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### **Issue # EE 08:**

Power factor corrections are supposed to reduce electricity consumption of a firm. Others dispute that and argue it reduces only electricity costs in case the power utility is offering a tariff where a reactive power demand charge are part of the monthly electricity bill. In discussing the nature or phenomena of reactive power experts use incomprehensive equations or explanations.

The question is:

1. What is reactive power, and
2. Under which circumstances may power factor corrections –
  - a. reduce electricity consumption in a plant, or
  - b. reduce electricity costs only, or
  - c. reduce both electricity costs and electricity consumption.

**Answer:**

#### **1.0 What is Reactive Power**

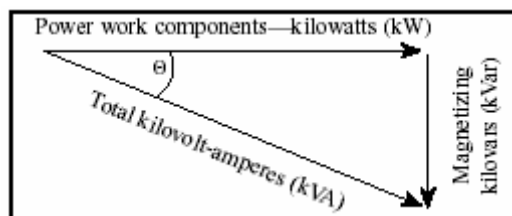
In any AC system the current, and therefore the power, is made up of a number of components based on the nature of the load consuming the power. These are resistive, inductive and capacitive components. In the case of a purely resistive load, for example, electrical resistance heating, incandescent lighting, etc., the current and the voltage are in phase, that is the current follows the voltage. Whereas, in the case of inductive loads, the current is out of phase with the voltage and it lags behind the voltage. Except for a few purely resistive loads and synchronous motors, most of the equipment and appliances in the present day consumer installation are inductive in nature, for example, inductive motors of all types, welding machines, electric arc and induction furnaces, choke coils and magnetic systems, transformers and regulators, etc. In the case of a capacitive load the current and voltage are again out of phase but now the current leads the voltage. The most common capacitive loads are the capacitors installed for the correction of power factor of the load.

The inductive or the capacitive loads are generally termed as the reactive loads. The significance of these different types of loads is that the **active (or true or useful) power** can only be consumed in the resistive portion of the load, where the current and the voltage are in phase. The reactive component of the load only consumes

**(watt less or) reactive power** which is necessary for energizing the magnetic circuit of the equipment (and is thus not available for any useful work). Inductive loads require two forms of power - **Working/Active power** (measured in **kW**) to perform the actual work of creating heat, light, motion, machine output, etc., and **Reactive power** (measured in **kVAr**) to sustain the electromagnetic field. To understand it better, we need to consider that there maybe two currents running through a circuit. One of these currents contains watts (watts produces work) and the other current contains no watts. Why do we need current with no watts (also referred to as watt-less current)? The answer is simple. The current known as watt-less current is required to produce the magnetic field around an electric motor. If there was no watt-less current then an electric motor would not turn. The problems arise due to the fact that we can sometimes have too much watt-less current, in those cases we need to remove some of it.

The vector combination of these two power components (active and reactive) is termed as **Apparent Power** (measured in **kVA**), the value of which varies considerably for the same active power depending upon the reactive power drawn by the equipment. The ratio of the active power (kW) of the load to the apparent power (kVA) of the load is known as the **power factor** of the load.

Fig. 1



$$\text{Power Factor} = \frac{\text{Active Power (kW)}}{\text{Apparent Power (kVA)}}$$

Thus when the nature of the load is purely resistive the kVAr or the reactive component will be nil and thus the angle  $\phi$  will be equal to 0 degrees and the power factor will be equal to unity. For a purely inductive load the power factor will be 0.0 lagging and for a purely capacitive load the power factor will be 0.0 leading.

**Thus, it is evident from above that, more the power factor departs from unity the more will be the kVA demand for the same kW load.** Since most of the HT tariffs include kVA Demand charges along with the Energy Charges, the more the kVA demand for the same kW load the more shall be the electricity bill of the consumer. To say it otherwise, the **customers with a low power factor will pay more for their useful electrical power.** (The Billing demand for the month is generally taken to be the actual maximum kVA demand of the consumer during the month or a fixed percentage of the contract demand or a fixed kVA value, whichever is higher, based on the type of the consumer and the tariff structure of the utility.)

## 2.0 The disadvantages of a low power factor are :

1. The load draws greater current for the same value of the useful power.

A simple example showing the current required by a single phase electric motor is given below:

Supplied Voltage – 240 Volts Single phase.  
Motor input – 10 KW  
Power Factor – **0.65**

$$\text{Current (I}_1\text{)} = \frac{\text{Power (kW)}}{\text{Volts (V)} * \text{PF}} = \frac{10000}{240*0.65} = \mathbf{64.1 \text{ Amp.}}$$

If the power factor of the motor is increased to **0.9** the current drawn by the motor shall be –

$$\text{Current (I}_2\text{)} = \frac{\text{Power (kW)}}{\text{Volts (V)} * \text{PF}} = \frac{10000}{240*0.9} = \mathbf{46.3 \text{ Amp.}}$$

Thus, as the power factor decreases the current required for the same value of active, or useful, power increases. The result is that the sizes of the equipment, like the switchgear, cables, transformers, etc., will have to be increased to cater the higher current in the circuit. **All this adds to the cost.**

Further, the greater current causes increased power loss or **I<sup>2</sup>R losses** in the circuits. Also due to higher current, the conductor temperature rises and hence the **life of the insulation is reduced.**

2. Also, with the increased current the **voltage drop increases** , thereby the voltage at the supply point is reduced. For different loads it causes voltage drop resulting in :
  - a. Lower output of the illumination system.
  - b. Less current is drawn by the heating devices so that the operating temperature drops. This results in increased consumption for the same rise of temperature
  - c. The induction motors slow down and therefore draw more current to produce a fixed torque for the loads. Again more consumption for the same torque.

In the transmission and distribution of the current itself, from the generating station to the consumer, heating losses will be greater at low power factor (varying in proportion to the square of the current) and the voltage drop will be in accordance with relation I\*Z (where Z is the impedance, combination of resistance and reactance) . Since the losses in the electricity system due to low power factor will incur additional cost, it is evident that these will have to be reflected to some extent in the charges to the consumers. This is implemented by metering the maximum demand in kVA or by applying a low power factor penalty component in the tariffs.

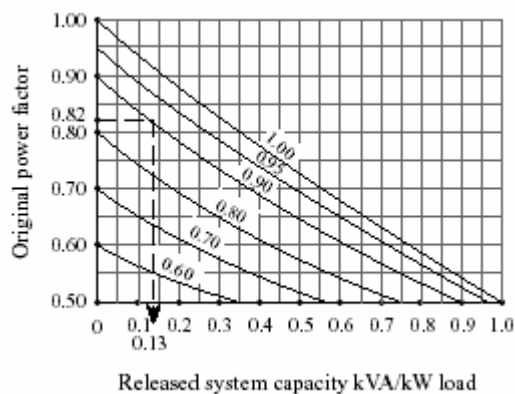
### **3.0 The advantages of a improved power factor :**

Higher power factors result in–

- a) reduced system losses, and the losses in the cables, lines, and feeder circuits and hence lower sizes could be opted.

- b) improved system voltages, thus enable maintaining rated voltage to motors, pumps and other equipment. The voltage drop in supply conductors is a resistive loss, and wastes power heating the conductors. A 5% drop in voltage means that 5% of your power is wasted as heat before it even reaches the motor. Improving the power factor, especially at the motor terminals, can improve your efficiency by reducing the line current and the line losses.
- c) Improved voltage regulation.
- d) increased system capacity, by release of kVA capacity of transformers and cables for the same kW , thus permitting additional loading without immediate augmentation.

Figure below shows the amount of capacity released for various amounts of correction. For the example given previously, the dotted lines indicate the system capacity released is 0.13 times the kilowatt load, which in this case is 10.4 kVA.



The table below shows relation between power factor and size of conductor for equal losses, of a typical system:

SN	PF	Relative Conductor Size Required for		Relative loss with Unchanged conductor (%)
		Same loss (%)	Same volt drop (%)	
1	0.60	279	167	279
2	0.70	204	143	204
3	0.80	156	125	156
4	0.90	123	111	123
5	1.00	100	100	100

- e) reduced power costs (depending on the electric utility tariff schedule) due to reduced kVA demand charges and so also by reduced power factor charges.

**Example :** Let us take an example of a cement industry with initial load condition of 5000 kVA at 60% power factor with a consumption of 19,20,000 units per month, supplied at 33 KV.

Taking the Tariff as below:

- |    |                                    |   |
|----|------------------------------------|---|
| 1. | Demand charges                     | Rs. 144/kVA/month                       |
| 2. | Energy Charges                     | Rs. 4.11 / Unit                         |
| 3. | PF surcharge for each 1% below 90% | 1% of (Demand charges + Energy Charges) |

#### A. Cost saving due to Power Factor improvement

- (i) As we already know, by improving the power factor there will be a reduction in the kVA demand of the load. Thus, in this case the kVA MD will drop from 5000 kVA (at 60%) to 3333.33 kVA (at 90%):

$$\text{Power Factor} = \cos \phi = \text{kW} / \text{kVA}$$

$$\cos \phi_1 = 0.6 = \text{kW} / \text{kVA}_1 = \text{kW} / 5000$$

$$\text{KW} = 5000 * 0.6$$

$$\cos \phi_2 = 0.9 = \text{kW} / \text{kVA}_2$$

$$\text{KW} = \text{kVA}_2 * 0.9$$

For the same value of kW ,

$$5000 * 0.6 = \text{kVA}_2 * 0.9$$

$$\text{kVA}_2 = (5000 * 0.6) / 0.9 = 3333.33 \text{ kVA}$$

Therefore reduction in energy bill due to reduction in maximum demand due to improved power factor from 0.6 to 0.9 shall be :

$$\text{Rs. } 144.00 * (5000 - 3333.33) = \text{Rs. } 240000.48 \text{ per month}$$

- (ii) In addition, by increasing the power factor from 60% to 90%, there shall be no power factor penalty/surcharge on account of low power factor. Thus the savings due to avoidance of the PF surcharge per month would be as below:

$$\text{Rs. } ((5000 - 3333) * 144 * (90 - 60)) * 1 / 100 = \text{Rs. } 72014.14$$

- (iii) Thus the total monthly reduction in bill due to P.F improvement from 0.6 to 0.9 would be:

$$\text{Rs. } 240000.48 + 72014.14 = \text{Rs. } 312014.88 \text{ per month.}$$

$$\text{Net reduction per annum} = 312014.88 * 12 = 3744178.56 \approx \text{Rs. } 37,44,179/-$$

#### B. Cost of investment for Power Factor improvement:

Size of capacitor required to improve the PF from 0.6 to 0.9

$$\begin{aligned} &= \text{kVA}_1 * \sin \phi_1 - \text{kVA}_2 * \sin \phi_2 \\ &= 5000 * \sin(53.1) - 3333.33 * \sin(25.84) \end{aligned}$$

$$=5000*0.8 - 3333.33*0.436$$

$$=4000-1453=2547 \text{ kVAr say } \mathbf{2550 \text{ kAVr}}$$

If we take the cost of capacitor bank per kVAr as Rs. 200/- ,  
the cost of the capacitor bank = 2550\*200 = Rs. 5,10,000/-

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

Total cost = Rs. 8,10,000/-

Annual depreciation and interest@ 20% = Rs. 810000\*0.2  
= Rs. 1,62,000/-

**Net Annual saving** = 37,44,179 - 1,62,000 = **Rs. 35,82,179/-**

Net monthly saving = Rs. 2,98,515/-

Therefore **payback period = 2.7 months**

#### 4.0 Improving Power Factor :

Methods for improving power factor may be classified as below :-

- a) first in which equipment operates at unity power factor thereby improving the overall power factor of the system, and
- b) the second where auxiliary equipment is used specifically to supply the magnetizing power or the kVAr needed by the load.

Equipment that operate at unity power factor include:

1. Unity power factor synchronous motors.
2. Unity power factor capacitor motors.
3. Incandescent lamps.
4. Resistance heaters and other non-inductive loads.

When this type of equipment is added to a system, the overall power factor of the system improves. This additional real power (kW) increases the demand and the energy cost, and is never done for the sole purpose of improving the power factor. However, the choice of load (such as a synchronous motor over an induction motor) can improve power factor.

For the present discussions, we will consider reducing the kVAR load rather than increasing the kilowatt load to improve the power factor.

$$\text{Power Factor} = \frac{\text{kW}}{\text{kVA}} = \frac{\text{kW}}{\sqrt{(\text{kW})^2 + (\text{kVAR})^2}}$$

Improving power factor by reducing the kVAr load requires the use of power factor equipment which operate at a leading power factor such as:

- Synchronous motors which are either over-excited or under loaded with full excitation so they will supply kVAr to the electrical system.

- Static capacitors which are electrical devices without moving parts that have the ability to provide magnetizing current to the load. Their efficiency is high since losses are less than one-half of 1 percent of their kVAC (or kVAR) rating.

In the past two other types of equipment were used to supply kVAr to a system: **synchronous condensers** and **synchronous converters**.

- The synchronous condenser is a synchronous motor without shaft extensions (so it cannot carry any mechanical load) which idles across the power system. Increasing its field excitation results in its furnishing magnetizing power (kVAr) to the system. Its principal advantage was the ease with which the amount of correction could be adjusted. These machines are automatically controlled and generate or consume reactive power depending on the system requirement.
- The synchronous converter was a machine with both slip rings and a commutator connected to the armature windings. This could supply direct current in much the same way as a conventional motor-generator set, but with some economy of size, weight, and material. Adjustment of the field excitation changes the amount of magnetizing power it could supply to the alternating current power lines.

Both of these machines have been replaced principally by the use of static capacitors.

### **5.0 Static Capacitors:**

Static capacitors are the cheapest and the simplest means for reactive power compensation . They are installed by power utilities in the transmission and distribution network and also at the consumers' premises on to different loads such as motors, transformers, incoming supply, etc. In present days automatic switching of the capacitors enables keeping a high power factor for heavily fluctuating loads as well.

### **6.0 kVAr Compensation or Power Factor Correction**

With the present scenario of power crisis it has become all the more important that whatever energy is available, it should be used most optimally. For these reasons proper management of the reactive power is all the more significant. In a power system, it is important that the power utilities and the consumers, both work together for providing the reactive power compensation. The power utilities have to provide reactive compensation for the transmission system's reactive power requirement, reduction of line losses and improved voltage regulation. Whereas, the consumers have to compensate for the additional reactive power requirement by the loads at their installations.

The power utilities take a number of steps for installation of reactive power compensation equipment. These include –

- 33 kV series compensation equipment.
- 220 kV series compensation equipment.

- Synchronous condensers.
- 33 kV shunt capacitors.
- 11 kV and LT shunt capacitors.
- Static VAR compensation equipment.

Further steps are continuously being taken by the utilities to make their system healthy and for providing additional compensation based on the system studies carried out.

Based on the reactive power requirement at their installations, the consumers have to provide for the necessary reactive compensation at their end to achieve the minimum power factor level prescribed by the utility (**0.9** in the case of Madhya Pradesh). The most economical and reliable method of reactive compensation is the installation of power capacitors. Lagging power factor can be corrected by connecting capacitors in parallel with the system. The current in a capacitor produces a leading power factor. Current flows in the opposite direction to that of the inductive device. When the two circuits are combined, the effect of capacitance tends to cancel that of the inductance.

Most customer loads (particularly motors, but many lighting circuits also) are inductive. A low power factor can generally be corrected by connecting appropriate capacitors. This is not the case if low power factor is caused by harmonics, in which case the installation of capacitors will not help, and may cause a serious problem. In high harmonic situations, expert help should be obtained before attempting to correct power factor problems.

Fig. 2. kVAr component before PF correction

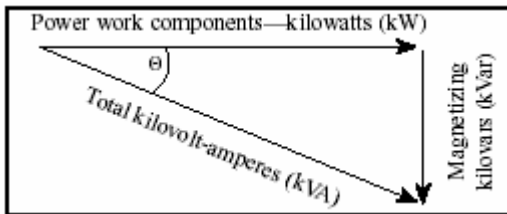
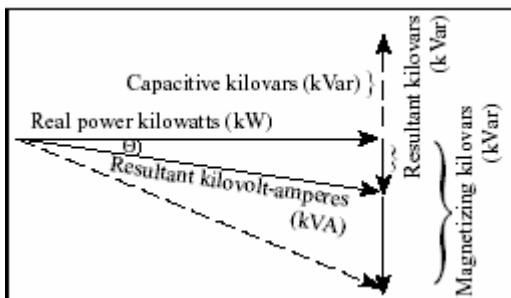


Fig. 3. resultant kVAr component after correction.



Note the smaller resultant with the capacitors added, but real power (kW) does not change. A properly chosen capacitance value will neutralize the inductance and produce unity power factor. Too little or too much capacitance must be avoided. Too little will not correct to a sufficiently high power factor to eliminate a

surcharge, and too much will result in leading power factor with possible undesirable effects.

### **6.1 Sources of kVA<sub>r</sub> requirement**

Motors, transformers, welding machines, induction heating coils and lighting ballasts are the major sources of lagging power factor. Factors affecting the power factor of an induction motor are size, speed and load. The larger the motor and faster its speed, the higher the full-load power factor. The power factor of a motor varies according to its load. The higher the percentage of the rated load, the higher the power factor. The above can be summarized as below:

- Well designed motors may cost more but will usually have a better power factor than lower priced machines.
- High speed motors should be used in preference to low speed machines.
- Over sizing of motors should be avoided . The minimum size compatible with safe and efficient working should be selected.
- Motors should be worked up to a maximum loading and therefore individual motors would be preferred to a single motor driving several loads where the loads are not always at a maximum.

### **6.2 Diagnosis**

If your system is found to have a low power factor, first check that there are no blown fuses or tripped breakers for any existing capacitor banks. After confirming this, call in an expert to check installed equipment, sizes, loads and locations. Utility bills should be examined for the average power factor experienced. It can then be determined what amount of capacitance is required, the type of control needed, and the desirable location for the application.

### **6.3 Methods of correction**

- a. For motors of 50 hp and above, it is best to install power factor correction capacitors at the motor terminals since distribution circuit loading is reduced. When this is done, motor settings that are over current protection relays must be adjusted down accordingly.
- b. In the second arrangement capacitor banks are connected at the bus for each motor control centre. This compromise to Method 1 will reduce installation costs.
- c. In the least expensive method the capacitor banks are connected at the service entrance. However, the disadvantage is that higher feeder currents still flow from the service entrance to the end of line equipment.

### **6.4 Use of synchronous motors**

Synchronous motors can be operated at power factors from unity to 20 leading and are sometimes used for plant power factor correction. The motors are usually designed to operate at a particular power factor, often between 100 per cent and 90 per cent leading. When rated near 20 power factor leading, synchronous motors are referred to as synchronous condensers.

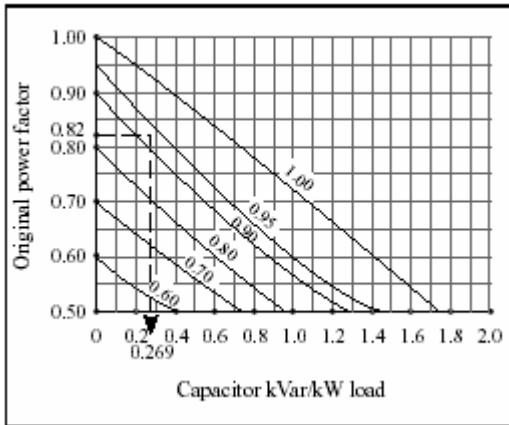
## 6.5 Estimating amount of kVAr of capacitance

The table below shows the kW multipliers used to determine capacitor kVAr required for power factor correction:

		Desired power factor (%)																			
		80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
50	962	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.248	1.275	1.306	1.337	1.369	1.403	1.442	1.481	1.529	1.590	1.732
51	.937	.962	.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
52	.893	.919	.945	.971	.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
53	.850	.876	.902	.928	.954	.980	1.007	1.033	1.060	1.088	1.116	1.144	1.174	1.206	1.237	1.271	1.308	1.349	1.397	1.457	1.600
54	.809	.835	.861	.887	.913	.939	.966	.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
55	.769	.795	.831	.847	.873	.899	.926	.952	.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
56	.730	.756	.782	.808	.834	.860	.887	.913	.940	.968	.996	1.024	1.051	1.085	1.117	1.151	1.189	1.229	1.277	1.338	1.480
57	.692	.718	.744	.770	.796	.822	.849	.875	.902	.930	.958	.986	1.013	1.047	1.079	1.113	1.151	1.191	1.239	1.300	1.442
58	.655	.681	.707	.733	.759	.785	.812	.838	.865	.893	.921	.949	.976	1.010	1.042	1.076	1.114	1.154	1.202	1.263	1.405
59	.618	.644	.670	.696	.722	.748	.775	.801	.828	.856	.884	.912	.939	.973	1.005	1.039	1.077	1.117	1.165	1.226	1.368
60	.584	.610	.636	.662	.688	.714	.741	.767	.794	.822	.850	.878	.905	.939	.971	1.005	1.043	1.083	1.131	1.192	1.334
61	.549	.575	.601	.627	.653	.679	.706	.732	.759	.787	.815	.843	.870	.904	.936	.970	1.008	1.048	1.096	1.157	1.299
62	.515	.541	.567	.593	.619	.645	.672	.698	.725	.753	.781	.809	.836	.870	.902	.936	.974	1.014	1.062	1.123	1.265
63	.483	.509	.535	.561	.587	.613	.640	.666	.693	.721	.749	.777	.804	.838	.870	.904	.942	.982	1.030	1.091	1.233
64	.450	.476	.502	.528	.554	.580	.607	.633	.660	.688	.716	.744	.771	.805	.837	.871	.909	.949	.997	1.058	1.200
65	.419	.445	.471	.497	.523	.549	.576	.602	.629	.657	.685	.713	.740	.774	.806	.840	.878	.918	.966	1.027	1.169
66	.388	.414	.440	.466	.492	.518	.545	.571	.598	.626	.654	.682	.709	.743	.775	.809	.847	.887	.935	.996	1.138
67	.358	.384	.410	.436	.462	.488	.515	.541	.568	.596	.624	.652	.679	.713	.745	.779	.817	.857	.905	.966	1.108
68	.329	.355	.381	.407	.433	.459	.486	.512	.539	.567	.595	.623	.650	.684	.716	.750	.788	.828	.876	.937	1.079
69	.299	.325	.351	.377	.403	.429	.456	.482	.509	.537	.565	.593	.620	.654	.686	.720	.758	.798	.840	.907	1.049
70	.270	.296	.322	.348	.374	.400	.427	.453	.480	.508	.536	.564	.591	.625	.657	.691	.729	.769	.811	.878	1.020
71	.242	.268	.294	.320	.346	.372	.399	.425	.452	.480	.508	.536	.563	.597	.629	.663	.701	.741	.783	.850	.992
72	.213	.239	.265	.291	.317	.343	.370	.396	.423	.451	.479	.507	.534	.568	.600	.634	.672	.712	.754	.821	.963
73	.186	.212	.238	.264	.290	.316	.343	.369	.396	.424	.452	.480	.507	.541	.573	.607	.645	.685	.727	.794	.936
74	.159	.185	.211	.237	.263	.289	.316	.342	.369	.397	.425	.453	.480	.514	.546	.580	.618	.658	.700	.767	.909
75	.132	.158	.184	.210	.236	.262	.289	.315	.342	.370	.398	.426	.453	.487	.519	.553	.591	.631	.673	.740	.882
76	.105	.131	.157	.183	.209	.235	.262	.288	.315	.343	.371	.399	.426	.460	.492	.526	.564	.604	.652	.713	.855
77	.079	.105	.131	.157	.183	.209	.235	.262	.289	.317	.345	.373	.400	.434	.466	.500	.538	.578	.620	.687	.829
78	.053	.079	.105	.131	.157	.183	.210	.236	.263	.291	.319	.347	.374	.408	.440	.474	.512	.552	.594	.661	.803
79	.026	.052	.078	.104	.130	.156	.183	.209	.236	.264	.292	.320	.347	.381	.413	.447	.485	.525	.567	.634	.776
80	-	.026	.052	.078	.104	.130	.157	.183	.210	.238	.266	.294	.321	.355	.387	.421	.459	.499	.541	.608	.750
81	-	-	.026	.052	.078	.104	.131	.157	.184	.212	.240	.268	.295	.329	.361	.395	.433	.473	.515	.582	.724
82	-	-	-	.026	.052	.078	.105	.131	.158	.186	.214	.242	.269	.303	.335	.369	.407	.447	.489	.556	.698
83	-	-	-	-	.026	.052	.079	.105	.132	.160	.188	.216	.243	.277	.309	.343	.381	.421	.463	.530	.672
84	-	-	-	-	-	.026	.053	.079	.106	.134	.162	.190	.217	.251	.283	.317	.355	.395	.437	.504	.646
85	-	-	-	-	-	-	.027	.053	.080	.108	.136	.164	.191	.225	.257	.291	.329	.369	.417	.478	.620
86	-	-	-	-	-	-	-	.026	.053	.081	.109	.137	.167	.198	.230	.265	.301	.343	.390	.451	.593
87	-	-	-	-	-	-	-	-	.027	.055	.082	.111	.141	.172	.204	.238	.275	.317	.364	.425	.567
88	-	-	-	-	-	-	-	-	-	.028	.056	.084	.114	.145	.177	.211	.248	.290	.337	.398	.540
89	-	-	-	-	-	-	-	-	-	-	.028	.056	.086	.117	.149	.183	.220	.262	.309	.370	.512
90	-	-	-	-	-	-	-	-	-	-	-	.028	.058	.089	.121	.155	.192	.234	.281	.342	.484
91	-	-	-	-	-	-	-	-	-	-	-	-	.030	.061	.093	.127	.164	.206	.253	.314	.456
92	-	-	-	-	-	-	-	-	-	-	-	-	-	.031	.063	.097	.134	.176	.223	.284	.426
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.032	.066	.103	.145	.192	.253	.395
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.034	.071	.113	.160	.221	.363
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.037	.079	.126	.187	.328
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.042	.089	.150	.292
97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.047	.108	.251
98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.061	.203
99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.142

(The numbers inside this table are the kW multipliers used to determine capacitor kVAr required for power factor correction.)

The graph given below can also be used for the same:



It is essential that the proper voltage rating of capacitors be used in order to achieve the nameplate kVar rating. The kVar rating is proportional to the square of the voltage. For example, if a 240V capacitor is used on a 208V system, the kVar rating will be equal to  $(208)^2/(240)^2$  times the nameplate value, that is, 0.75 times the nameplate value. This means that the required kVar must be increased by one third (33 per cent) to achieve the desired level of power factor correction.

Over correction of power factor is avoided by selecting the correct capacitance and by the automatic switching on of the capacitor with the motor. Individual power factor corrections are more appropriate for constant loads. Central correction of power factor may be economical where there are small items of plant with fluctuating usage, not all being operated at the same time (having a high diversity). Care must be taken that over correction is not made due to overloading. Automatic switching of capacitors is necessary over 40 KVAR.

**7.0 Conclusion** - Benefits of increased Power Factor to different consumers can be described as below

The Consumers whose applicable tariffs do not include MD charges and Power Factor surcharge shall benefit from **reduction in energy consumption** due to increased efficiency of their system, better voltage profiles, reduced  $I^2R$  losses and release of system capacity. The consumers whose applicable tariffs include MD charges and the PF surcharge shall be able to reduce their energy demand as well as consumption and thus shall benefit from **both the reduced cost of energy and reduced consumption of electricity**. These consumers can expect a payback period of under one year when power factor correction is properly applied.

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