International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 3 Issue 7, June 2016

ISSN: 2394-4404

Power Factor And Its Importance: Analysis And Case Study

Harsimran Singh Kochhar
(Student)B.E. Electrical Engineering,
Electrical Engineering Department
PEC University of Technology,
Chandigarh

Prof. Sulata Bhandari
Associate Professor,
Electrical Engineering Department
PEC University of Technology,
Chandigarh

***Abstract:** Power and energy are most valuable in the present technology driven world. Therefore Research must be carried out for finding out the causes of their wastage and loss. Then we should upgrade the power system so as to eliminate or at least minimize this loss. Due to the onset of industrial revolution the use of inductive loads have increased to a great extend. Moreover in the present world which is dominated by semiconductors the use of nonlinear semiconductors in industries and everyday life has increased manifolds. These nonlinear semiconductor and inductive loads makes the system power factor poor and cause huge losses and decrease efficiency of the power system. Therefore it is very important to have knowledge about the basics of power factor. What are the causes of poor power factor of a system? How can we improve the system power factor?*

This paper has two parts. In the fiest part these questions will be addressed and in the second part a case study will be discussed. The motivation behind writing this paper is to prepare a ready reference for anyone who wants to know about power factor.

***Keywords:** power factor improvement, losses.*

I. INTRODUCTION

Power factor comes into picture only in A.C circuits and can be defined in three ways:

DEFINITION NO.1:

Power factor of a system is defined as the cosine of the phase angle difference (θ) between the voltage across and current through the system.

Cosine of phase angle difference (θ) between voltage and current wave form.

DEFINITION NO.2:

Power factor can be defined as the ratio of active power to the apparent power. In raw terms it can also be defined as the factor of apparent power which gives the active power.

$$\textbf{Power factor} = \frac{\text{Active power}}{\text{Apparent power}}$$

This is the most popular definition of power factor.

APPARENT POWER: The product VI is called the apparent power and is denoted by the symbol S. it is expressed in VA (volt-ampere).

ACTIVE POWER: The product of r.m.s value of voltage and current with the cosine of the angle between them is called active power and is denoted by P. Its unit is W (Watts). P = VI cosθ.

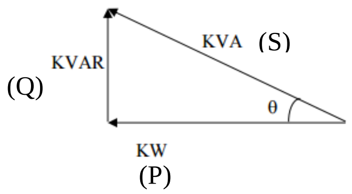
REACTIVE POWER: The product of r.m.s value of voltage and current with the sine of the angle between them is called reactive power and is denoted by Q. Its unit is VAR (volt-ampere reactive) Q = VI sinθ.

RELATION BETWEEN P, Q AND S:

$$\mathbf{S^2 = P^2 + Q^2}$$

This relation gives us the power triangle.

ISSN: 2394-4404



$$P.F. = \frac{KW}{KVA} = \cos\theta$$

$$\frac{KVAR}{KVA} = \sin\theta$$

$$KVA = \sqrt{KW^2 + KVAR^2} = KV * I * \sqrt{3}$$

Figure 1: The power triangle

Reactive power is wattless or the non-working part of power which is used to generate magnetic flux. More the reactive power higher is the apparent power and lower the power factor. If the power factor is low, the industry requires more energy to fulfill its demand, and hence its efficiency reduces.

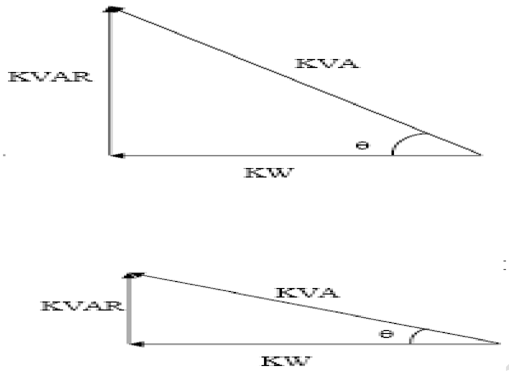


Figure 2: As KVAR increases power factor decreases for same KW

DEFINITION NO.3:

Power factor can also be defined as the cosine of the load angle.

Load angle is defined as the tangent inverse of the ratio of the reactive part to resistive part of the load.

II. CAUSES OF LOW POWER FACTOR

- ✓ All the inductive loads such as single phase and three phase induction motors.
- ✓ Fluctuating Load in Power System: Load on a power system varies. At low loads, the supply voltage is rises that increases the magnetizing current and lead to decreased power factor.
- ✓ Industrial heating furnaces cause a low power factor.
- ✓ High intensity discharge lighting or Arc lamps have a very low operating power factor.
- ✓ Harmonic Currents

III. NEED FOR IMPROVEMENT OF POWER FACTOR

A. FOR DECREASING OUR ELECTRICAL ENERGY BILL

- ✓ If system power factor is low more reactive power (KVAR) is required which results into higher requirement of apparent power (KVA) that is what the electrical energy provider is supplying. Therefore, a system's low power factor forces the energy provider to expand its generation and transmission capacity to handle this increased demand. If the system power factor is high, less reactive power (KVAR) is required which results into lower requirement of apparent power (KVA), which equates to savings for the energy provider.
- ✓ Avoiding penalty for poor system power factor put by the electrical energy provider by improving the system power factor.
- ✓ Avoiding penalty put by the electrical energy provider for exceeding the maximum sanctioned contract demand.

B. INCREASING THE SYSTEM CAPACITY AND DECREASING LOSSES IN THE SYSTEM

If system power factor is high the KW capacity of the system increases. For example, a 10000 KVA transformer working at .8 power factor supplies 8000 KW (active power) and 6000 KVAR (reactive power) to the bus. If the power factor is increased to .9 the same transformer supplies 9000 KW (active power) and 4358 KVAR (reactive power) to the bus. Therefore by improving the power factor the capacity of the system increased to 9000KW and the energy provider supplies the same 1000 KVAR.

C. VOLTAGE LEVELS IN YOUR SYSTEM WILL INCREASE AND OHMIC/HEATING LOSSES WILL DECREASE AND EQUIPMENT LIFE WILL INCREASE

Poor system power factor leads to increased supply current and hence more heating/ohmic losses in the distribution system. As the losses increase voltage drops are experienced. Voltage drops and heating reduces the life of the equipments and leads to their premature failure.

IV. METHODS TO IMPROVE THE SYSTEM POWER FACTOR

The main cause of a poor system power factor is the reactive load of the system. Reactive load includes basically inductors and capacitors. All the motor windings come under inductive loads and form a major part of the industrial load. There is not much capacitive load as such in a system instead capacitors are intentionally added to the system in order to improve the system power factor as will be explained ahead.

- ✓ In a pure inductance, current through the inductor lags behind voltage across it by 90°.
- ✓ In a pure capacitance, voltage across it lags the current through it by 90°.

www.ijiras.com | Email: contact@ijiras.com

ISSN: 2394-4404

- ✓ Therefore, if capacitors are employed to draw leading current, the effects of lagging inductive current can canceled out and the system power factor will improve.

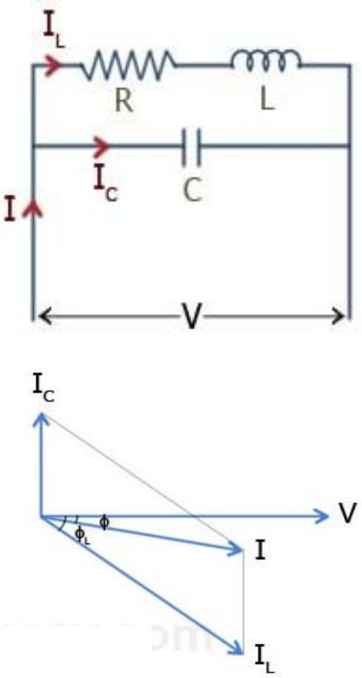


Figure 3: RLC circuit and its phasor diagram

In Figure 3 a common RLC circuit is shown. Explanation of phasor diagram:

Here,

I_L = inductive current drawn by L = current drawn by the circuit when capacitor C is not used,

ϕ_L = It is the relative phase angle between load current and voltage V when capacitor is not used.

I_C = capacitive current drawn by C,

I = resultant current when C is used,

ϕ = It is the relative phase angle between voltage V and net current I.

Now as seen in the phasor diagram in Figure 3,

$\phi < \phi_L$. Hence $\cos\phi > \cos\phi_L$, therefore power factor has improved.

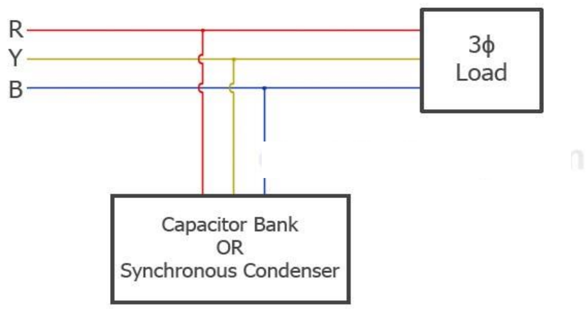


Figure 4: Use of capacitor bank or synchronous condenser for power factor improvement

Some the methods employed for power factor improvement are discussed below with their advantages and disadvantages.

A. CAPACITOR BANK

- ✓ Easiest method.
- ✓ Used in areas where large inductive load is present.
- ✓ Capacitor banks can be connected in star or delta.
- ✓ Along with the capacitor banks an Automatic Power Factor Controller unit is also installed which switches the capacitors ON and OFF according to the varying reactive power demand.

ADVANTAGES

- ✓ Less losses
- ✓ Less maintenance
- ✓ Weight is low
- ✓ Easy installation

DISADVANTAGES

- ✓ Short lifespan (7-9 years)
- ✓ Capacitors can get damaged as a result of over voltage
- ✓ Cannot be repaired.
- ✓ Because of frequent switching, harmonics and switching surges can be produced

B. SYNCHRONOUS CONDENSER

- ✓ An over excited synchronous motor draws leading current and behaves like a capacitor and it is called a Synchronous Condenser.
- ✓ Its salient feature is that it allows step-less power factor correction. Synchronous Condensers are used in very large factories, industries and main supply substations.

ADVANTAGES

- ✓ Lifespan is long (about 25 years)
- ✓ Step-less control of power factor
- ✓ More reliable
- ✓ Unaffected by harmonics
- ✓ Switching is not required and therefore no harmonics are produced.

DISADVANTAGES

- ✓ Losses are high
- ✓ Costly
- ✓ Maintenance costs are high.
- ✓ Creates noise pollution.
- ✓ As synchronous motor is not self starting, therefore auxiliary starting device is needed.
- ✓ Suitable for equipment above 500 KVA.

V. COMPARATIVE STUDY AT DIFFERENT POWER FACTORS

A comparative study has been carried out in which losses in the system in rupees per hour have been calculated at different system power factors. The results have been tabulated as follows:

VOLTS	POWER FACTOR	kW	kVAR	kVA	AMPS	INCREASE IN CURRENT DUE TO LOW POWER PACTOR (I in A)	EXTRA MONEY (IN RS PER HOUR) PAID TO ELECTRICITY BOARD

www.ijiras.com | Email: contact@ijiras.com

430	1	200	00.00	200.00	465.11	0	0
430	.95	200	64.03	210.52	489.59	24.47	63.13
430	.9	200	96.85	222.22	516.79	51.67	133.33
430	.85	200	123.94	235.29	547.19	82.07	211.76
430	.8	200	150.00	250.00	581.39	116.27	300.00
430	.75	200	176.38	266.67	620.15	155.03	400.00
430	.7	200	204.03	285.71	664.45	199.33	514.28
430	.6	200	266.66	333.33	775.19	310.07	800.00
430	.5	200	356.41	400	930.23	465.11	1200.00

Table 1: Table showing losses occurring at different power factors

NOTE:

Unit rate taken = Rs 6 / kVAh

For calculating extra money or losses (in RS per hour) paid to electricity board

Formula used: (6 Rs/kVAh)* (I in A)*(430V) * (1 hour)

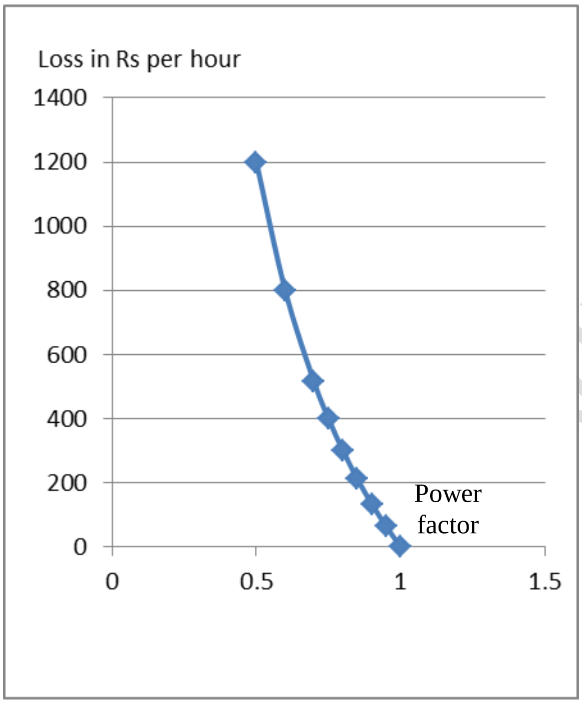


Figure 5: Graph showing loss in rupees vs. power factor

VI. PAY BACK PERIOD FOR INVESTMENT IN POWER FACTOR CORRECTION

If the current system power factor is 0.65 and other system parameters are as follows:

- ✓ 200kW load
- ✓ 720 working hours per month
- ✓ 440 Volt, 3 phase service
- ✓ Rate Schedule:
- ✓ Energy Rate:

601 paise /kVAh upto 100 kVAh

621 paise /kVAh above 100 kVAh

Monthly bill when power factor is .9

No. of kVAh consumed = (100/.9)*720 = Rs 160000

Monthly bill = 159900*6.21+100*6.01 = Rs 9,93,580

Monthly bill when power factor is 1

No. of kVAh consumed = (200/1)*720 = Rs 144000

Monthly bill = 143900*6.21+100*6.01 = Rs 8,94,220

Savings = Rs 9,93,580 - Rs 8,94,220 = Rs 99360

Now to achieve unity power factor if we install capacitors, then Capacitor Cost = Rs 200/kVAR

(Calculated using the data: Rs 5500 for 27 kVAR capacitor so 1 kVAR for Rs.200approx.)

KVAR’s to be compensated = 200*(square root (1-.9^2))
= 96.86 kVAR

Cost of the capacitors= 43.58*200= Rs.19,372.88

Cost of switching and associated equipment And installation, etc.= Rs. 3,00,000

Total investment on installation of capacitors = Rs. 3,19,372.88

Payback time: 319372.88 / 99360 = 3.2 months

Installation of capacitors will pay for themselves in 3.2 months.

VII. CONCLUSION

The payback period of an APFC unit is very less so each industry should install it in its premises so as to avoid losses and reduce their electrical energy consumption.

REFERENCES

[1] www.google.com/patents
[2] www.neundorfer.com
[3] www.wikipedia.org
[4] www.scribd.com