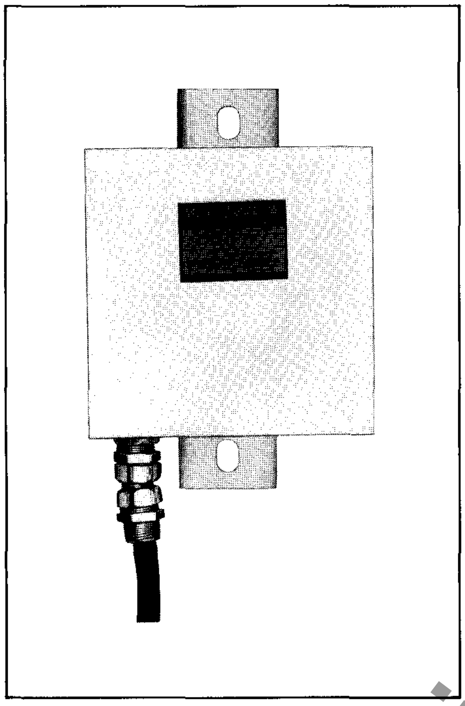
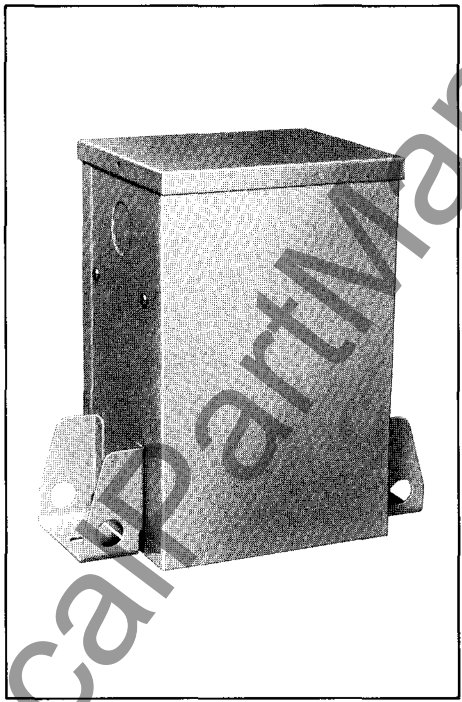
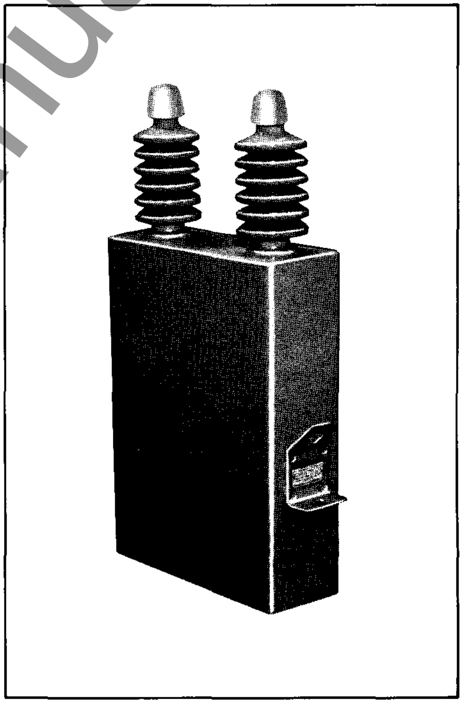
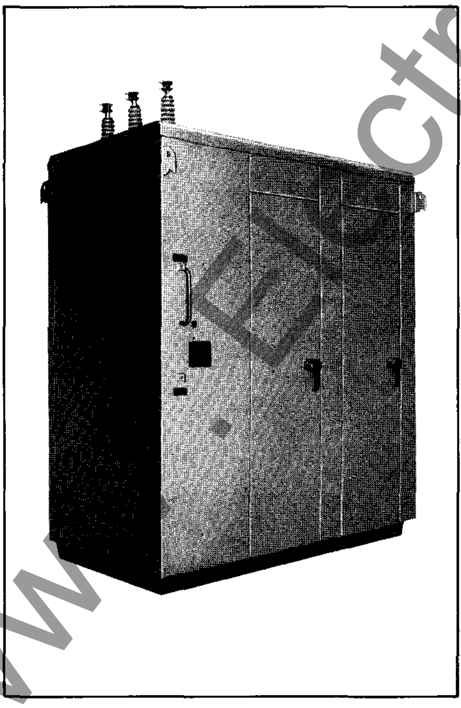
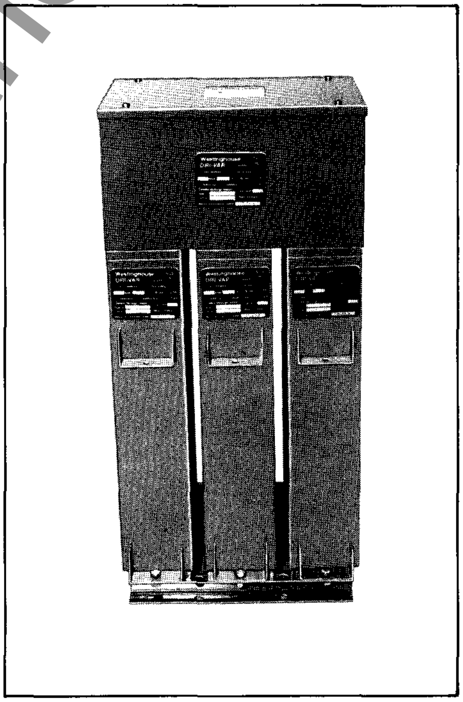
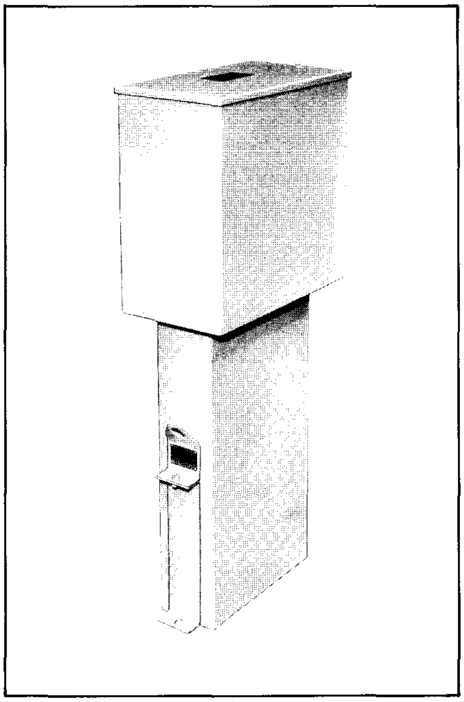
Power Factor Correction Capacitors

What power factor is

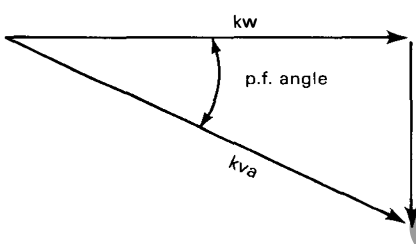
Any electrical circuit containing inductive apparatus carries two kinds of power, REAL and REACTIVE. REAL power, measured in kilowatts (kw), does the actual "productive" work. The REACTIVE or "nonproductive" power, measured in reactive kilovolt-amperes (kvar), provides the magnetic field required by an inductive device, and enables the REAL power to do its job. The TOTAL power that the system carries is the vector sum of the two, and is measured in kilovolt-amperes (kva). This is illustrated by the "Power Triangle" shown below.

The power factor of such a system is simply a ratio of REAL and TOTAL power, or:

$$\text{Power factor} = \frac{kw}{kva} = \cos \text{pf angle}$$

If the circuit contains only resistance, the power factor is 100 percent (100 percent of the power is useful). In a system containing resistance and inductance, the power factor may be anything between 0 percent and 100 percent, depending on the amount of inductive devices present.

In most plants, a major portion of the load is inductive devices and the power factor is considerably less than 100 percent. The result: high electric bills and inefficient plant distribution systems.



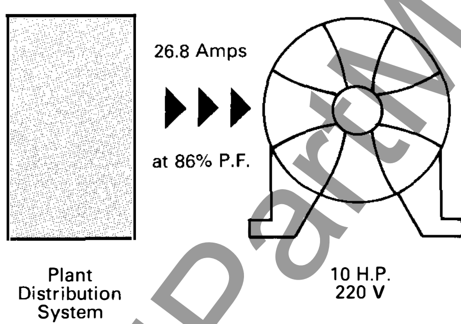
Capacitors supply kilovars

Westinghouse capacitors supply the magnetizing power, or kilovars, required by inductive loads. This "on site" generation of kilovars *at the load* means that the REACTIVE power no longer has to be transmitted all the way from the utility generator. It's like digging a private well instead of hauling water in from some outside source.

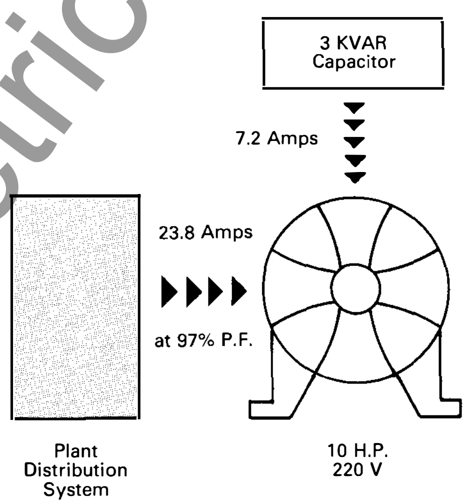
For example, a typical 10-horsepower, 220-volt, 1800-rpm induction motor, like the one illustrated at right, has a full-load power factor of approximately 86 percent. To operate this motor, the power company must supply–and your transformers, conductors, and controls must be capable of carrying–approximately 26.8 amperes of line current. Part of the current does "productive" work in turning the rotor. The remainder is required to magnetize the motor, doing no useful work.

By installing a small capacitor, 3 kvar in this case, right at the motor and supplying most of the magnetizing current locally, only 23.8 amperes need be supplied by the source. As a result, the power factor is improved to 97 percent and the line current is reduced 11 percent.

The situation is even worse when the motor is operating at less than full load. For example, the motor in the illustration has a power factor of about 72.5 percent at half load. Since motor sizes are ordinarily determined by starting requirement rather than full-load conditions, most drives are "overmotored" and the resultant power factor is extremely low.



Capacitor Not Installed



Capacitor Installed

Major benefits you get from Westinghouse capacitors

Power costs are slashed

If your plant operates without capacitors, the extra . . . and necessary . . . kilovars are a part of the total load which determines the capacity of the generators, lines, transformers, and other equipment the utility uses to supply electric service. This represents considerable investment by the utility; therefore, the power factor of your plant is an important consideration in determining the cost of supplying your power requirements.

With most rate structures, the power factor influences the billing in some manner. Some increase the billing if the power factor falls below a specified level . . . others provide a bonus for raising the power factor to desirable levels.

Depending on the plant conditions and the local utility rate practices, capacitors can often pay for themselves in as little as six to eight months.

System capacity is increased

Magnetizing current, which may increase line current flow by two-thirds or more, must be supplied by the same system that supplies the working current. Capacitors supply the "nonproductive" magnetizing current locally, confining it to the smallest possible segment of the system. This releases more of the system's capacity to carry useful, working current.

As the line current is reduced, more equipment can be added to existing feeders. In one circuit, for example, a 112½-kva transformer fed four induction motors operating at 86 percent power factor. To add a fifth motor required installing a larger transformer and rewiring the feeder, or capacitors could be added at a fraction of the cost. On a capacitor-served line, a fifth motor could be installed using the existing transformer and feeder wiring, and total current demand would remain approximately the same.

Multiply this example by the total number of circuits in your plant to arrive at the full benefits of capacitors on your system. You get more production capacity for the same power dollar. Distribution circuits and equipment do not become overloaded. No new distribution equipment must be added. The result: more money saved with Westinghouse capacitors.

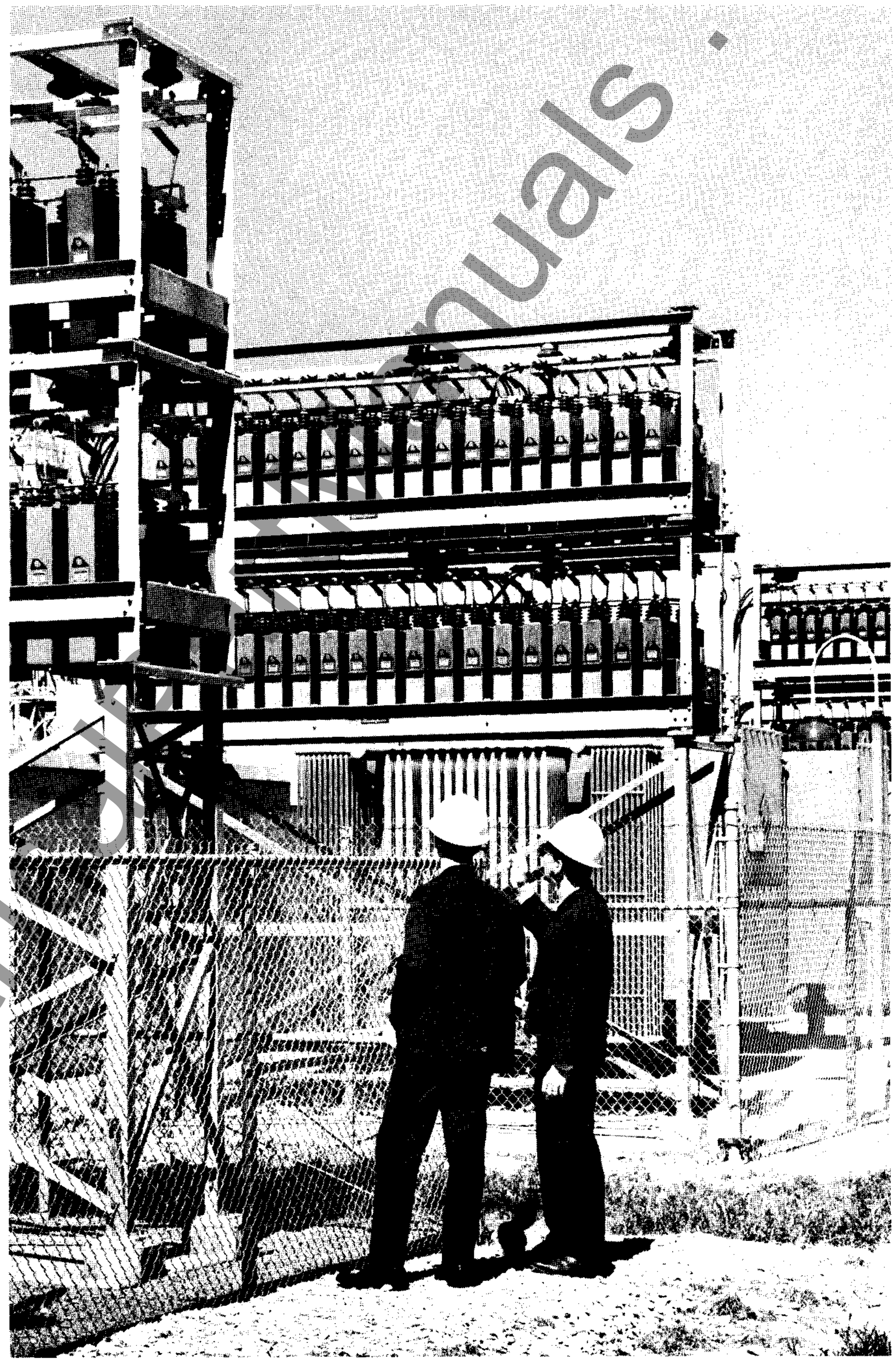
Voltage is improved, lighting becomes more efficient, motor performance is stepped up

Low voltage costs you money. Excessive voltage drop – say 10 percent – increases slip, creates motor-killing heat. Low voltage can make an otherwise adequate lighting system ineffective. Motor controls and instruments operate below par. Furnaces may produce less than rated temperature, or take longer to reach rated heat. The source of these annoyances is REACTIVE current, required by inductive loads.

Westinghouse capacitors put kilovars on the line without consuming useful power and put an end to expensive penalties of low voltage. The voltage level of your plant goes up, and stays up, from substation to motor. Westinghouse capacitors not only return their cost by reducing demand at the meter, but substantially reduce maintenance and increase equipment life.

Power losses are reduced

Any distribution system loses some of the power it carries. Some of these losses, however, can be cut by the application of Westinghouse capacitors which reduce the total current in the circuits. Kilowatt losses are proportional to the square of the current, and current is reduced in proportion to improvement in power factor. Therefore, when power factor improves, kilowatt losses are reduced. Savings in your power bill from this source alone can be appreciable – 15 percent to 20 percent per year of the cost of capacitors.



Westinghouse outdoor stack-type capacitor equipment provides the most economical means of obtaining large blocks of kvar for power-factor correction.

How to select and apply Westinghouse capacitors accurately, economically

What is the most desirable power factor for you?
In actual practice, it is generally neither necessary nor economical to raise your power factor to unity, or 100 percent. In terms of capacitor costs, the few percentage points before 100 percent are increasingly expensive to attain. In most instances, power factor should be raised to approximately 95 percent.

First, however, check your feeder circuits to determine the power factor under which you are currently operating. Next, find out what you are being charged at your present power factor. Such charges may or may not be itemized on your bill. Rates are usually made in one of the following ways:

1. High power-factor bonus
2. Low power-factor penalty
3. Straight kva demand charge
4. Power factor used to affect the energy charge

From your power billing data over a period of months, calculate your average charges. The most desirable power factor for you is the point where you eliminate all or most of the charges made for kilovars. Your utility and local Westinghouse representative will help you arrive at the optimum power factor for your plant.

Capacitor calculating chart
The chart makes it possible to determine the number of capacitors required to improve the power factor of a particular load from its present level to any desired level. (Refer to the example below.)

Example:
Assume a 100-kw load operating at 68 percent power factor is to be raised to 95 percent power factor.

From the chart, to raise the original power factor of 68 percent to 95 percent requires .750 kvar of capacitors/kw load.

Multiplying this figure by the 100-kw load means that 75 kvar of capacitors will be required.

Desired power factor in percent▼

	80	81	82	83	84	85	86	87
50	0.982	1.003	1.034	1.060	1.086	1.112	1.139	1.165
51	.937	.962	.989	1.015	1.041	1.067	1.094	1.120
52	.893	.919	.945	.971	.997	1.023	1.050	1.076
53	.850	.876	.902	.928	.954	.980	1.007	1.033
54	.809	.835	.861	.837	.913	.939	.966	.992
55	.769	.795	.821	.847	.873	.899	.926	.952
56	.730	.756	.782	.808	.834	.860	.887	.913
57	.692	.718	.744	.770	.796	.822	.849	.875
58	.655	.681	.707	.733	.759	.785	.812	.838
59	.618	.644	.670	.696	.722	.748	.775	.801
60	.584	.610	.636	.662	.688	.714	.741	.767
61	.549	.575	.601	.627	.653	.679	.706	.732
62	.515	.541	.567	.593	.619	.645	.672	.698
63	.483	.509	.535	.561	.587	.613	.640	.666
64	.450	.476	.502	.528	.544	.580	.607	.633
65	.419	.445	.471	.497	.523	.549	.576	.602
66	.398	.414	.440	.466	.492	.518	.545	.571
67	.358	.384	.410	.436	.462	.488	.515	.541
68	.329	.355	.381	.407	.433	.459	.486	.512
69	.299	.325	.351	.377	.403	.429	.456	.482
70	.270	.296	.322	.348	.374	.400	.427	.435
71	.242	.268	.294	.320	.346	.372	.399	.425
72	.213	.239	.263	.291	.317	.343	.370	.396
73	.186	.212	.238	.264	.290	.316	.343	.369
74	.159	.185	.211	.237	.263	.289	.316	.342
75	.132	.158	.184	.210	.236	.262	.289	.315
76	.105	.131	.157	.183	.209	.235	.262	.288
77	.079	.105	.131	.157	.183	.209	.236	.262
78	.053	.079	.105	.131	.157	.183	.210	.236
79	.026	.052	.078	.104	.130	.156	.183	.209
80	.000	.026	.052	.078	.104	.130	.157	.183
81	....	.000	.026	.052	.078	.104	.131	.157
82	....	....	.000	.026	.052	.078	.105	.131
83	....	....	....	.000	.026	.052	.079	.105
84	....	....	....	....	.000	.026	.053	.079
85	....	....	....	....	....	.000	.027	.053
86	....	....	....	....	....	....	....	.026
87	....	....	....	....	....	....	....	....
88	....	....	....	....	....	....	....	....
89	....	....	....	....	....	....	....	....
90	....	....	....	....	....	....	....	....
91	....	....	....	....	....	....	....	....
92	....	....	....	....	....	....	....	....
93	....	....	....	....	....	....	....	....
94	....	....	....	....	....	....	....	....
95	....	....	....	....	....	....	....	....

▲
Original power factor in percent

88	89	90	91	92	93	94	95	96	97	98	99	100
1.192	1.220	1.248	1.276	1.306	1.337	1.369	1.403	1.442	1.481	1.529	1.590	1.732
1.147	1.175	1.203	1.231	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1.544	1.687
1.103	1.131	1.159	1.187	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1.500	1.643
1.060	1.088	1.116	1.144	1.174	1.205	1.237	1.271	1.308	1.349	1.397	1.457	1.600
1.019	1.047	1.075	1.103	1.133	1.164	1.196	1.230	1.267	1.308	1.356	1.416	1.559
.979	1.007	1.035	1.063	1.090	1.124	1.156	1.190	1.228	1.268	1.316	1.377	1.519
.940	.968	.996	1.024	1.051	1.085	1.117	1.151	1.189	1.229	1.277	1.338	1.480
.902	.930	.958	.986	1.013	1.047	1.079	1.113	1.151	1.191	1.239	1.300	1.442
.865	.893	.921	.949	.976	1.010	1.042	1.076	1.114	1.154	1.202	1.263	1.405
.828	.856	.884	.912	.939	.973	1.005	1.039	1.077	1.117	1.165	1.226	1.368
.794	.822	.850	.878	.905	.939	.971	1.005	1.043	1.083	1.131	1.192	1.334
.759	.787	.815	.843	.870	.904	.936	.970	1.008	1.048	1.096	1.157	1.299
.725	.753	.781	.809	.836	.870	.902	.936	.974	1.014	1.062	1.123	1.265
.693	.721	.749	.777	.804	.838	.870	.904	.942	.982	1.030	1.091	1.233
.660	.688	.716	.744	.771	.805	.837	.871	.909	.949	.997	1.058	1.200
.629	.657	.685	.713	.740	.774	.806	.840	.878	.918	.966	1.027	1.169
.598	.626	.654	.682	.709	.743	.775	.809	.847	.887	.935	.996	1.138
.568	.596	.624	.652	.679	.713	.745	.779	.817	.857	.905	.966	1.108
.539	.567	.595	.623	.650	.684	.716	.750	.788	.828	.876	.937	1.079
.509	.537	.565	.593	.620	.654	.686	.720	.758	.798	.840	.907	1.049
.480	.508	.536	.564	.591	.625	.657	.691	.729	.769	.811	.878	1.020
.452	.480	.508	.536	.563	.597	.629	.663	.701	.741	.783	.850	.992
.423	.451	.479	.507	.534	.568	.600	.634	.672	.712	.754	.821	.963
.396	.424	.452	.480	.507	.541	.573	.607	.645	.685	.727	.794	.936
.369	.397	.425	.453	.480	.514	.546	.580	.618	.658	.700	.767	.909
.342	.370	.398	.426	.453	.487	.519	.553	.591	.631	.673	.740	.882
.315	.343	.371	.399	.426	.460	.492	.526	.564	.604	.652	.713	.855
.289	.317	.345	.373	.400	.434	.466	.500	.538	.578	.620	.687	.829
.263	.291	.319	.347	.374	.408	.440	.474	.512	.552	.594	.661	.803
.236	.264	.292	.320	.347	.381	.413	.447	.485	.525	.567	.634	.776
.210	.238	.266	.294	.321	.355	.387	.421	.459	.499	.541	.608	.750
.184	.212	.240	.268	.295	.329	.361	.395	.433	.473	.515	.682	.724
.158	.186	.214	.242	.269	.303	.335	.369	.407	.447	.489	.556	.698
.132	.160	.188	.216	.243	.277	.309	.343	.381	.421	.463	.530	.672
.106	.134	.162	.190	.217	.251	.283	.317	.355	.395	.437	.504	.645
.080	.108	.136	.164	.191	.225	.257	.291	.329	.369	.417	.478	.620
.053	.081	.091	.137	.167	.198	.230	.265	.301	.343	.390	.451	.593
.027	.055	.082	.111	.141	.172	.204	.238	.275	.317	.364	.425	.567
....	.028	.056	.084	.114	.145	.177	.211	.248	.290	.337	.398	.540
....	....	.028	.056	.086	.117	.149	.183	.220	.262	.309	.370	.512
....	....	....	.028	.058	.089	.121	.155	.192	.234	.281	.342	.484
....	....	....	....	.030	.061	.093	.127	.164	.206	.253	.314	.456
....	....	....	....	....	.031	.063	.097	.134	.176	.223	.284	.426
....	....	....	....	....	....	.032	.066	.103	.145	.192	.253	.395
....	....	....	....	....	....	....	.034	.071	.113	.160	.221	.363
....	....	....	....	....	....	....	....	.037	.079	.126	.187	.328

Figures from chart x kw load = kvar of capacitors required for power-factor correction.

Where capacitors should be installed

The primary purpose of power-factor correction, namely reduction of the power bill, simply requires that the capacitors be connected on the load side of the metering point. But intelligent location of the capacitors can pay extra dividends for the careful planner.

The capacitors may be installed at any of several points in the plant distribution system. However, maximum benefits are obtained when the capacitors are located as near to the load as possible, especially in the case of induction motors.

1. By locating the capacitors near the load, the kilovars are confined to the smallest possible segment of the system.

2. The motor starter can be used to switch the capacitor as well as start the motor, thereby eliminating the cost of an extra switch for the capacitor.

3. In addition, switching through the motor starter provides semi-automatic control of the capacitors and a separate control is not required. The capacitors are in the circuit only when they are required . . . when the motor is operating.

However, in some cases it may be more practical and economical to install the capacitors in groups or banks at power centers or on feeders.

The advantages of group installations are twofold:

1. Diversity—when several motors or loads are not on the line at the same time or are running intermittently, a capacitor bank at a power center permits the purchase of smaller total amounts of kvar than if capacitors were located at each of the motor loads.

2. When many small motors are operated simultaneously, it is considerably more economical to purchase larger blocks of kvar in banks or groups rather than have many small capacitors installed at each motor.

Figure 1 illustrates several typical locations where capacitors can be installed for power-factor correction. The most effective location is at the load, as shown by capacitor C_1. The next choice would be C_2 or C_3, both of which would ordinarily require some type of switch or circuit breaker. Finally, C_4 is shown on the primary side of the stepdown transformer connected to the system by means of a high-voltage breaker.

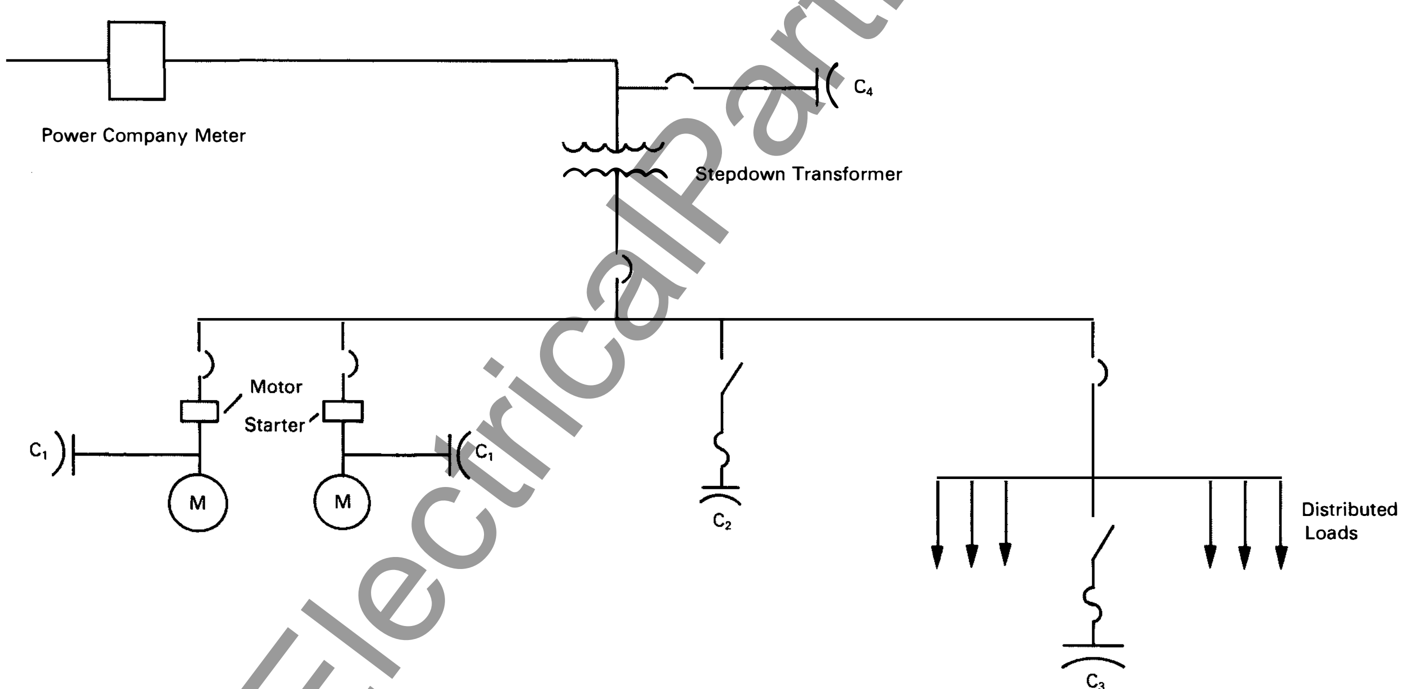
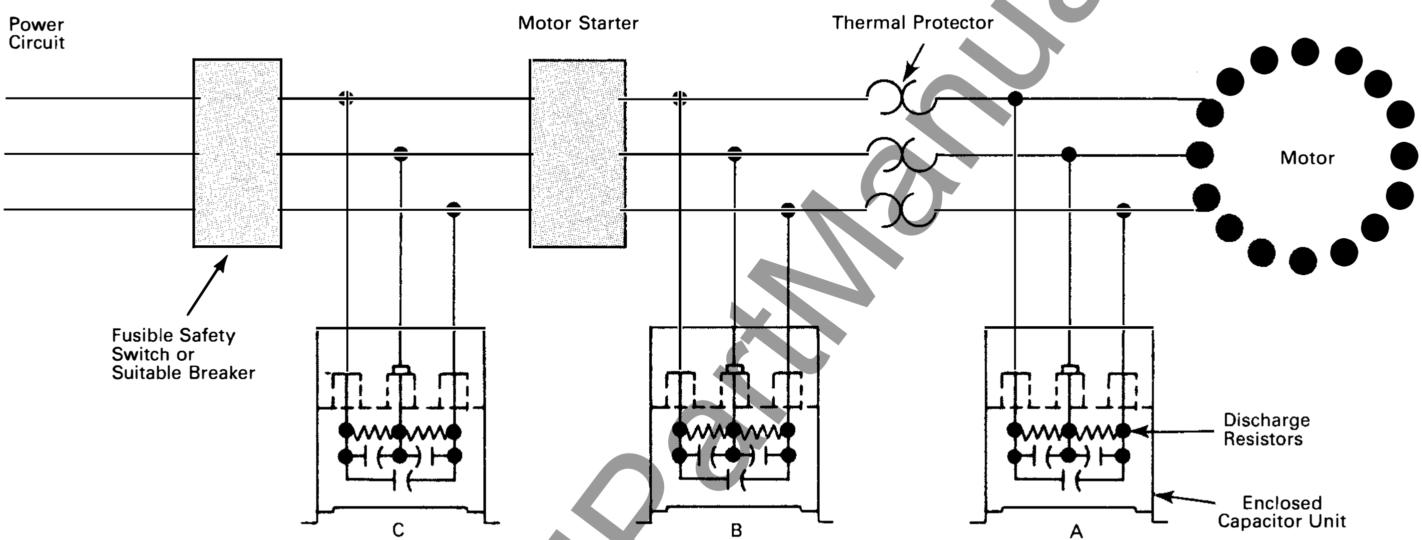


Figure 1

Connecting capacitors to induction motor circuits

There are several accepted methods of connecting capacitors to induction motors. Three of the most preferred are shown below.



1
Position "A" is recommended for new installation only, since a reduced size of thermal protector may be required. The capacitors are connected on the motor side of the thermal protector, thus only motor watts flow through the protector. The kvar's are supplied directly to the motor by the capacitor. Therefore, the selection of the thermal protector must be based on the reduced line current.

2
Position "B" shows the capacitors connected on the line of the protector, but also switched with the motor. As in position "A," the capacitors are energized only when the motor is in operation.

3
Position "C" shows the capacitors permanently connected to the circuit, but with the operation of a fusible safety switch or circuit breaker.

In both "B" and "C," full motor current flows through the thermal protector.

Whenever a motor and a capacitor are to be switched as a unit, the capacitor should be sized carefully. If the kvar rating of the capacitor is appreciably greater than the no-load magnetizing kvar of the motor, damaging overvoltages or transient torques can occur. For this reason, most motor manufacturers specify the maximum kvar rating capacitor to be applied to a specific motor.

Induction Motor/Capacitor Application Tables

The following tables contain **suggested maximum** capacitor ratings for induction motors switched with the capacitor. The data is general in nature and representative of general purpose induction motors of standard design. The preferable means to select capacitor ratings is based on the "maximum recommended Kvar" information available from the motor manufacturer. If this is not possible or feasible, the tables can be used.

An important point to remember is that if the capacitor used with the motor is too large, self-excitation may cause a motor-damaging overvoltage when the motor and capacitor combination is disconnected from the line. In addition, high transient torques capable of damaging the motor shaft or coupling can occur if the motor is reconnected to the line while rotating and still generating a voltage of self-excitation.

Definitions

KVAR—rating of the capacitor in reactive kilovolt-amperes. This value is approximately equal to the motor no-load magnetizing kilovars.

% AR—percent reduction in line current due to the capacitor. A capacitor located on the motor side of the overload relay reduces line current through the relay. Therefore, a different overload relay and/or setting may be necessary. The reduction in line current may be determined by measuring line current with and without the capacitor or by calculation as follows:

$$\% \text{ AR} = 100 - 100 \times \frac{\text{(Original PF)}}{\text{(Improved PF)}}$$

If a capacitor is used with a lower KVAR rating than listed in tables, the % AR can be calculated as follows:

$$\% \text{ AR} = \text{Listed } \% \text{ AR} \times \frac{\text{Actual KVAR}}{\text{KVAR in Table}}$$

The tables can also be used for other motor ratings as follows:

A. For standard 60 HZ motors operating at 50 HZ:
KVAR = 1.7 – 1.4 of KVAR listed
% AR = 1.8 – 1.35 of % AR listed

B. For standard 50 HZ motors operating at 50 HZ:
KVAR = 1.4 – 1.1 of KVAR listed
% AR = 1.4 – 1.05 of % AR listed

(Continued on Page 9)

Induction-motor/capacitor application tables for motors (manufactured in 1956 or later) 230, 460, and 575 volt motors

Table 1
NEMA design B — normal starting torque and current

Induction-motor horse-power rating	Nominal motor speed in rpm and number of poles											
	3600 2		1800 4		1200 6		900 8		720 10		600 12	
	kvar	% AR	kvar	% AR	kvar	% AR	kvar	% AR	kvar	% AR	kvar	% AR
5	2	13	2	17	3	23	3	28	4	36	5	49
7½	2½	13	3	16	3	19	4	25	6	33	7½	46
10	3	12	3	14	4	18	5	24	6	30	10	39
15	5	11	5	14	5	17	7½	21	7½	27	10	34
20	6	10	6	13	7½	16	7½	20	10	25	15	31
25	7.5	10	6	13	7½	16	10	19	10	23	20	31
30	7.5	10	7.5	12	10	16	10	18	15	21	20	28
40	7.5	10	10	11	15	15	15	18	15	20	25	28
50	10	10	15	11	20	15	20	18	20	19	30	28
60	10	9	15	11	25	14	20	17	25	19	35	27
75	15	9	20	10	25	13	25	14	30	16	40	19
100	20	9	25	10	30	11	30	13	35	15	45	17
125	25	9	30	9	30	11	40	13	40	14	50	17
150	25	9	30	9	35	11	45	12	50	13	60	17
200	35	9	40	9	50	10	60	12	70	13	80	17
250	40	9	50	8	60	10	70	12	80	12	100	17
300	45	9	60	8	70	10	80	12	90	12	110	17
350	50	9	70	7	80	10	100	12	100	12	125	16
400	70	8	70	7	80	10	110	12	125	12	150	16
450	75	7	80	7	100	9	120	11	125	12	150	16
500	90	7	90	7	120	9	125	11	140	12	175	16

Table 2
NEMA design C — high starting torque, normal current

Induction-motor horse-power rating	Nominal motor speed in rpm and number of poles							
	1800 4		1200 6		900 8		720 10	
	kvar	% AR	kvar	% AR	kvar	% AR	kvar	% AR
5	2	18	2½	23	4	29	...	..
7½	3	18	3	19	4	25	...	..
10	3	15	4	17	5	22	...	..
15	4	15	5	17	7½	20	...	..
20	4	15	5	17	7½	19	...	..
25	5	13	5	15	10	19	...	..
30	5	13	7½	15	10	19	20	23
40	10	13	10	15	15	18	...	..
50	15	13	10	15	20	18	25	23
60	15	12	20	15	25	18	25	23
75	20	11	20	13	30	17	35	23
100	25	10	25	12	40	17	40	17
125	30	10	35	11	40	14	45	16
150	35	9	40	10	45	13	50	12
200	45	9	50	10	60	13	60	12
250	50	8	60	10	70	13	75	12
300	60	8	70	10	80	12	80	12
350	70	8	75	9	90	12	100	12

C. For standard 60 HZ wound-rotor motors:
KVAR = 1.1 of KVAR listed
% AR = 1.05 of % AR listed

Note: For A, B, C, the larger multipliers apply motors of higher speeds; ie. 3600RPM = 1.7 mult., 1800RPM = 1.65 mult., etc.

D. To derate a capacitor used on a system voltage lower than the capacitor voltage rating, such as a 240 volt capacitor used on a 208 volt system, use the following formula:

$$\text{Actual KVAR} = \text{Nameplate KVAR} \times \frac{(\text{Applied Voltage})^2}{(\text{Nameplate Voltage})^2}$$

Induction-motor/capacitor application tables for motors (manufactured in 1956 or later) 2300 and 4000 volt motors

Table 3
NEMA design B — normal starting torque and current

Induction-motor horse-power rating	Nominal motor speed in rpm and number of poles											
	3600 2		1800 4		1200 6		900 8		720 10		600 12	
	kvar	% AR	kvar	% AR	kvar	% AR	kvar	% AR	kvar	% AR	kvar	% AR
100	25	7	25	10	25	11	25	11	25	12	25	17
125	25	7	25	9	25	10	25	10	25	11	50	15
150	25	7	25	8	25	8	25	9	50	11	50	15
200	25	7	25	6	50	8	50	9	50	10	75	14
250	50	7	50	5	50	8	50	9	75	10	100	14
300	50	7	50	5	75	8	75	9	75	9	100	12
350	50	6	50	5	75	8	75	9	75	9	100	11
400	50	5	50	5	75	6	100	9	100	9	100	10
450	75	5	50	5	75	6	100	8	100	8	100	8
500	75	5	75	5	100	6	125	8	125	8	125	8
600	75	5	100	5	100	5	125	7	125	8	125	8
700	100	5	100	5	100	5	125	7	150	8	150	8
800	100	5	125	5	125	5	150	7	150	8	150	8

Table 4
NEMA design C — high starting torque, normal current

Induction-motor horse-power rating	Nominal motor speed in rpm and number of poles							
	1800 4		1200 6		900 8		720 10	
	kvar	% AR	kvar	% AR	kvar	% AR	kvar	% AR
100	25	11	25	11	25	11	25	11
125	25	11	25	11	25	11	25	11
150	25	9	25	9	50	9	..	..
200	50	9	50	9	50	9	..	..
250	50	8	50	9	50	9	..	..
300	50	6	75	9	75	9	..	..
350	50	6	75	8	75	9	..	..

Selection of switches and breakers

Circuit breakers and switches for use with capacitors must have a current rating in excess of rated capacitor current to provide for overcurrent from overvoltages at fundamental frequency and harmonic currents. The following percent of the capacitor-rated current should be used:

Fused and unfused
safety switches 165%
Type AB-I De-ion®
breakers or equivalent 150%
Air circuit breakers................... 135%

Contactors:
Open type........................... 135%
Enclosed type 150%

① Switching device ratings are based on percentage of capacitor-rated current as indicated (above).
The interrupting rating of the switch must be selected to match the system fault current available at the point of capacitor application.
Whenever a capacitor bank is purchased with less than the ultimate kvar capacity of the rack or enclosure, the switch rating should be selected based on the ultimate kvar capacity – not the initial installed capacity.

Recommended switching devices①

Capacitor rating		Amperes			
Volts	Kvar	Capacitor rated current	Safety switch fuse rating	AB-I breaker trip rating	Air breaker trip rating
240	2½	6.0	15	15	15
	5	12.0	20	20	20
	7½	18.0	30	30	30
	10	24.1	40	40	40
	15	36.1	60	70	50
	20	48.1	80	90	70
	25	60	100	100	90
	30	72.2	125	125	100
	45	108	200	175	150
	50	120	200	200	175
	60	144	250	225	200
	75	180	300	275	250
	90	217	400	350	300
	100	240	400	400	350
	120	289	500	500	400
	125	301	500	500	450
	135	325	600	500	500
	150	361	600	600	500
	180	433	800	700	600
	200	480	800	800	700
	225	541	900	900	800
	240	578	1000	900	800
	250	602	1000	900	900
	270	650	1200	1000	1000
	300	720	1200	....	1200
	360	866	1600	....	1200
	375	903	1500	....	1200
480	2	2.41	15	15	15
	5	6.01	15	15	15
	7½	9.0	15	15	15
	10	12.0	20	20	20
	15	18.0	30	30	30
	20	24.0	40	40	40
	25	30.0	50	50	50
	30	36.1	60	70	50
	35	42	70	70	60
	40	48.1	80	100	70
	45	54	90	100	80
	50	60.1	100	100	90
	60	72.2	125	125	100
	75	90.2	150	150	125
	80	96.2	175	150	150
	90	108	200	175	150
	100	120	200	200	175
	120	144	250	225	200
	125	150	250	225	200
	150	180	300	300	250
	160	192	350	300	300
	180	216	400	350	300
	200	241	400	400	350
	225	271	500	500	400
	240	289	500	500	400
	250	301	500	500	400
	300	361	600	600	500
	320	385	700	600	600
	360	433	800	700	600
	375	451	800	700	600
	400	481	800	800	800
	450	541	900	900	800
600	5	4.8	15	15	15
	7½	7.2	15	15	15
	10	9.6	20	15	15
	15	14.4	25	30	20
	20	19.2	35	30	30
	25	24.1	40	40	40
	30	28.9	50	50	40
	35	33.6	60	50	50
	40	38.5	70	70	70
	45	43.3	80	70	70
	50	48.1	80	100	70
	60	57.8	100	100	90
	75	72.2	125	125	100
	80	77.0	150	125	125
	100	96.2	175	150	150
	120	115	200	175	175
	125	120	200	200	175
	150	144	250	225	200
	160	154	300	250	225
	180	173	300	300	250
	200	192	350	300	300
	225	217	400	350	300
	240	231	400	350	350
	250	241	400	400	350
	300	289	500	500	400
	320	306	600	500	500
	360	347	600	600	500
	375	361	600	600	500
	400	385	700	600	600
	450	433	800	700	600

An example of how a higher power factor saves you money

A power-factor study of your plant shows a peak demand of 480 kva at 75 percent power factor. Since the power bill is based on kva demand plus energy charges, reduction in the demand charge by raising the power factor will result in appreciable savings.

Assuming that you decide to raise the power factor to 95 percent, how much corrective capacitor kvar is required and how much will the power charges be reduced?

Step #1—Capacitors required

480 kva @ 75% pf = 480 x 75
= 360 kw (pf = kw/kva)

From the "Capacitor Calculating Chart" correcting from 75% pf to 95% pf would require:
360 kw x 0.553 = 200 kvar of capacitors

Step #2—Savings
Typical power bill

	Present bill @ 75% pf	New bill @ 95% pf
Monthly demand, kva	480	380
Monthly consumption, kwhr	80,000	80,000
Billing demand charge @ $1.20/kva	$ 576.00	$ 456.00
Energy charge (kwhr)		
1st group @ 1.80¢/kwhr for first 50 kwhr/kva demand		
50 x 480 kva = 24,000 kwhr @ 1.80¢/kwhr	432.00	
50 x 380 kva = 19,000 kwhr @ 1.80¢/kwhr		342.00
2nd group @ 1.60¢/kwhr for next 50 kwhr/kva demand		
50 x 480 kva = 24,000 kwhr @ 1.60¢/kwhr	384.00	
50 x 380 kva = 19,000 kwhr @ 1.60¢/kwhr		304.00
3rd group @ 1.40¢/kwhr for all remaining kwhr		
80,000 − 48,000 = 32,000 kwhr @ 1.40¢/kwhr	448.00	
80,000 − 38,000 = 32,000 kwhr @ 1.40¢/kwhr		588.00
Total energy charge	$1,264.00	$1,234.00
Total bill (demand charge + energy charge)	$1,840.00	$1,690.00

Net savings per month @ 95% pf = $150.00 (approx. 8% reduction)

Assuming the installed cost of the capacitors to be $10/kvar, the capacitors would pay for themselves in 13⅓ months . . . and the savings would still continue.

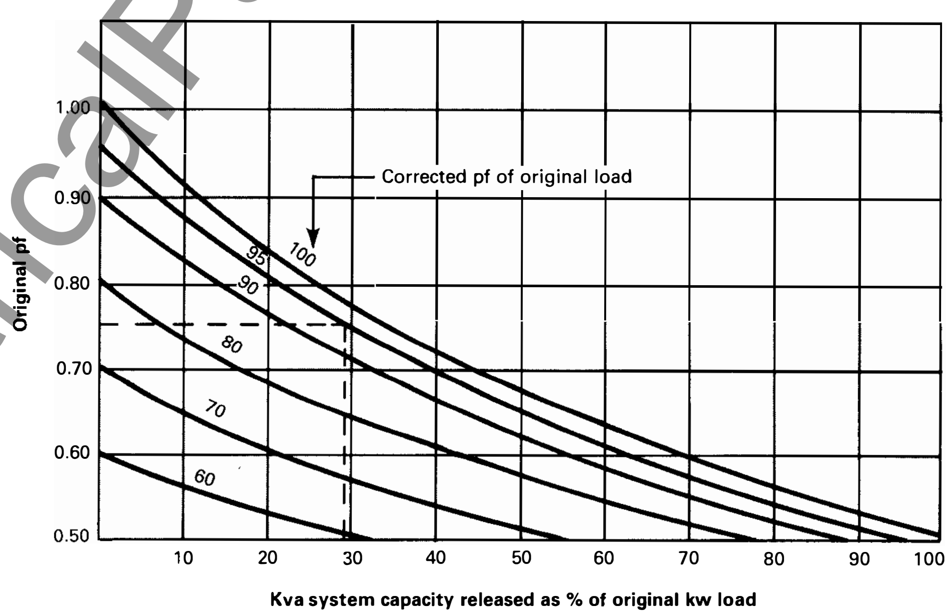
Additional benefits of power-factor correction

Released system capacity
Capacitors supply the REACTIVE current required by inductive loads, and thereby release more of your system's capacity to carry useful protective current. In short, you get more production capacity for the same power dollar.

The chart at right can be used to determine how much system capacity is released as your power factor is improved.

Using the previous example problem, improving the power factor from 75 percent to 95 percent will release 30 percent of the original kw load, or 0.30 x 360 kw = 108 kva. This means an additional load of 108 kva at 75 percent power factor may be added to existing circuits without exceeding the original kva demand.

Released system capacity



Voltage improvement
Low power factor can reduce plant voltage when REACTIVE current is drawn from the feeder lines . . . the greater the current, the greater the voltage drop. The addition of Westinghouse capacitors to supply this REACTIVE current without consuming useful power reduces voltage drops . . . results in improved voltage levels from the point of application all the way back to the source.

When capacitors are installed on the load side of transformers, the following formula may be used for calculating voltage rise:

$$\%\text{ voltage rise through transformer} = \frac{\text{capacitor kvar} \times \%\text{ transformer reactance}}{\text{kva of transformer}}$$

Reduced power losses
In an electrical circuit, kilowatt losses are proportional to the line current squared. The application of Westinghouse capacitors to improve system power factor reduces line current, and thereby benefits your system with lower power losses.

For estimating purposes, the following formula can be used to approximate the reduction in losses:

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

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