demand) drawn and the second part for actual energy drawn during the billing cycle. Capacity or demand is in kVA (apparent power) or kW terms.

The reactive energy (i.e.) kVA_{rh} drawn by the service is also recorded and billed for in some utilities, because this would affect the load on the utility. Accordingly, utility charges for maximum demand, active energy and reactive power drawn (as reflected by the power factor) in its billing structure. In addition, other fixed and variable expenses are also levied.

ELECTRICITY BILLING +

The tariff structure generally includes the following components:

a) Maximum demand Charges These charges relate to maximum demand registered during month/billing period and corresponding rate of utility.

b) Energy Charges These charges relate to energy (kilowatt hours) consumed during month / billing period and corresponding rates, often levied in slabs of use rates. Some utilities now charge on the basis of apparent energy (kVAh), which is a vector sum of kWh and kVA_{rh}.

c) Power factor penalty or bonus rates, as levied by most utilities, are to contain reactive power drawn from grid.

ELECTRICITY BILLING +

d) Fuel cost adjustment charges as levied by some utilities are to adjust the increasing fuel expenses over a base reference value.

e) Electricity duty charges levied w.r.t units consumed.

f) Meter rentals

g) Lighting and fan power consumption is often at higher rates, levied sometimes on slab basis or on actual metering basis.

h) Time Of Day (TOD) rates like peak and non-peak hours are also prevalent in tariff structure provisions of some utilities.

i) Penalty for exceeding contract demand

j) Surcharge if metering is at LT side in some of the utilities

ELECTRICITY BILLING +

Analysis of utility bill data and monitoring its trends helps energy manager to identify ways for electricity bill reduction through available provisions in tariff framework, apart from energy budgeting.

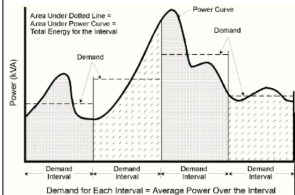
The utility employs an electromagnetic or electronic trisector meter, for billing purposes. The minimum outputs from the electromagnetic meters are

- ✓ Maximum demand registered during the month, which is measured in preset time intervals (say of 30 minute duration) and this is reset at the end of every billing cycle
- ✓ Active energy in kWh during billing cycle
- ✓ Reactive energy in kVarh during billing cycle and
- ✓ Apparent energy in kVAh during billing cycle



DEMAND CURVE

The month's maximum demand will be the highest among such demand values recorded over the month. The meter registers only if the value exceeds the previous maximum demand value and thus, even if, average maximum demand is low, the industry / facility has to pay for the maximum demand charges for the highest value registered during the month, even if it occurs for just one recording cycle duration i.e., 30 minutes during whole of the month. A typical demand curve is shown in Figure 1.4.



As can be seen from the Figure 1.4 above the demand varies from time to time. The demand is measured over predetermined time interval and averaged out for that interval as shown by the horizontal dotted line. Of late most electricity boards have changed over from conventional electromechanical trisector meters to electronic meters, which have some excellent provisions that can help the utility as well as the industry.



ELECTRICAL LOAD MANAGEMENT AND MAXIMUM DEMAND CONTROL

Need for Electrical Load Management :

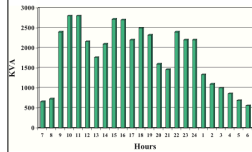
✓ In a macro perspective, the growth in the electricity use and diversity of end use segments in time of use has led to shortfalls in capacity to meet demand. As capacity addition is costly and only a long time prospect, better load management at user end helps to minimize peak demands on the utility infrastructure as well as better utilization of power plant capacities.

✓ The utilities (State Electricity Boards) use power tariff structure to influence end user in better load management through measures like time of use tariffs, penalties on exceeding allowed maximum demand, night tariff concessions etc. Load management is a powerful means of efficiency improvement both for end user as well as utility.

✓ As the demand charges constitute a considerable portion of the electricity bill, from user angle too there is a need for integrated load management to effectively control the maximum demand.



STEP BY STEP APPROACH FOR MAXIMUM DEMAND CONTROL



1. Load Curve Generation Presenting the load demand of a consumer against time of the day is known as a 'load curve'. If it is plotted for the 24 hours of a single day, it is known as an 'hourly load curve' and if daily demands plotted over a month, it is called daily load curves. A typical hourly load curve for an engineering industry is shown in Figure 1.5. These types of curves are useful in predicting patterns of drawl, peaks and valleys and energy use trend in a section or in an industry or in a distribution network as the case may be.

STEP BY STEP APPROACH FOR MAXIMUM DEMAND CONTROL +



2. Rescheduling of Loads Rescheduling of large electric loads and equipment operations, in different shifts can be planned and implemented to minimize the simultaneous maximum demand. For this purpose, it is advisable to prepare an operation flow chart and a process chart. Analysing these charts and with an integrated approach, it would be possible to reschedule the operations and running equipment in such a way as to improve the load factor which in turn reduces the maximum demand.

3. Storage of Products/in process material/ process utilities like refrigeration It is possible to reduce the maximum demand by building up storage capacity of products/ materials, water, chilled water / hot water, using electricity during off peak periods. Off peak hour operations also help to save energy due to favourable conditions such as lower ambient temperature etc. Example: Ice bank system is used in milk & dairy industry. Ice is made in lean period and used in peak load period and thus maximum demand is reduced.

STEP BY STEP APPROACH FOR MAXIMUM DEMAND CONTROL +



4. Shedding of Non-Essential Loads When the maximum demand tends to reach preset limit, shedding some of non-essential loads temporarily can help to reduce it. It is possible to install direct demand monitoring systems, which will switch off non-essential loads when a preset demand is reached. Simple systems give an alarm, and the loads are shed manually. Sophisticated microprocessor controlled systems are also available, which provide a wide variety of control options like:

- ✓ Accurate prediction of demand
- ✓ Graphical display of present load, available load, demand limit
- ✓ Visual and audible alarm
- ✓ Automatic load shedding in a predetermined sequence
- ✓ Automatic restoration of load
- ✓ Recording and metering

STEP BY STEP APPROACH FOR MAXIMUM DEMAND CONTROL +



5.Operation of Captive Generation and Diesel Generation Sets
When diesel generation sets are used to supplement the power supplied by the electric utilities, it is advisable to connect the D.G. sets for durations when demand reaches the peak value. This would reduce the load demand to a considerable extent and minimize the demand charges.

6.Reactive Power Compensation The maximum demand can also be reduced at the plant level by using capacitor banks and maintaining the optimum power factor. Capacitor banks are available with microprocessor based control systems. These systems switch on and off the capacitor banks to maintain the desired Power factor of system and optimize maximum demand thereby.

POWER FACTOR IMPROVEMENT AND BENEFITS



Power factor Basics In all industrial electrical distribution systems, the major loads are resistive and inductive. Resistive loads are incandescent lighting and resistance heating. In case of pure resistive loads, the voltage (V), current (I), resistance (R) relations are linearly related, i.e.

$$V = I \times R \text{ and Power (kW)} = V \times I$$

Typical inductive loads are A.C. Motors, induction furnaces, transformers and ballast-type lighting. Inductive loads require two kinds of power: a) active (or working) power to perform the work and b) reactive power to create and maintain electro-magnetic fields. Active power is measured in kW (Kilo Watts). Reactive power is measured in kVAR (Kilo Volt-Amperes Reactive).

The vector sum of the active power and reactive power make up the total (or apparent) power used. This is the power generated by the SEBs for the user to perform a given amount of work. Total Power is measured in kVA (Kilo Volts-Amperes) (See Figure 1.1).

POWER FACTOR IMPROVEMENT AND BENEFITS



The active power (shaft power required or true power required) in kW and the reactive power required (kVAR) are 90° apart vectorially in a pure inductive circuit i.e., reactive power kVAR lagging the active kW. The vector sum of the two is called the apparent power or kVA, as illustrated above and the kVA reflects the actual electrical load on distribution system.

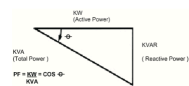


Figure 1.1 kW, kVAR and kVA Vector

The ratio of kW to kVA is called the power factor, which is always less than or equal to unity. Theoretically, when electric utilities supply power, if all loads have unity power factor, maximum power can be transferred for the same distribution system capacity. However, as the loads are inductive in nature, with the power factor ranging from 0.2 to 0.9, the electrical distribution network is stressed for capacity at low power factors. 1. Electrical System

IMPROVING POWER FACTOR



The solution to improve the power factor is to add power factor correction capacitors (see Figure 1.2) to the plant power distribution system.



They act as reactive power generators, and provide the needed reactive power to accomplish kW of work. This reduces the amount of reactive power, and thus total power, generated by the utilities.

THE ADVANTAGES OF PF IMPROVEMENT BY CAPACITOR ADDITION



- a) Reactive component of the network is reduced and so also the total current in the system from the source end.
- b) I^2R power losses are reduced in the system because of reduction in current.
- c) Voltage level at the load end is increased.
- d) kVA loading on the source generators as also on the transformers and lines upto the capacitors reduces giving capacity relief. A high power factor can help in utilising the full capacity of your electrical system.

COST BENEFITS OF PF IMPROVEMENT



While costs of PF improvement are in terms of investment needs for capacitor addition the benefits to be quantified for feasibility analysis are:

- ✓ Reduced kVA (Maximum demand) charges in utility bill
- ✓ Reduced distribution losses (KWH) within the plant network
- ✓ Better voltage at motor terminals and improved performance of motors
- ✓ A high power factor eliminates penalty charges imposed when operating with a low power factor
- ✓ Investment on system facilities such as transformers, cables, switch gears etc for delivering load is reduced.