APPLICATION GUIDE FOR POWER FACTOR CORRECTION

From the Engineers at Myron Zucker, Inc.

MZI

TABLE OF CONTENTS

Section **Page**

Tables **Page**

APPLICATION GUIDE FOR POWER FACTOR CORRECTION

SECTION I - POWER FACTOR

UNDERSTANDING POWER FACTOR

Loads are predominantly inductive or resistive in most modern electrical distribution systems. Resistive loads include incandescent lighting and resistance heating. Inductive loads include motors, induction furnaces, transformers and ballast-type lighting. Inductive loads, such as motors, require two types of power:

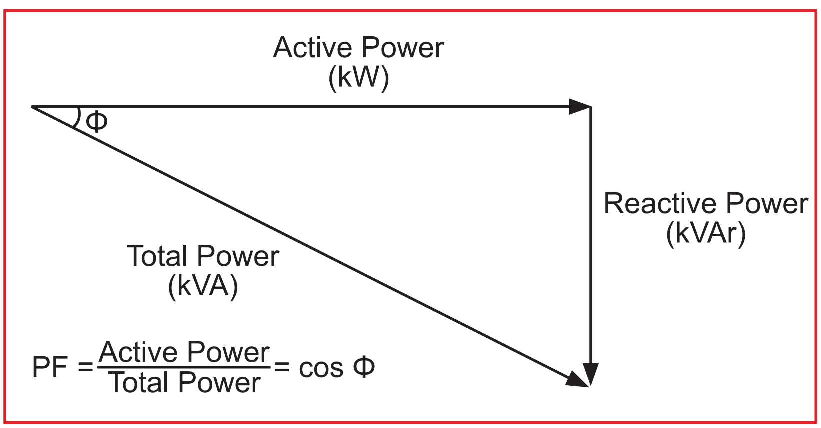
1. Active power to perform the work
2. Reactive power to create and maintain electro-magnetic fields

For a given device, active power varies with changes in load, while reactive power remains constant. The vector sum of the active power and reactive power results in total power. Total power is the power that must be generated by the utility provider for the user.

- Active power, also referred to as real power, working power, or load power is commonly measured in kW (1000 watts)
- Reactive power, also referred to as imaginary power, inductive power, or magnetizing power is measured in kVAr (1000 volt-amperes reactive)
- Total power also referred to as apparent power is measured in kVA (1000 volt-amperes)

A low power factor requires a larger amount of total power for a given amount of active power, whereas a high power factor requires a lesser amount of total power for the same amount of active power. Utilities provide total power to the user, and by means of continuous metering determine actual values of the components of power shown in **Figure 1**. These values are provided on the monthly billing statements. If a facility operates at a low power factor, the utility provider may add a penalty. In like manner, a high power factor may result in a rebate or credit.

Figure 1



IMPROVING POWER FACTOR

Power factor can be increased (improved) by adding power factor correction capacitors (PFCC) to the plant power distribution system. This reduces the amount of reactive power required, and thus the total power generated by the utility. Consider the case in **Figure 2**.

In this case the utility provider applied a penalty formula when the power factor fell below 85%, resulting in a monthly penalty of $650.00. Also, to provide 812 kW of active power the 1500 kVA transformer is loaded to approximately 78% capacity (1160/1500 = 77.3%).

To improve the power factor to a value greater than 85%, a PFCC with a capacitance of 410 kVAr is added to the system. This improves the power factor to 89%, and reduces the required total power to 913 kVA as shown in **Figure 3**.

The user, operating with the same active power, but now with capacitors installed, has eliminated the $650.00 monthly penalty. Estimating labor and material at $7,400.00 results in an ROI of less than 12 months.

Total power is reduced by 247 kVA (1160 - 913 = 247). This reduces the load on the 1500 kVA transformer from 78% to 60%, freeing up more capacity for the addition of future loads.

Figure 2

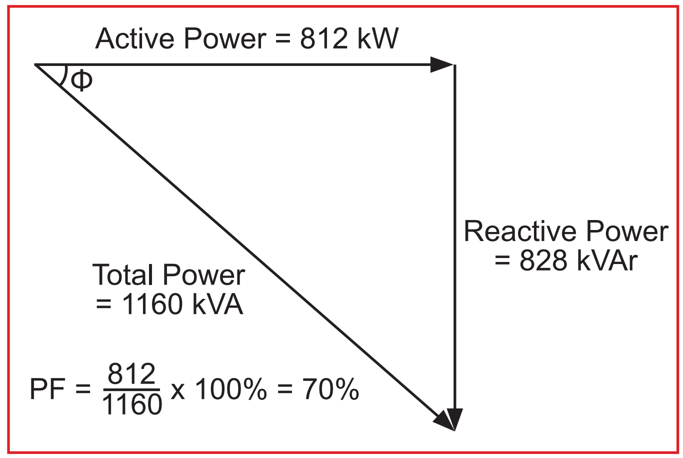
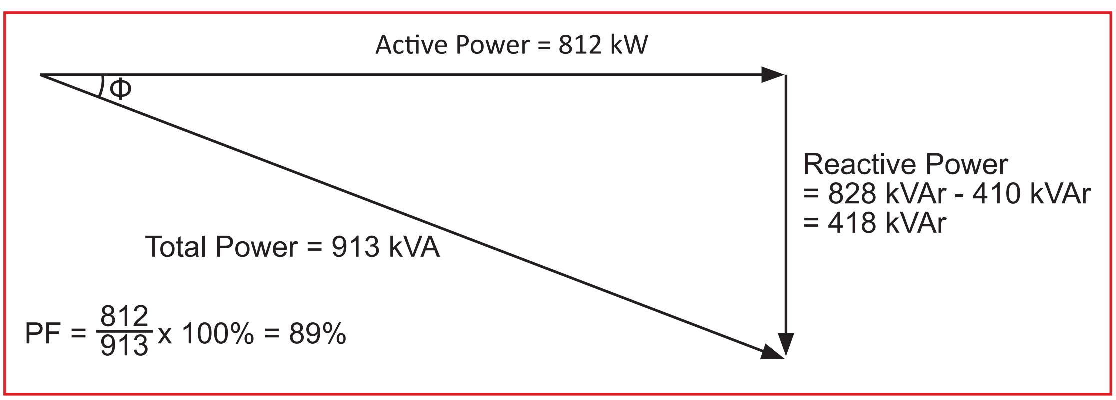


Figure 3



SECTION II - THE ADVANTAGES OF MAINTAINING A HIGH POWER FACTOR

ELIMINATION OF PENALTY DOLLARS

A high power factor eliminates the penalty utility providers impose while operating with a low power factor. For many years, most utility providers demanded a minimum of 85% power factor as an average for each monthly billing. Now, many of these same utilities are demanding 95% power factor. Facilities that fall short of the minimum pay a monthly penalty.

Utility companies have different ways of presenting power factor penalties on monthly billing statements. The actual wording or formula in the utility rate contract may spell out the required power factor, or it may refer to kVA billing, or it may refer to kW demand billing with power factor adjustment multipliers. The utility provider representative should be consulted to explain the particular rate contract used in the monthly bill. This insures the proper steps will be taken to eliminate penalty fees by maintaining a proper power factor.

ADDITIONAL ELECTRICAL SYSTEM CAPACITY

A high power factor can help utilize the full capacity of the electrical distribution system. To refresh this point, refer to the power triangle diagrams shown in **Figures 1, 2, and 3**. Remember, total power is the power generated by the utility provider which includes both the active power and the reactive power, and it is the active power that performs the work. Since total power is the amount of power passing through the transformer, it is limited by the transformer's rated size: e.g. 750 kVA, 1500 kVA, 2500 kVA, etc. In the previous example, the transformer load was reduced from 1160 to 913 kVA, thus allowing for more load to be added in the future.

REDUCTION OF I^2R LOSSES

Potential savings in billed kW-Hrs can be realized depending upon where PFCCs are located in an electrical system. When PFCCs are energized, total power is reduced from their location in the system back to the utility source. In other words, PFCCs reduce the electrical current flowing from the utility provider's generator to the capacitor location. This reduction in current can be as high as 20%. Power loss results from current passing through a conductor and is expressed by the following formula:

$$\textit{Power Loss} = \textit{Current}^2 \times \textit{Resistance} = I^2R$$

Power loss is measured in *watts*, current measured in *amperes*, and resistance measured in *ohms*.

Considering the formula above, it becomes obvious that locating the PFCC at the extremities of the feeders and branch circuits (where the loads are) can result in a reduction in power loss of approximately 30% for a typical facility type. Note, this is a reduction in power loss and not in total power consumption.

SECTION III - HOW TO DETERMINE THE AMOUNT OF kVAr REQUIRED

ANALYSIS OF UTILITY BILLS

Monthly utility bills should be studied and analyzed. Since loads vary from month to month, or season to season, it is good practice to consider the last twelve months of bills. Most utility providers print out the average power factor for the month, and the total active energy consumed during that billing period. However, with some utility providers, power factor may not be obvious on that monthly bill. Myron Zucker, Inc. (MZI) experienced staff has the expertise to provide detailed utility bill analysis. The average active power for the billing period can be calculated by dividing the total active energy consumed by the total number of hours of the billing period.

With values of active power and power factor known, the power triangle diagram can be developed and the reactive power can be determined. To improve the power factor to 100%, the value of reactive power determined from this analysis is equal to the capacitance of the PFCC in kVAr. Sizing of PFCC can also be determined by the use of Table 1, which simplifies the calculations.

INSTRUCTIONS FOR USING TABLE 1:

1. Find the billing (original) power factor in the first column.
2. Read across the first row for the desired power factor.
3. Find the multiplier value where the above two values intersect.
4. Determine the PFCC capacitance in kVAr by multiplying the average active power by the multiplier value.

EXAMPLE:

The utility bill shows an average power factor of .72 with an average active power of 627 kW. How much capacitance in kVAr is required to improve the power factor to .95?

STEPS:

1. Locate .72 in the first column.
2. Read across the first row to the desired power factor of .95.
3. Find the multiplier value of .635 where the above two values intersect.
4. Multiply the average active power of 627 kW by .635 (627 kW x .635 = 398 kVAr).
5. Select a 400 kVAr PFCC to improve the power factor to 95%.

Once capacitance is determined the next task is to determine the PFCC mounting location.

Note: Depending on the facility's load profile, the use of average active power could result in undercorrection. If the load profile is unknown or cannot be estimated, a power study may be required.

TABLE 1

MULTIPLIERS TO DETERMINE CAPACITOR kVAr REQUIRED FOR POWER FACTOR CORRECTION

Original Power Factor	Desired Power Factor																				
	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00
0.50	0.982	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.248	1.276	1.306	1.337	1.369	1.403	1.440	1.481	1.529	1.589	1.732
0.51	0.937	0.962	0.989	1.015	1.041	1.067	1.094	1.120	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
0.52	0.893	0.919	0.945	0.971	0.997	1.023	1.050	1.076	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
0.53	0.850	0.876	0.902	0.928	0.954	0.980	1.007	1.033	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
0.54	0.809	0.835	0.861	0.887	0.913	0.939	0.966	0.992	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
0.55	0.769	0.795	0.821	0.847	0.873	0.899	0.926	0.952	0.979	1.007	1.035	1.063	1.093	1.124	1.156	1.190	1.227	1.268	1.316	1.376	1.519
0.56	0.730	0.756	0.782	0.808	0.834	0.860	0.887	0.913	0.940	0.968	0.996	1.024	1.054	1.085	1.117	1.151	1.188	1.229	1.277	1.337	1.480
0.57	0.692	0.718	0.744	0.770	0.796	0.822	0.849	0.875	0.902	0.930	0.958	0.986	1.016	1.047	1.079	1.113	1.150	1.191	1.239	1.299	1.442
0.58	0.655	0.681	0.707	0.733	0.759	0.785	0.812	0.838	0.865	0.893	0.921	0.949	0.979	1.010	1.042	1.076	1.113	1.154	1.202	1.262	1.405
0.59	0.619	0.645	0.671	0.697	0.723	0.749	0.776	0.802	0.829	0.857	0.885	0.913	0.943	0.974	1.006	1.040	1.077	1.118	1.166	1.226	1.369
0.60	0.583	0.609	0.635	0.661	0.687	0.713	0.740	0.766	0.793	0.821	0.849	0.877	0.907	0.938	0.970	1.004	1.041	1.082	1.130	1.190	1.333
0.61	0.549	0.575	0.601	0.627	0.653	0.679	0.706	0.732	0.759	0.787	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.156	1.299
0.62	0.516	0.542	0.568	0.594	0.620	0.646	0.673	0.699	0.726	0.754	0.782	0.810	0.840	0.871	0.903	0.937	0.974	1.015	1.063	1.123	1.266
0.63	0.483	0.509	0.535	0.561	0.587	0.613	0.640	0.666	0.693	0.721	0.749	0.777	0.807	0.838	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.451	0.474	0.503	0.529	0.555	0.581	0.608	0.634	0.661	0.689	0.717	0.745	0.775	0.806	0.838	0.872	0.909	0.950	0.998	1.068	1.201
0.65	0.419	0.445	0.471	0.497	0.523	0.549	0.576	0.602	0.629	0.657	0.685	0.713	0.743	0.774	0.806	0.840	0.877	0.918	0.966	1.026	1.169
0.66	0.388	0.414	0.440	0.466	0.492	0.518	0.545	0.571	0.598	0.626	0.654	0.682	0.712	0.743	0.775	0.809	0.846	0.887	0.935	0.995	1.138
0.67	0.358	0.384	0.410	0.436	0.462	0.488	0.515	0.541	0.568	0.596	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.965	1.108
0.68	0.328	0.354	0.380	0.406	0.432	0.458	0.485	0.511	0.538	0.566	0.594	0.622	0.652	0.683	0.715	0.749	0.786	0.827	0.875	0.935	1.078
0.69	0.299	0.325	0.351	0.377	0.403	0.429	0.456	0.482	0.509	0.537	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.906	1.049
0.70	0.270	0.296	0.322	0.348	0.374	0.400	0.427	0.453	0.480	0.508	0.536	0.564	0.594	0.625	0.657	0.691	0.728	0.769	0.817	0.877	1.020
0.71	0.242	0.268	0.294	0.320	0.346	0.372	0.399	0.425	0.452	0.480	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.214	0.240	0.266	0.292	0.318	0.344	0.371	0.397	0.424	0.452	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.186	0.212	0.238	0.264	0.290	0.316	0.343	0.369	0.396	0.424	0.452	0.480	0.510	0.541	0.573	0.607	0.644	0.685	0.733	0.793	0.936
0.74	0.159	0.185	0.211	0.237	0.263	0.289	0.316	0.342	0.369	0.397	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.132	0.158	0.184	0.210	0.236	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.288	0.315	0.343	0.371	0.399	0.429	0.460	0.492	0.526	0.563	0.604	0.652	0.712	0.855
0.77	0.079	0.105	0.131	0.157	0.183	0.209	0.236	0.262	0.289	0.317	0.345	0.373	0.403	0.434	0.466	0.500	0.537	0.578	0.626	0.685	0.829
0.78	0.052	0.078	0.104	0.130	0.156	0.182	0.209	0.235	0.262	0.290	0.318	0.346	0.376	0.407	0.439	0.473	0.510	0.551	0.599	0.659	0.802
0.79	0.026	0.052	0.078	0.104	0.130	0.156	0.183	0.209	0.236	0.264	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.633	0.776
0.80	0.000	0.026	0.052	0.078	0.104	0.130	0.157	0.183	0.210	0.238	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.609	0.750
0.81		0.000	0.026	0.052	0.078	0.104	0.131	0.157	0.184	0.212	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82			0.000	0.026	0.052	0.078	0.105	0.131	0.158	0.186	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.555	0.698
0.83				0.000	0.026	0.052	0.079	0.105	0.132	0.160	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.529	0.672
0.84					0.000	0.026	0.053	0.079	0.106	0.134	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85						0.000	0.027	0.053	0.080	0.108	0.136	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86							0.000	0.026	0.053	0.081	0.109	0.137	0.167	0.198	0.230	0.264	0.301	0.342	0.390	0.450	0.593
0.87								0.000	0.027	0.055	0.083	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88									0.000	0.028	0.056	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89										0.000	0.028	0.056	0.086	0.117	0.149	0.183	0.220	0.261	0.309	0.369	0.512
0.90											0.000	0.028	0.058	0.089	0.121	0.155	0.192	0.233	0.281	0.341	0.484
0.91												0.000	0.030	0.061	0.093	0.127	0.164	0.205	0.253	0.313	0.456
0.92													0.000	0.031	0.063	0.097	0.134	0.175	0.223	0.283	0.426
0.93														0.000	0.032	0.066	0.103	0.144	0.192	0.252	0.395
0.94															0.000	0.034	0.071	0.112	0.160	0.220	0.363
0.95																0.000	0.037	0.079	0.126	0.186	0.329
0.96																	0.000	0.041	0.089	0.149	0.292
0.97																		0.000	0.048	0.108	0.251
0.98																			0.000	0.060	0.203
0.99																				0.000	0.143
																					0.000

SECTION IV - LOCATION OF REQUIRED CAPACITORS

CAPACITOR PLACEMENT WITHIN AN ELECTRICAL SYSTEM

There are four methods for placing capacitors within an electrical system.

Method #1: CAPACITOR AT LOAD (CALMOUNT® BRAND CAPACITOR)

Install a single PFCC at each sizeable motor such that it energizes whenever the motor is in operation. This is referred to as a ***Calmount®*** brand capacitor (Capacitor-At-Load). **Table 2** and **Table 3** list suggested maximum capacitor ratings for two different motor designs. These tables are based on assumptions and averages and in some cases, depending on motor application, can result in overcorrection. If possible, capacitors for at-the- load applications should be sized based on motor manufacturer recommendation or motor nameplate data.

Method #1 is typically the most advantageous. The PFCC could be connected either in location (A) or (B) as shown in **Figure 4.**

Location A - Normally used for most motor applications.

Location B - Used when motors are jogged, plugged, reversed; for multi-speed motors, or reduced-voltage start motors.

Advantages of Method #1:

- Corrects Power Factor, unloads the transformer, reduces losses in conductors from source to motor location.
- Voltage drop to motor is reduced - thus optimizing motor performance.
- Installation simple - no new disconnect or circuit breakers required.

Figure 4

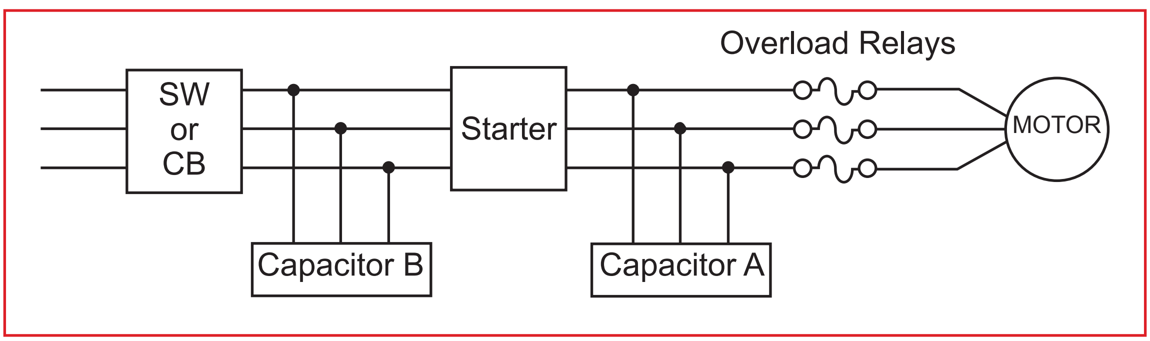


TABLE 2

SUGGESTED MAXIMUM CAPACITOR RATINGS USED FOR HIGH EFFICIENCY MOTORS AND OLDER DESIGN (PRE "T-FRAMES") MOTORS*

Induction Motor Horsepower Rating	No. of Poles and Nominal Motor Speed in RPM											
	2 3600 RPM		4 1800 RPM		6 1200 RPM		8 900 RPM		10 720 RPM		12 600 RPM	
	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %
3	1.5	14	1.5	15	1.5	20	2	27	2.5	35	3	41
5	2	12	2	13	2	17	3	25	4	32	4	37
7.5	2.5	11	2.5	12	3	15	4	22	5	30	6	34
10	3	10	3	11	3	14	5	21	6	27	7.5	31
15	4	9	4	10	5	13	6	18	8	23	9	27
20	5	9	5	10	6	12	7.5	16	9	21	12.5	25
25	6	9	6	10	7.5	11	9	15	10	20	15	23
30	7	8	7	9	9	11	10	14	12.5	18	17.5	22
40	9	8	9	9	10	10	12.5	13	15	16	20	20
50	12.5	8	10	9	12.5	10	15	12	20	15	25	19
60	15	8	15	8	15	10	17.5	11	22.5	15	27.5	19
75	17.5	8	17.5	8	17.5	10	20	10	25	14	35	18
100	22.5	8	20	8	25	9	27.5	10	35	13	40	17
125	27.5	8	25	8	30	9	30	10	40	13	50	16
150	30	8	30	8	35	9	37.5	10	50	12	50	15
200	40	8	37.5	8	40	9	50	10	60	12	60	14
250	50	8	45	7	50	8	60	9	70	11	75	13
300	60	8	50	7	60	8	60	9	80	11	90	12
350	60	8	60	7	75	8	75	9	90	10	95	11
400	75	8	60	6	75	8	85	9	95	10	100	11
450	75	8	75	6	80	8	90	9	100	9	110	11
500	75	8	75	6	85	8	100	9	100	9	120	10

* For use with 3-phase, 60 hertz NEMA Classification B Motors to raise full load power factor to approximately 95%

TABLE 3

SUGGESTED MAXIMUM CAPACITOR RATINGS "T-FRAME" NEMA "DESIGN B" MOTORS*

Induction Motor Horsepower Rating	No. of Poles and Nominal Motor Speed in RPM											
	2 3600 RPM		4 1800 RPM		6 1200 RPM		8 900 RPM		10 720 RPM		12 600 RPM	
	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %	Capacitor kVAr	Current Reduction %
2	1	14	1	24	1.5	30	2	42	2	40	3	50
3	1.5	14	1.5	23	2	28	3	38	3	40	4	49
5	2	14	2.5	22	3	26	4	31	4	40	5	49
7.5	2.5	14	3	20	4	21	5	28	5	38	6	45
10	4	14	4	18	5	21	6	27	7.5	36	8	38
15	5	12	5	18	6	20	7.5	24	8	32	10	34
20	6	12	6	17	7.5	19	9	23	10	29	12.5	30
25	7.5	12	7.5	17	8	19	10	23	12.5	25	17.5	30
30	8	11	8	16	10	19	15	22	15	24	20	30
40	12.5	12	15	16	15	19	17.5	21	20	24	25	30
50	15	12	17.5	15	20	19	22.5	21	22.5	24	30	30
60	17.5	12	20	15	22.5	17	25	20	30	22	35	28
75	20	12	25	14	25	15	30	17	35	21	40	19
100	22.5	11	30	14	30	12	35	16	40	15	45	17
125	25	10	35	12	35	12	40	14	45	15	50	17
150	30	10	40	12	40	12	50	14	50	13	60	17
200	35	10	50	11	50	11	70	14	70	13	90	17
250	40	11	60	10	60	10	80	13	90	13	100	17
300	45	11	70	10	75	12	100	14	100	13	120	17
350	50	12	75	8	90	12	120	13	120	13	135	15
400	75	10	80	8	100	12	130	13	140	13	150	15
450	80	8	90	8	120	10	140	12	168	14	160	15
500	100	8	120	9	150	12	160	12	180	13	180	15

* For use with 3-phase, 60 hertz NEMA Classification B Motors to raise full load power factor to approximately 95%

Method #2: FIXED CAPACITOR BANK (CAPACIBANK® brand capacitor)

Install a fixed value of capacitance, electrically connected, at one or more locations in the plant's electrical distribution system energized at all times.

Method #2 is often used when the facility has few motors of any sizeable horsepower to which PFCC can economically be added. A fixed value of capacitance can be added to the main buses in a motor control center. In most cases, however, the fixed bank (***Capacibank®*** brand capacitor) is usually located near the service entrance switchgear. In all cases, a separate fused switch, or circuit breaker, must be provided ahead of the capacitor bank.

It is very important to note the following when a fixed bank is installed. When the system is lightly loaded (perhaps on weekends or holidays), and too much capacitance is energized, voltage can increase to a value that causes failure of motors, lamps, and controls. Also unbalanced loads or other similar conditions can result in unacceptable levels of harmonic distortion. MZI research findings indicate the value of fixed capacitance in kVAr must not exceed 20% of the transformer rated power in kVA. Values larger than this can result in a large resonant current, potentially harmful to the system.

Note that while the fixed bank can unload the transformer, and show an improved power factor on your monthly bill, it does nothing to reduce the distribution power loss and its contribution to the billed active power.

Method #3: AUTOMATIC CAPACITOR BANK (AUTOCAPACIBANK® brand capacitor)

Install an automatically controlled capacitor bank (***Autocapacibank®*** brand PFCC) that closely maintains a pre-selected value of power factor. This is accomplished by means of a controller. The controller continuously monitors the actual power factor and switches on or off capacitance in steps of kVAr as needed. This type of bank eliminates the concern of having too much capacitance energized during light load periods or as loads vary.

The automatic bank has its advantages but also has its disadvantages. Since it is usually near the incoming service entrance switchgear, the automatic bank does nothing to reduce the total current within the distribution conductors and the associated power loss.

Method #4: COMBINATION OF METHODS

Since no two electrical distribution systems are identical, each must be carefully analyzed to arrive at the most cost effective solution, using one or more of the methods.

SECTION V - ENGINEERING DATA

DEFINITIONS AND BASIC RELATIONSHIPS

Variable (Symbol)	Base Unit (Symbol)	Common Unit (Symbol)	Notes	Equations
Capacitance (C)	Farad (F)	Micro farad (µF)	1 micro farad (µF) = 10^{-6} F	$\textbf{C in µF} = \frac{\text{kVAr} \times 10^3}{(2\pi f) \times (\text{kV})^2}$
Active Power (P)	Watts (W)	Kilowatt (kW)	Also real, working or load power	
Power Loss (P_L)	Watts (W)	Kilowatt (kW)	Also dissipated power	$\mathbf{P_L}$ **in Watts** = I^2R
Reactive Power (Q)	Volt-ampere reactive (VAr)	Kilo volt-amperes reactive (kVAr)	Also imaginary, inductive or magnetizing power	$\textbf{kVAr} = \sqrt{\text{kVA}^2 - \text{kW}^2}$
Total Power (S)	Volt-ampere (VA)	Kilo volt-amperes (kVA)	Also apparent power	$\textbf{kVA} = \frac{\sqrt{3} \times V \times A}{10^3}$ (3-phase)
Voltage (V or E)	Volt (V)		Also potential difference or electromotive force	
Current (I)	Ampere (A)			
Capacitor Current (I_C)	Ampere (A)			$I_c = \frac{\text{kVAr} \times 10^3}{\sqrt{3} \times V}$ (3-phase)
Resistance (R)	Ohms (Ω)			
Frequency (f)	Cycles per second (cps) or hertz (Hz)			
Power Factor (PF)	Dimensionless, expressed as decimal or %			$\textbf{PF} = \frac{\text{kW}}{\text{kVA}} = \cos \Phi$

Applied Voltage	208 V	240 V	480 V	600 V
Amps/kVAr	2.78	2.41	1.20	0.96

TABLE 4

RECOMMENDED WIRE SIZES, SWITCHES, AND FUSES FOR 3-PHASE, 60 Hz CAPACITORS

(These wire sizes are based on 135% of rated current in accordance with the National Electrical Code, Article 460.)

	240 VOLTS				480 VOLTS				600 VOLTS			
kVAr	Current* (Amps)	Wire Size 90° C-Type THHN XHHW* or Equiv.†	Fuse (Amps)	C.B. or Switch (Amps)	Current* (Amps)	Wire Size 90° C-Type THHN XHHW* or Equiv.†	Fuse (Amps)	C.B. or Switch (Amps)	Current* (Amps)	Wire Size 90° C-Type THHN XHHW* or Equiv.†	Fuse (Amps)	C.B. or Switch (Amps)
1	2.4	14	5	30	1.2	14	3	30	1.0	14	3	30
1.5	3.6	14	6	30	1.8	14	3	30	1.4	14	3	30
2	4.8	14	10	30	2.4	14	5	30	1.9	14	3	30
2.5	6.0	14	10	30	3.0	14	6	30	2.4	14	5	30
3	7.2	14	15	30	3.6	14	6	30	2.9	14	5	30
4	9.6	12	20	30	4.8	14	10	30	3.8	14	6	30
5	12	12	20	30	6.0	14	10	30	4.8	14	10	30
6	14	10	25	30	7.2	14	15	30	5.8	14	10	30
7.5	18	10	30	30	9.0	14	15	30	7.2	14	15	30
10	24	8	40	60	12	12	20	30	9.6	12	20	30
12.5	30	8	50	60	15	10	25	30	12	12	20	30
15	36	6	60	60	18	10	30	30	14	10	25	30
17.5	42	6	70	100	21	8	35	60	16	10	30	30
20	48	4	80	100	24	8	40	60	19	8	35	60
22.5	54	4	90	100	27	8	50	60	22	8	35	60
25	60	2	100	100	30	8	50	60	24	8	40	60
27.5	66	2	125	200	33	6	60	60	26	8	45	60
30	72	2	125	200	36	6	60	60	29	8	50	60
32.5	78	1/0	150	200	39	6	65	100	31	8	50	60
35	84	1/0	150	200	42	6	70	100	34	6	60	60
37.5	90	1/0	150	200	45	6	75	100	36	6	60	60
40	96	2/0	175	200	48	4	80	100	38	6	65	100
42.5	102	2/0	175	200	51	4	90	100	41	6	70	100
45	108	3/0	200	200	54	4	90	100	43	6	75	100
50	120	3/0	200	200	60	2	100	100	48	4	80	100
52.5	126	3/0	200	200	63	2	110	200	50	4	80	100
55	132	4/0	250	400	66	2	125	200	53	4	90	100
60	144	4/0	250	400	72	2	125	200	58	2	100	100
65	156	4/0	250	400	78	1/0	150	200	62	2	110	200
70	168	300MCM	300	400	84	1/0	150	200	67	2	125	200
75	180	300MCM	300	400	90	1/0	150	200	72	2	125	200
80	192	350MCM	350	400	96	2/0	175	200	77	1/0	150	200
90	216	500MCM	400	400	108	3/0	200	200	86	1/0	150	200
100	240	500MCM	400	400	120	3/0	200	200	96	2/0	175	200
125	300	(2)4/0	500	600	150	4/0	250	400	120	3/0	200	200
150	360	(2)300MCM	600	600	180	300MCM	300	400	144	4/0	250	400
175	420	(2)350MCM	700	800	210	500MCM	400	400	168	300MCM	300	400
200	480	(2)500MCM	800	800	240	500MCM	400	400	192	350MCM	350	400
225	540	(3)300MCM	900	1200	270	(2)4/0	500	600	216	500MCM	400	400
250	600	(3)350MCM	1000	1200	300	(2)4/0	500	600	240	500MCM	400	400
275	660	(3)500MCM	1100	1200	330	(2)300MCM	600	600	264	(2)4/0	500	600
300	720	(3)500MCM	1200	1200	360	(2)300MCM	600	600	288	(2)4/0	500	600
350					420	(2)350MCM	700	800	336	(2)300MCM	600	600
400					480	(2)500MCM	800	800	384	(2)350MCM	700	800
450					540	(3)300MCM	900	1200	432	(2)400MCM	750	800
500					600	(3)350MCM	1000	1200	480	(2)500MCM	800	800
550					660	(3)500MCM	1100	1200	528	(3)300MCM	900	1200
600					720	(3)500MCM	1200	1200	576	(3)350MCM	1000	1200

* Rated current based on operation at rated voltage, frequency, and KVAR

† Consult National Electrical Code for other wire types. Above size based on 35°C Ambient Operation. (Refer to NEC table 310-16.)

Note: Fuses furnished within Capacitor Assembly may be rated at higher value than shown in this table. The table is correct for field installations and reflects the manufacturer's suggested rating for overcurrent protection and disconnect means in compliance with the National Electrical Code.

NOTES