# Technical Guide
# "Power Factor Improvement"

## Small and Medium Enterprises Development Authority

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### Government of Pakistan
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## 1 Disclaimer

This information memorandum is to introduce the subject matter and provide a general idea and information on the said matter. Although, the material included in this document is based on data/information gathered from various reliable sources; however, it is based upon certain assumptions, which may differ from case to case. The information has been provided on AS IS WHERE IS basis without any warranties or assertions as to the correctness or soundness thereof. Although, due care and diligence has been taken to compile this document, the contained information may vary due to any change in any of the concerned factors, and the actual results may differ substantially from the presented information. SMEDA, its employees or agents do not assume any liability for any financial or other loss resulting from this memorandum in consequence of undertaking this activity. The contained information does not preclude any further professional advice. The prospective user of this memorandum is encouraged to carry out additional diligence and gather any information which is necessary for making an informed decision, including taking professional advice from a qualified consultant/technical expert before taking any decision to act upon the information.

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## 2 Introduction to SMEDA

The Small and Medium Enterprises Development Authority (SMEDA) was established in October 1998 with an objective to provide fresh impetus to the economy through development of Small and Medium Enterprises (SMEs).

With a mission "to assist in Employment Generation and Value Addition to the national income, through development of SME sectors, by helping increase the number, scale and competitiveness of SMEs", SMEDA has carried out 'sectoral research' to identify Policy, Access to Finance, Business Development Services, strategic initiatives and institutional collaboration & networking initiatives.

Preparation and dissemination of prefeasibility studies in key areas of investment has been a successful hallmark of SME facilitation by SMEDA.

Concurrent to the prefeasibility studies, a broad spectrum of Business Development Services is also offered to the SMEs by SMEDA. These services include identification of experts and consultants and delivery of need-based capacity building programs of different types in addition to business guidance through help desk services.

### 2.1 Industry Support Program

In order to enhance competitiveness of SMEs and achieve operational excellence, SMEDA established an Industry Support Cell (ISC) for provision of foreign technical support and knowledge transfer in collaboration with International Development Organizations. SMEDA's Industry Support Program (ISP) initially launched with Japan International Cooperation Agency (JICA) and actively engaged in reducing energy inefficiencies and improving production and quality of products with the support of Japanese Experts. Later on, similar activities with other international partner organizations like German Corporation for International Cooperation (GIZ), Training and Development Centers of the Bavarian Employers' Association (bfz), Germany, and United Nations Industrial Development Organization (UNIDO) were also successfully implemented.

## 3 Power Factor Improvement

Power factor improvement can be defined as

**"The Techniques/Methods to improve the power factor of the electrical system"**

Power factor improvement is done in order to avoid low power factor penalty from utility (WAPDA in our case). Low power factor penalty is charged when the power factor of the system is less than 90 % (0.90).

Before going into the details of power factor improvement we first have to look at the causes of low power factor.

## 4 Causes of Low Power Factor

For this we must remember the following formulae

$$Power\ Factor = \frac{kW}{kVA}$$

Furthermore,

$$Power\ Factor = \frac{kW}{kW + kVAR}$$

As we know that power factor is the ratio of active power to apparent power as mentioned above, and power factor will be lower when kW is smaller in relation to kVA and as we know that kVA is the sum of kW and kVAR, thus we can say that higher kVAR results in lower power factor.

Now, the next question is what causes a larger kVAR in a system?

The answer is inductive loads

Inductive loads (which are the sources of reactive power) include:

- Transformers
- Induction Motors
- Induction Generators
- High Intensity Discharge (HID) lighting and many more

These inductive loads constitute a major portion of the power consumed in industrial and commercial units

Reactive power (kVAR) required by inductive loads increase the amount of apparent power (kVA) in the electrical distribution system. This increase in kVAR and kVA results in a larger angle θ (measured between kW and kVA) and as θ increases, cos θ (power factor) decreases

So, inductive loads (with larger kVAR) result in lower power factor

## 5 Techniques/Methods of Power Factor Improvement

There are three ways of improving Power Factor of Electrical System. These three are mentioned below:

A. Installing Capacitors

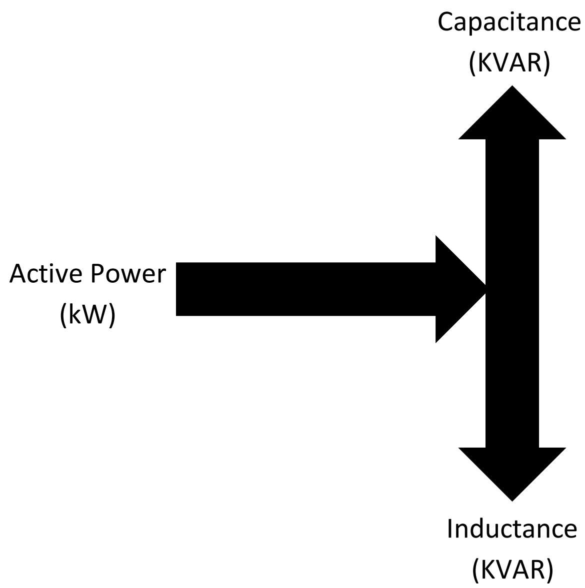
B. Synchronous Generators

C. Synchronous Motors

Out of these three the most popular one is the installation of Capacitors. In Pakistan Power Factor is improved by installing Capacitors. We will discuss this method in detail.

### 5.1 Installation of Capacitors

Capacitors supply kVAR into the system which balance out the inductive kVAR of the electrical system and as a result power factor is improved. The following figure illustrates how the capacitive kVAR and inductive kVAR balance out each other




The capacitive kVAR and the inductive kVAR work at an angle of 180 degrees to each other and the active power is at 90 degrees to them. Therefore, both capacitive and inductive kVAR try to balance each other in an opposing way and the existence of both capacitor and inductor in the same circuit results in the continuous alternating transfer of energy between the two and in this way power factor of the system is improved

## 6 Capacitor kVAR calculation for PF Improvement

Let's suppose that we have original power factor of cos $\theta_1$=0.7 .and we want to improve our power factor to cos $\theta_2$ which is 0.96. The formula for the calculation of capacitive kVAR is mentioned below

$$Required\ Capacitor\ kVAR = Active\ Power\ (Tan\ \theta_1 - Tan\ \theta_2)$$

Which implies that

$$kVAR = P\ (Tan\ \theta_1 - Tan\ \theta_2)$$

Now here

$\theta_1$ = $\cos^{-1}$ (0.7) = 0.7954

$\theta_2$ = $\cos^{-1}$ (0.96) = 0.2838

Suppose that we have running active power of P=10 kW

Thus putting values in above formula

$$kVAR = 10\ kW\ (\ Tan\ (0.7954) - Tan\ (0.2838))$$

$$kVAR = 7.2853$$

Rating of capacitor in single phase is as follow

$$kVAR\ (Single\ Phase) = \frac{7.2853}{3} = 2.43$$

Now for calculating capacitive kVAR to Farads, we will use the following formula

$$Capacitance - \frac{kVAR}{2\pi f V^2}$$

This formula will give results in micro farads (µF)

Here

$\pi$ = 3.1417

f = 50

V = 415

kVAR = 2.43

Thus

**C = 4.49 X 10⁻⁸ µF**

Now using either kVAR value or capacitance value we can select the capacitors for power factor improvement and design our capacitor bank.

## 7 Main components of PF Improvement Panel

PF improvement panel is designed in such a way that it has auto as well as manual operation. Meaning, it can automatically control PF value with the help of multi-step power factor relay which continuously turn capacitors on and off to get the required PF value. In case of fixed load manual operation can be used by manually operating the capacitor bank by considering PF value.

PF correction relays/controller come in different steps like 6 step, 8 step, 12 step etc. Here step means the number of switching positions or number of capacitors that it can connect to the system for PF improvement.

A sample picture of Entes RG-12T (12 step power factor controller) is shown below:


Power factor improvement capacitors are normally rated in kVAR. The normal range of available capacitors is from 20 kVAR to 100 kVAR for LT power factor improvement panels.

A sample picture of Shizuki RG-2 power factor improvement capacitor is shown below:

The main components of PF improvement panel are listed below:

1. PF correction multi step relay/controller
2. Capacitors
3. Magnetic Contactors
4. Fuse
5. Control Relays
6. Auto-Manual selector switch
7. LED indicators

A sample picture of PF improvement panel is shown below

## 8 Conclusion

CEO / Owner of every factory should check PF value and Low Power Factor Penalty in electricity bill of each month because most of them are unaware of the fact that they are paying extra rupees in terms of low power factor penalty.

If factory owner finds any low power factor penalty in their electricity bills while using PF Improvement panel then either their PF improvement panel is not working properly or they have an undersized PF improvement panel.