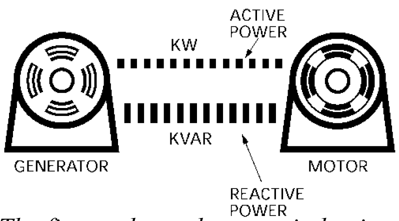
Function of Capacitors



The figure above shows an induction motor operating under partially loaded conditions without Power Factor Correction. Here the feeder line must supply BOTH magnetizing (reactive) and active power.

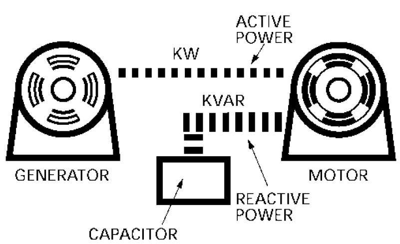
Electric power has two components:

Active power, which produces work.

Reactive power, which is needed to generate magnetic fields required for operation of inductive electrical equipment, but performs no useful work.

Active power is measured in KW (1000 Watts)
Reactive power is measured in KVAR (1000 Volt-Amperes Reactive)
Total power is measured in KVA (1000 Volts-Amperes) The ratio of **working power** to **total power** is called **Power Factor**. The function of Power Factor Correction Capacitors is to increase the power factor by supplying the reactive power when installed at or near inductive electrical equipment.

Equipment Causing Poor Power Factor



The figure above shows the result of installing a capacitor near the same motor to supply the reactive power required to operate it. The total current requirement has been reduced to the value of the active power only, thus either reducing power cost or permitting the use of more electrical equipment on the same circuit.

A great deal of equipment causes poor power factor. One of the worst offenders is lightly loaded induction equipment. Examples of this type of equipment, and their approximate power factors follow:

- 80% power factor or better: Air conditioners (correctly sized),pumps, centerless grinders, cold headers, upsetters, fans or blowers.
- 60% to 80% power factor: Induction furnaces, standard stamping machines, and weaving machines.
- 60% power factor and below: Single-stroke presses, automated machine tools, finish grinders, welders.

When the above equipment functions within a facility, savings can be achieved by utilizing GE industrial capacitors.

How Capacitors Save Money

Capacitors lower electrical costs two ways: In many areas, the electrical rate includes a penalty charge for low power factor. Installation of power capacitors on the electrical distribution system within a facility makes it unnecessary for the utility to supply the reactive power required by inductive electrical equipment. The savings the utility realizes in reduced generation, transmission, and distribution costs are passed on to the customer in the form of lower electrical bills.

The second source of savings derived through the use of power factor correction capacitors is in the form of increased KVA capacity in the electrical distribution system. Installation of capacitors to furnish the non-productive current requirements of the facility makes it possible to increase the connected load by as much as 20 percent without a corresponding increase in the size of the transformers, conductors, and protective devices making up the distribution system which services the load.

Benefits of Power Factor Improvement

Power factor (PF) is the ratio of useful current to total current. It is also the ratio of useful power expressed in kilowatts (KW) to total power expressed in kilowatt-amperes (KVA). Power factor is usually expressed as a decimal or as a percentage.

$$PF = \frac{\text{Useful Power}}{\text{Total Power}}$$

Example: Kilowatts = 60 KW, KVA = 100 KVA

$$PF = \frac{60\ KW}{100\ KVA} = .60 = 60\%$$

The significant effect of improving the power factor of a circuit is to reduce the current flowing through that circuit which in turn results in the following benefits:

$$KVA = \sqrt{3} \times KV \times I$$

Benefit No. 1

Less Total Plant KVA for the Same KW Working Power.

Dollar savings are very significant in areas where utility billing is affected by KVA usage.

Example: 600 KW working power vs KVA required

POWER FACTOR	60%	70%	80%	90%	100%
ACTIVE POWER	600 KW	600 KW	600 KW	600 KW	600 KW
REACTIVE POWER	800 KVAR	612 KVAR	450 KVAR	291 KVR	0 KVAR
TOTAL POWER	1000 KVA	857 KVA	750 KVA	667 KVA	600 KVA

This allows for more efficient operation of plant transformers and "frees up" KVA for additional load. Cost avoidance can be significant.

KW = KVA x PF

Benefit No. 2

More KW Working Power for the Same KVA Demand

Released system capacity allows for additional motors, lighting, etc. to be added without overloading existing distribution equipment.

Example: 600 KVA demand vs available KW

POWER FACTOR	60%	70%	80%	90%	100%
ACTIVE POWER	360 KW	420 KW	480 KW	540 KW	600 KW
REACTIVE POWER	480 KVAR	428 KVAR	360 KVAR	262 KVR	0 KVAR
TOTAL POWER	600 KVA	600 KVA	600 KVA	600 KVA	600 KVA

$$\% \text{ voltage rise}^* = \frac{\text{KVAR} \times \%Z_L}{\text{KVA of transformer}}$$

* with capacitor at the transformer

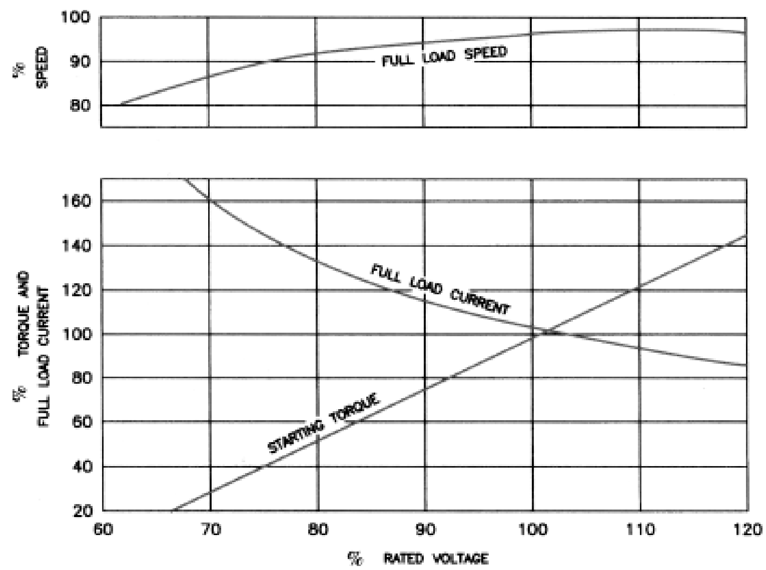
Z_L = transformer impedance % from nameplate

Benefit No. 3

Improved Voltage Regulation Due to
Reduced Line Voltage Drop

This benefit will result in more efficient performance of motors and other electrical equipment.

Example: The graphs below depict what happens to the full load speed and starting torque of a motor at various levels of rated voltage.

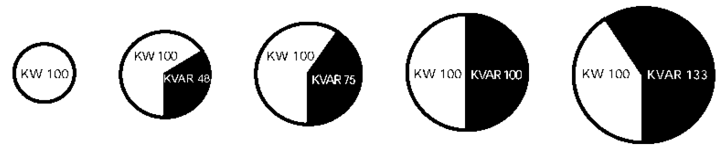


$$I = \frac{KVA \times 10^3}{\sqrt{3}V}$$

Benefit No. 4

Reduction in Size of Transformers, Cables and Switchgear in New Installations – Thus Less Investment

Example: The figure below represents the increasing size of conductors required to carry the same 100 KW at various power factors.



KVA - 100	*KVA - 111*	*KVA - 125*	*KVA - 141*	*KVA - 167*
PF - 100%	*PF - 90%*	*PF - 80%*	*PF - 70%*	*PF - 60%*

Benefit No. 5

Reduced Power Losses in Distribution Systems

$$\% \text{ reduction of power losses} = 100 - 100 \left(\frac{\text{original PF}}{\text{new PF}}\right)^2$$

Since the losses are proportionate to the square of the current, the formula at left applies.

Example: Improve power factor from 65 percent to 90 percent

$$\text{Reduction of power losses} = 100 - 100 \times \left(\frac{.65}{.90}\right)^2 = 48\%$$

Power Bill Savings

Poor power factor necessitates increased generation and transmission costs to provide the required amount of real power (KW). In order to equitably distribute these costs to the end user, many utilities utilize a rate structure that penalizes poor power factor.
To illustrate the power bill savings that can be obtained through capacitor installation, it is assumed that the utility serving a facility has the following rate schedule:

Sample Rate Schedule:
The billing demand is calculated such that a penalty is incurred for power factors below 90%.

$$\text{Billing Demand} = \frac{\text{KW demand } x\ .90}{\text{Actual PF}}$$

Demand Charge per Month:

First 10 KW	*$5.25/KW*
Next 40 KW	*$4.00/KW*
Next 100 KW	*$3.50/KW*
Excess KW	*$2.75/KW*

Utility Demand Charges Before Improvement:
see page 33, example 2

$$\text{Billing Demand} = \frac{425 \text{ KW } x\ .90}{.63} = 607.1 \text{ KW}$$

Therefore our KW demand charges would be:

10 x $5.25	*$ 52.50*
40 x $4.00	*$ 160.00*
100 x $3.50	*$ 350.00*
457.1 x $2.75	*$1,257.03*
	$1,819.53

Utility Demand Charges After Improvement:

$$\text{Billing Demand} = \frac{425 \text{ KW } x\ .90}{.90} = 425 \text{ KW}$$

10 x $5.25	*$ 52.50*
40 x $4.00	*$ 160.00*
100 x $3.50	*$ 350.00*
275 x $2.75	*$ 756.25*
	$1,318.75

Savings per month *= $1,819.53 – $1,318.75 = $500.78*

Annual savings *= $6,009.36*

Payback Analysis:

Automatic Correction: 325 kvar, 480 volts, 25 kvar per step = 37FC7325F25
list price = $13,034 ÷ $6,009.36 = 2.2 year payback (based on list price)

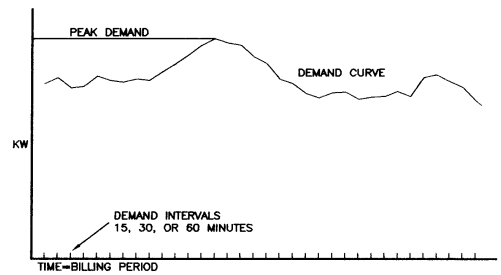
Fixed Correction: 325 kvar, 480 volts = 65L936TC2
list price = $3,009 ÷ $6,009.36 = approximately a 6 month payback (based on list price)

NOTES:
1. KWH charges are not shown since the significant dollar savings in this example are in the demand rate structure.
2. Due to variations in rate schedules throughout the country, it is impossible to provide an example of each schedule. Please check with your power company and local representative to determine your potential savings through power factor correction.

Factors That Affect Your Electric Bill

1. Energy Charge -
Number of kilowatt-hours used during the billing period.
Number of kilovolt amperes (KVA) used during the billing period

2. Demand Charge -
This charge compensates the utility for the capital investment required to serve the facility's peak load. Demand charges may be a large portion of the total electric bill, sometimes as high as 75%. Demand charges can be reduced by reducing energy peaks, reducing KVA, and improving power factor.



1 - Uncorrected KVA
2 - Corrected KVA

3. Power Factor Penalty Charge -
A penalty imposed to encourage the user to improve power factor. Power companies usually impose a billing penalty when power factor (P.F.) drops below 90% - although this figure could be as high as 95%. In nearly all cases, the least expensive and most efficient method to reduce this charge is by adding capacitors.