SAVE ELECTRIC ENERGY BY CORRECTING POWER FACTOR

THE EARTH, THE WATER AND THE AIR ARE NOT A GIFT TO US FROM OUR PARENTS BUT A LOAN FROM OUR CHILDREN.

An old Indian saying

Electric energy is a major requirement in today’s world. Every country spends huge amounts of money and natural resources in the production and distribution of electric power. Electric power is required by us for almost all stationary power requirements. Heating, cooling, lighting, motion etc. are the major power consumers.

The electrical Power Distribution System (PDS) is the backbone of any modern facility. For this reason, it is essential that we be familiar with the system's capabilities and limitations. Likewise, issues about quality of power used are becoming more important as additional non-linear loads come on line. The traditional, simple solutions of the past no longer apply, and allowances must be made for harmonics and other power quality concerns. Consideration should be given to addressing these complications through proper engineering design and evaluation.

Conventional methods used to compensate for inductive reactive power have very slow response. Last generation systems cannot cope up with the requirements posed by fast switching loads like welding machines, CNC machines, cranes, hoists, elevators, steel rolling mills, molding machines and so on. Such loads impose heavy demand of reactive power for short duration on the system. To compensate for fast changing loads, it is absolutely essential that correction be affected within the shortest time feasible.

Power Factor Concepts:

The term power factor is defined as a ratio of the current drawn that produces real work to the total current drawn. Like most aspects of modern electrical systems, power factor is a complex issue intertwined with utility rate structures, economic consideration and system capacities.

Power factor ranges from 1.0, or unity, to near zero. Incandescent lighting loads are resistive and result in a power factor of 1.0, or 100 percent. The power factor ratio becomes less than unity when loads draw reactive and or harmonic currents in addition to the current that does real work. Real work performed by motors, heaters, and lights is a result of the current in phase with the voltage. This real work is measured as active power in kw, and can be equated to hp, cal, or lumens based on the efficiency of the device converting the electrical power to another form of power.

Electrical power, expressed in kw, is the capacity to do work. This is equivalent to power in a mechanical system in that force, or voltage, accompanied by displacement, or current flow, delivers power. No work is done, however, and no energy is expended unless power is applied over a period of time. When power is applied over a period of time, energy-expressed in kwh is expended and work is performed.

Inductive loads such as motors, transformers, and lighting ballasts constitute a large portion of the load at most industrial facilities and to a lesser extent in commercial buildings. The inductance of these devices causes the current to lag behind the voltage. This lagging effect is caused by the magnetizing current required for operating these electro-mechanical devices. Without this magnetizing current, the devices would not work. Thus the lagging power factor effect is a fact of life that must be addressed.

Current not operating in phase with the voltage does not produce any real work, and **therefore cannot be billed as kwh of electrical energy consumed. However, as these amperes of magnetizing current "move back and forth" in the distribution equipment, they do place an additional burden on the electrical system**. These magnetizing amps cause additional heating to occur in equipment and conductors upstream from the load resulting in avoidable energy loss. This current contributes to reactive power known as kilovolt amperes reactive (kvar). **Because the utility company must invest in oversized equipment and lose energy in transmission to serve low power factor loads,** a penalty is commonly assessed on the electric bill to recover these equipment costs and the lost energy from the magnetizing current flowing through the equipment and conductors. At present in India only industrial loads are under the penalty purview.

Capacitive components in an electrical system cause the current to lead the voltage. The leading current of a capacitor will counteract the lagging current required by an inductive device and cancel the effect of the lagging current. Since very few capacitive components exist in typical electrical systems, capacitors or synchronous machines often are used to supply leading current to meet the kvar requirements of inductive loads. This reduces the kvar demand on the utility supply and the components in the PDS. Over-correction with too much capacitance can cause a leading power factor of less than unity. This situation is undesirable and can cause over voltage conditions, system instability and resonance to occur.

Power Factor Calculations:

The power factor ratio measures the relative amounts of work-producing active power measured in kw versus the total apparent power (kva). Power factor is defined as the cosine (cos) in the following equations:

Power factor = cos Power = Vrms Irms cos PF = kw / kva

Most Electricity Distribution Companies have today adopted the carrot and stick policy towards industrial consumers. They offer financial rewards for maintaining a power factor greater than the stipulated minimum and levy a penalty from users who do not attain the minimum.

Traditionally, power factor is based on the 50 Hz fundamental frequency. Harmonic currents drawn by adjustable speed drives, PCS, PLCs, and electronic office equipment are increasing in the modern facility. As a result, power factor now must be viewed in reference to harmonic frequencies of the 50 Hz fundamental.

Conventional power factor is now called displacement power factor to relate it to the displacement between the system current and voltage waveforms.

Distortion power factor, on the other hand, takes into account the harmonic currents that do not contribute to the real work produced by the load. Distortion power factor is defined as the ratio of the fundamental component of the line current to the total line current. The total power factor is thus a combination of both displacement and distortion power factors.

Power Factor Correction:

The two most common types of devices used for power factor correction are capacitors and tuned harmonic filters.

Capacitors can be applied easily and commonly are used in industrial and commercial facilities which have minimum amount of harmonics. Both single-value banks and automatically switched variable banks are available. Overheating problems with capacitor banks are becoming more common as harmonic current levels increase. Furthermore, switched capacitor banks, without appropriate design precautions, also can cause high-voltage switching surges as capacitors are switched in and out of service.

Tuned harmonic filters consisting of inductors and capacitors can be used to provide power factor correction where harmonics are present. Filters can be tuned to specific harmonic frequencies, allowing harmonic currents to circulate in the filter and thus reduce their effects on the rest of the system.

Reactive Power Compensation:

Power Factor has continued to remain in discussions of Electrical power industry for a long time. The reason is its direct reflection on the efficiency of the electrical system right from generation to transmission and distribution to the lowest end. The present day complex load pattern is pulling down the power factor and stressing the system. This calls for increase in the generating capacities and strengthening of the distribution network with additional capital expenditure and doubtful returns on the investment. **For optimal utilization of the system it becomes imperative to maintain high power factor by improving both displacement and distortion power factor of the network. This allows generating, PDS, and user companies save money and cater to additional load requirement from the existing infrastructure. The cascading effect will be in saving in fuel required for generation, additional revenue for PDS utilities and reduction in consumer's maximum demand**.

The most common and rugged method of power factor improvement is by addition and removal of tuned filter stages to the system.

Harmonics Suppression Recommendations:

With the advent of IEEE 519-92, the increasing demand by utilities for power factor improvement and the proliferation of non-linear loads in industrial power distribution systems, specification of harmonic mitigation has become common.

IEEE 519, 1981 "Recommended Practices and Requirements for Harmonic Control in Electric Power Systems," was published in 1981. The document established levels of voltage distortion acceptable to the distribution system. This document has been widely applied in establishing needed harmonic correction throughout the electrical power industry. However with the increase in industrial usage of adjustable speed drives, rectifiers, and other non-linear loads, it became apparent that a rewrite of IEEE 519, treating the relationship of harmonic voltages to the harmonic currents flowing within PDS, was necessary to support control of harmonic voltages. The new IEEE 519, published in 1992, sets forth limits for both harmonic voltages on the utility transmission and distribution system and harmonic currents within the industrial distribution systems. Since harmonic voltages are generated by the passage of harmonic currents through distribution system impedances, by controlling the currents or system impedances within the user facility, one can control harmonic voltages on the utility distribution. Unfortunately, there is some user confusion regarding the application and intent of the information included in IEEE 519, 1992. Section 10, “Recommended Practices for Individual Consumers” describes the current distortion limits that apply within the industrial plant. Consulting engineers and applications engineers may not be clear as to the proper use of Table 10.3, which outlines the limits of harmonic distortion as a function of the nature of the electrical distribution system.

MAXIMUM HARMONIC CURRENT DISTORTION IN % OF I_L						
INDIVIDUAL HARMONIC ORDER (Odd Harmonics)						
I_{SC} / I_L	**<11**	**11≤h<17**	**17≤h<23**	**23≤h<35**	**35≤h**	**TDD**
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
Even harmonics are limited to 25% of the odd harmonic limits. TDD refers to Total Demand Distortion and is based on average maximum demand current at the fundamental frequency, taken at the PCC.						
*All power generation equipment is limited to these values regardless of I_{SC} / I_L.						
I_{SC} = Maximum short circuit current at PCC. I_L = Maximum demand load current (fundamental) at the PCC. h = Harmonic number.						

VOLTAGE DISTORTION LIMITS		
Bus Voltage at PCC	**Individual Voltage Distortion (%)**	**Total Voltage Distortion THD (%)**
69 kV and below	3.0	5.0

****