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Pertinent Energy Management with Power Factor Considerations: An Industrial review

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Abstract: In a supply system, to endorse the most favourable conditions, it is imperative to have a power factor as close to unity as possible. Poor power factor has a direct effect on the electrical system and on consumer's electricity bills. The result proposed is based on the quantitative data collected from an industrial environment. This analysis gives an insight into improving the power factor and hence reducing the electricity bills.

Key words: Power factor, Maximum demand, Automatic Power factor controllers.

INTRODUCTION

Electrical energy is almost exclusively generated, transmitted and distributed in the form of alternating current. Most loads are inductive in nature and hence have a low lagging power factor. Low power factor causes an increase in current which lead to additional losses of active power in all elements of power system- from the power station generator to the utilization devices. Hence low power factor is highly undesirable.

Causes of Low Power Factor: Induction motors are a prime cause of low power factor for many consumers. Poor power factor is an issue especially for customers with large numbers of small fractional horsepower motors, those who purchase cheap or poorly made motors. Most small fractional horsepower motors have low power factors in the 50 to 60 per cent range. As the rated horsepower of the motor increases, in general, the power factor of the motor at full load increases. Therefore, larger horsepower motors have better power factors than small horsepower motors if each motor is properly loaded.

Power factor may vary significantly between two motors of the same size made by different manufacturers. It is important to select motors from reputable manufacturers and consider the power factor ratings of the individual motors. Generally, if a motor has a high power factor, it is constructed of better materials, will last longer, and may have a longer warranty.

Effects of low power factor on consumer: If the power factor of the consumer is less than 0.9, the consumer has to pay a certain poor power factor penalty. Poor power factor reduces the earning capacity of the power station and simultaneously increases the electricity bills of the consumer. As station output in KW =KVA * (Power factor), therefore the number of unit supplied by it depends on the power factor. The lower the power factor, the lesser the KWh it delivers to the system. This leads to the conclusion that low power factor decreases the earning capacity of the power station and thus they penalize the consumer. Also poor power factor causes the maximum demand value to increase since KVA =KW/power factor.

As the consumers are charged according to the maximum demand values, the low power factor means greater maximum demand charges and hence higher energy bills. Power factor is more significant in industries as most AC motors are of induction type with low lagging power factor and used largely by industries. Arc lamps, electrical discharge lamps and industrial heating furnaces operate at low lagging power factor. The State Electricity Boards (SEB's) has installed Digital Electronic Energy (Tri-Vector) Meters for consumers, which has the provision of showing the PF and insisting to maintain the average Power Factor above a Specified limit (0.85 – 0.90 PF) Otherwise, for every reduction of 0.01 from the specified PF, PENALTY is levied on the Energy Consumption Charges (KWh) on the Electricity Bill. SEB's are also offering PF incentives if the PF is maintained above the specified PF. In few states, where the metering unit is KVAh and if the PF is maintained at its optimum of 0.99, the electricity bill amount itself is reduced considerably.

Maximum Demand: Maximum Demand is the power consumed over a predetermined period of time, which is usually between 8 – 30 minutes. The most common period of time in the majority of countries, is 15 minutes. Since Power Factor = cos φ = KW/ KVA so power factor and maximum demand in KVA exhibit an inverse relation. The demand charges levied per KVA in electricity bill will reduce as maximum demand lowers. Also since

$$\text{Power Factor Surcharge} = \frac{(0.90 - \text{Pfactual}) \text{ X MD X MDcharge}}{0.90}$$

Where, MD is the Maximum Demand for the month in KVA, MDcharge is the maximum demand charge per kVA, set by the Public Utilities Regulatory Commission in the tariffs, so as maximum demand reduces, power factor surcharge also lower downs.

Observations: The above stated concepts are braced by the data collected in an industrial environment over a period of 20 months in **Table 1 and Table 2.**

Table-1: Power factor recorded and Power factor penalty paid by the consumer.

Month	Power factor recorded	Power factor penalty paid by the consumer (in Rs)
1	0.66	19,204.70
2	0.62	20,064.42
3	0.66	17,468.86
4	0.68	15,470.61
5	0.65	16,873.00
6	0.63	20,268.00
7	0.64	19,721.00
8	0.62	19,946.00
9	0.70	16,868.00
10	0.72	15,834.00
11	0.75	14,194.00
12	0.71	16,528.80
13	0.66	20,729.46
14	0.66	16,468.47
15	0.66	19,002.99
16	0.60	20,005.45
17	0.58	21,839.15
18	0.63	15,534.96
19	0.63	29,184.40
20	0.59	32,523.49

Table -2: Maximum Demand Before and after installing power factor Controller in KVA.

Month	Maximum Demand (Before installing power factor Controller in KVA) MD(B)	Maximum Demand (After installing power factor Controller in KVA) MD(A)
1	48	35.2
2	41.5	28.5
3	38	28.5
4	40	28.5
5	32	28.5
6	32	22.4
7	37	26.3
8	38	21.20
9	51	39.6
10	54	43.2
11	76	63.3
12	50	39.4
13	46	33.73
14	46	33.73
15	43	31.53
16	42	28
17	37	23.85
18	36	25.2
19	40	28
20	35	22.94

DISCUSSION

Improvement of Power Factor

Use of Automatic power factor controller (APFC): Power factor can be improved by the use of Automatic Power Factor Controller (APFC). APFC employs capacitor banks and since capacitors draw a current leading the supply voltage V by 90^0, they neutralize the quadrature or wattles component of current drawn by the equipment across which they are connected (relevant phasor diagram - figure 2 and 3) Thus the capacitor banks minimize the phase difference between voltage and current which eventually leads to improved power factor. APFC panel has a Micro-controller based Programmable Controller, which switches the Capacitor bank (figure 1) of suitable capacity automatically, in multiple stages by directly reading the reactive power (RKVA) which works in the Principle of VAR Sensing, tends to maintain the PF to 0.99 Lag. The capacitor banks may be selected in number of stages as 4/5/6/7/8 according to the load pattern.

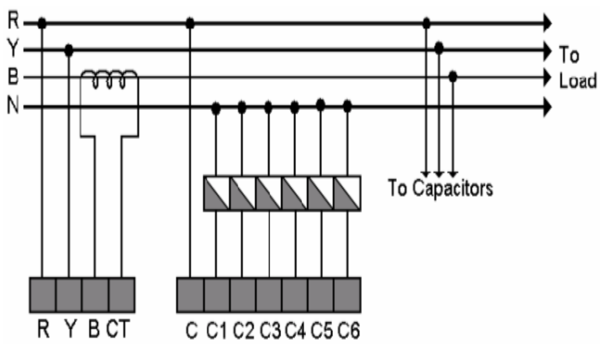

Figure 1: Wiring diagram of Automatic Power Factor Controller

Technique involved in APFC – The phasor diagrams

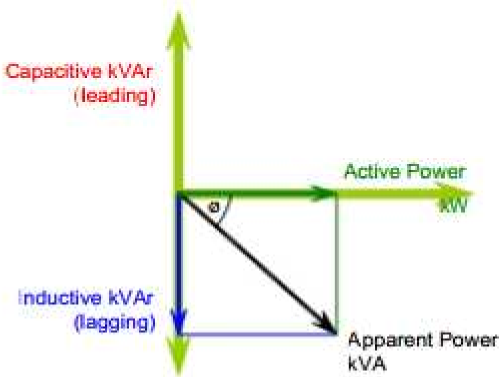

Figure 2: Phasor diagram between active,reactive and apparent power without Capacitive bank.

The figure above represents

1. Inductive KVAr lags the KW by 90^0
2. Apparent power KVA is the phasor sum of KW+KVAr(ag)
3. Power factor is cosine of angle

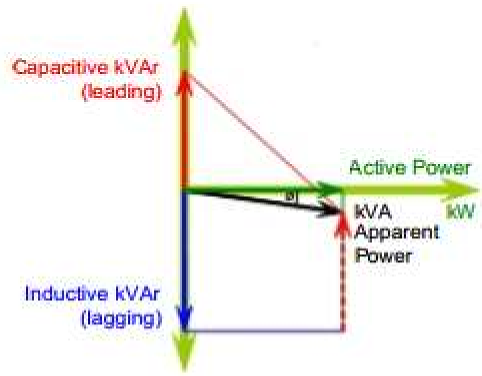

Figure 3: Phasor diagram between active,reactive and apparent power with Capacitive bank.

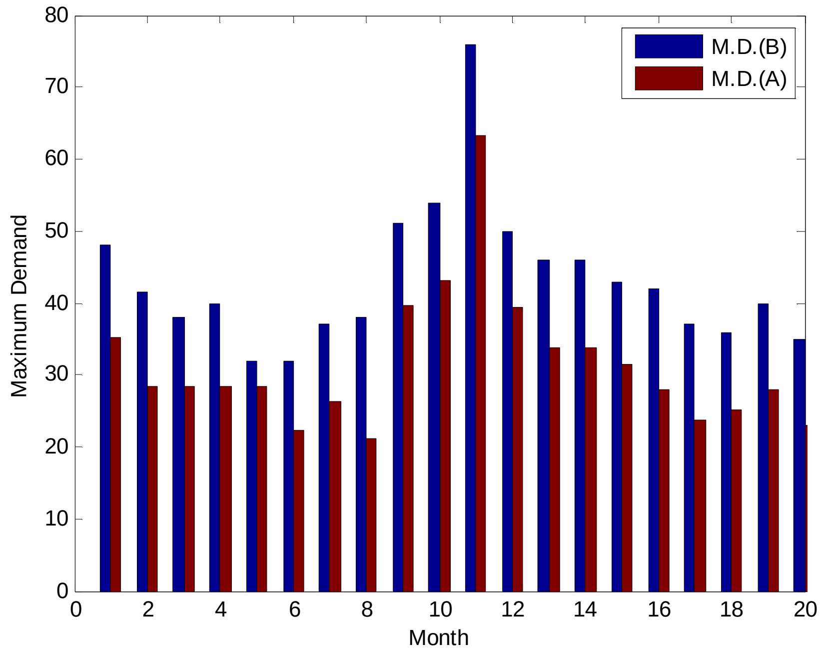

Figure 4: Bar chart showing comparison between MD(A) and MD(B)

The figure above represents

- Capacitive KVAr leads the KW by 90^0
- 2.KVA is the phasor sum of KW+KVAr(lead)
- The phase angle reduces.

Conclusion from the phasor diagrams: Power factor is improved as angle □ is reduced and cosine □ therefore leads towards 1.00(unity power factor).

Effects of power factor improvement on maximum demand: Since Power Factor = cos φ = KW/ KVA, so power factor and maximum demand (in KVA) exhibit an inverse relation. Assuming that the power factor value increases to 0.9 with installation of APFC, the table below shows the decline in maximum demands for each month (Month 1-20)

CONCLUSION

Any energy consuming industrial system with low power factor is bound to pay a huge poor power factor penalty depending on its utility and geographic area. Since the capacitors have a leading power factor, they could effectively aid as remedy for poor power factor problem. Installation of automatic power factor controllers can commendably reduce the penalty cost bear by the consumer. Improving power factor can also lead to decrease in the value of maximum demand because of their inverse relation which further reduces the energy bills.

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