Study on Electrical Load Management and Power Factor

M. Hemavarthini[1], R. Lavanya[2], Z. Benazir Fatthima[3]
[1,2,3] Student, Department of Electrical and Electronics Engineering,
Rajagopal Polytechnic College,
Gudiyattam – 632 602, Tamil nadu, India

***Abstract*:- The electricity billing for medium and large Enterprises (HT) is normally done on two parts. One is based on capacity or demand drawn and the other one is actual energy during the billing cycle. The tariff structure generally includes the components such as the maximum demand charges relating to maximum demand registered during month or billing period and corresponding rate of utility, energy charges relating to energy (kWhr) consumed during month or billing period, often levied in slabs of use rates and some utilities now charge on the basis of apparent energy (kVAr), power factor penalty or bonus rate which is done to contain the reactive power drawn from the grid, fuel cost adjustment charges, electricity duty charges with respect to unit consumed, meter rentals, time of day rates(TOD) like peak and non-peak hours and penalty for exceeding contract demand. Analysis of utility bill data and monitoring its trends helps Energy Manager to identify ways of Electricity Bill reduction.**

Keywords:* *Power Factor (PF), Electrical Load Management (ELM), Rate of Utility, Time of Day (TOD) Rates

1. INTRODUCTION

1.1 Electrical Load Management (ELM)

Better Load Management at user end helps to minimize peak demands on utility infrastructure as well as better utilization of power plant capacities. Load Management is a powerful means of efficiency improvement both for end users and as well as utility [1]. The typical electrical power supply system is shown in Fig.1 and electrical distribution system in Fig.2.

1.2 Load Factor

The load factor corresponds to the ratio between your actual energy consumption (kWh) and the maximum power recorded (demand) for that period of time. Increasing your load factor will diminish the average unit cost (demand and energy) of the kWh. Depending on your situation, improving your load factor could mean substantial savings. Load curve generation is presenting the load demand of a consumer against the time of the day is knows as a Load Curve [2]. If it is plotted for 24 hrs of a single day it is known as Hourly Load Curve and if daily demands plotted over a month then it is known as Daily Load Curves. The Maximum Demand (Daily Load Curve, Hourly kVA) is as shown in Fig.3.

By analyzing load profile and needs, the load factor can be improved by,

❖ Demand Reduction:

- Reduce demand by distributing your loads over different times or by installing load management systems.

❖ Increase Production:

- Keeping the demand stable and increasing your consumption is often a cost-effective way to increase production while maximizing the use of power.

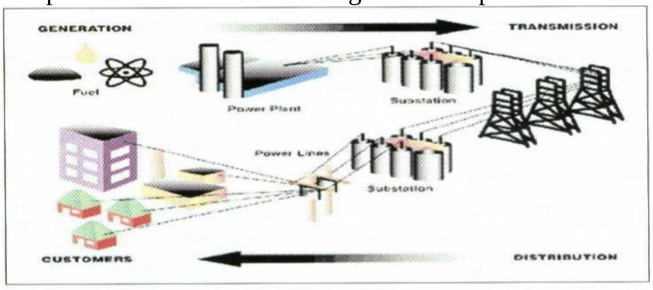

Fig.1 Typical Electric Power Supply System

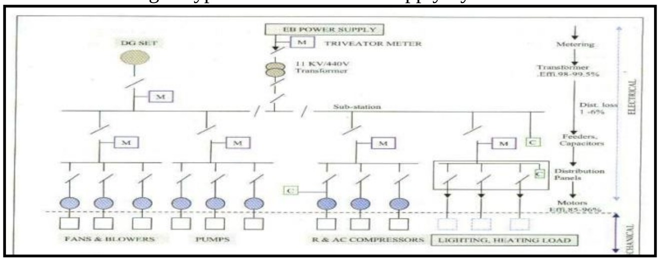

Fig.2 Electrical Distribution System Single Line Diagram

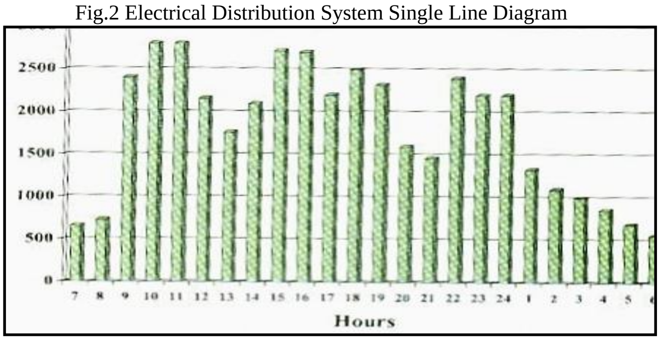

Fig.3 Maximum Demand (Daily Load Curve, Hourly kVA)

By analyzing load profile and needs, the load factor can be improved by:

- Demand Reduction: Reduce demand by distributing your loads over different times or by installing load management systems.
- Increase Production: Keeping the demand stable and increasing your consumption is often a cost-effective way to increase production while maximizing the use of power.

❖ Rescheduling of Loads:

Rescheduling of large electric load and equipment operations, in different shifts can be planned for this purpose it is advisable to prepare a Operation Flow Chart and Process Chart for example storage of products / in process material / process utilities like refrigeration in order to reduce maximum demand by building up storage capacity of products / materials, water, chilled water / hot water using electricity during off peak periods [3]. For example, Ice Bank system is used in milk & Dairy industry. Ice is made in lean period and used in peak load period.

❖ Shedding of Non- Essential Loads:

When the Maximum load tends to reach pre-set limits shedding some of non-essential loads temporarily can help to reduce it. This may be achieved by installing direct demand monitoring system which will switch of non-essential loads as per Programme when a preset demand is reached. It is also advisable to connect the operation of captive generation and diesel generation sets for durations when demand reaches the peak values [4]. The Maximum demand can also be reduced by using capacitor banks and maintaining the optimum of power factor.

2. POWER FACTOR IMPROVEMENTS & BENEFITS

AC Power is transmitted with the least losses if the current is undistorted and exactly synchronized with the voltage. For example, resistance heaters draw current exactly synchronized and proportional to the voltage. But most other loads like Inductive motors, Computers and adjustable speed motor drives, draw current with a time lag (Phase Shift) or Distort it (Introducing Harmonics).It takes more current to deliver a fixed amount of power when the current is phase shifted or distorted [5]. True power is measured in watts (W), is the power drawn by the electrical resistance of a system that does useful work and reactive power is measured in volt-amperes, reactive, (VAR) is the power stored in and discharged by the inductive motors, transformers and solenoids all draw reactive power whereas apparent power is measured in volt-amperes (VA) is the voltage on an AC system multiplied by all the current that flows in it. It is the vector sum of the true and the reactive power.

Power Factor (PF) is the ratio of the true power used in a system to the apparent power drawn from the source. It's usually expressed in percent: W/VA x 100. The cosine of the angle between VA and W in this vector diagram ø is a measure of power factor. It includes larger, VAR current, lower, and power factor. There are two types of PF one is the Displacement PF (DPF), which considers only the Phase shift component and the other one is the True Power Factor (TPF) that accounts for both for distortion as well as Phase shift. Utilities that impose low power factor penalties tend to meter and bill only on DPF. Ignoring the effects of harmonic distortion leads to some fairly simple mathematical relationships illustrated by the power triangle in Fig.4 and real power in Fig 5.

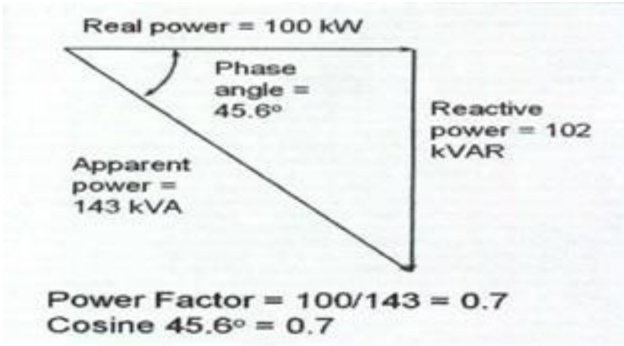

Fig.4 Power Triangle

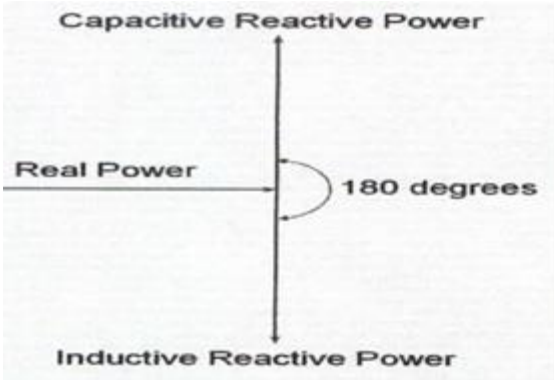

Fig.5 Real Power

The Solution to Improve the Power Factor is to add Power Factor Correction capacitors. They act as a reactive power generator and provide the needed reactive power to accomplish kW of work [6]. This reduces the amount of reactive power and thus Total Power Generated by the Utilities. Fig.6 shows the effect of 0.7 PF at 200kW.

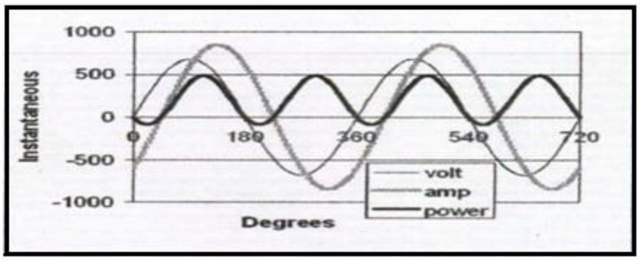

Fig.6 Power factor 0.7 at 200 Kw

3. ADVANTAGE OF PF IMPROVEMENT BY CAPACITOR ADDITION:

- I2R power losses are reduced in the system because of reduction in current.
- Voltage level at the load end is increased.
- kVA loading on the source generators as also on the transformers and lines up to the capacitors reduces giving capacity relief. A high power factor can help in utilizing the full capacity of your electrical system.
- Replace over-sized motors with Energy efficiency motors of the right horsepower. Any motor's power factor is dramatically worse when it is loaded significantly below the full nameplate horsepower rating.
- Shut down idling motors. When totally unloaded, even uncoupled, a motor still draws over half its full-load reactive power.

- Avoid operation of equipment above its rated voltage. Over-voltage increases reactive.

4. COST BENEFITS OF PF IMPROVEMENT:

- Reduced kVA (Maximum demand) charges in utility bill
- Reduced distribution losses (kWH) within 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, switchgears etc., for delivering load is reduced.

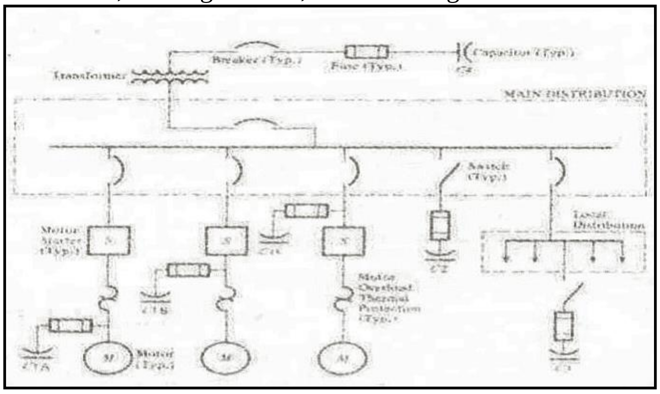

Fig.7 Typical capacitor locations

5. CONCLUSION

Thus a careful selection of capacitors could be done based on kVAr Rating = kW (tan a1 – tan a2)
Where
kVAr Rating = Size of the capacitor
kW = the average power drawn
tan a1= trigonometric ratio for the present PF
tan a2 = trigonometric ratio for the desired PF
For maximum power factor improvement and benefit the location of capacitors are carefully selected. Fig.7 indicates typical capacitor locations. Maximum benefit of capacitors is derived by locating them as close as possible to the load.

6. REFERENCES

[1] ABB, "Power factor corrections and harmonic filtering in electrical plants", Technical application paper no.8, july 2008.
[2] Ali Bazzi.M and Philipkrein.T, " Review of methods for real time loss minimization in machines"IEE Transactions on industry applications, vol.46, no.6, pp2319-2328, 2010.
[3] Kessal.A, Rahmani.L et al. "Power factor correction based on fuzzy controller with fixed switching frequency", Electronics and Electrical Engineering-Kaunas : Technologija, no.2, pp67-72, 2012.
[4] Rifat Shahriar.M et al. "A PWM based scheme for power factor correction", 6th international forum on strategic technology, IFOST 2011, Aug 22-24, 2011.
[5] Thirugnanasambandam.M. et al., "Analysis of electrical motors load factors and energy savings in an Indian cement industry", Elsevier Energy, no.36, pp.4307-4314, 2011.
[6] APFC of Lakshmi Electric Control room "An optimized and fully automatic solution for power factor maintenance and harmonics control in LV industrial distribution system.