EPM 333: Economics of Generation &Operation

Power Factor Correction: Solved Problems – 2008/2009

EXAMPLE 1: DESIRED POWER FACTOR

A substation transformer is supplying a load of 360 kW at 0.6 power factor lagging. It is required to calculate:

(a) The kVAR rating of a loss-free capacitor required for constant kW correction to 0.95 lagging.

(b) The kVA rating of a synchronous motor required for constant kVA correction to 0.95 lagging.

Solution

(a) Based on Fig. 5,

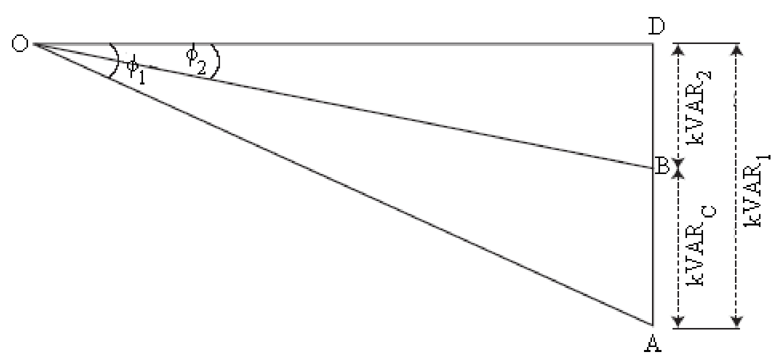

Fig. 5: Constant kW demand PF correction

$\phi1 = \cos^{-1} 0.6 = 53.1301^o$

$\phi2 = \cos^{-1} 0.95 = 18.1949^o$

PFC size = kW of load ($\tan \phi 1 - \tan \phi 2$) kVAR

= 362 kVAR.

Hence, a 362 kVAR loss-free static capacitor is required.

(b) Based on Fig. 6

$\phi 1 = \cos^{-1} 0.6 = 53.1301^o$
$\phi 2 = \cos^{-1} 0.95 = 18.1949^o$
kVA before correction = OA = 360 / 0.6

= 600

kW after correction = OE = 600 * 0.95

= 570

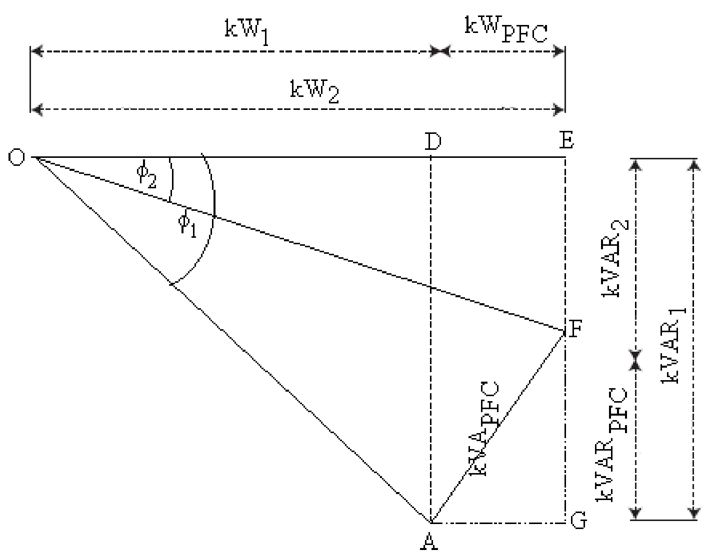

Fig. 6: Constant kVA demand PF correction

Hence,

kW input to the motor = AG = 570 - 360

= 210

kVAR lagging before correction = DA = 600 sin 53.1301

= 480

kVAR lagging after correction = EF = 600 sin 18.1949

= 187

Hence,

KVAR leading output of the motor = FG = DA – EF

= 480 – 187

= 293

Finally,

The rating of the required synchronous motor = $(AG^2 + FG^2)^{0.5}$

= 361 kVA.

EXAMPLE 2: MOST ECONOMICAL POWER FACTOR / CAPACITOR BASED

A load of 700-kVA maximum demand at 0.7 power factor lagging is to be corrected to the most economical power factor. The annual tariff may be taken as 6 $/kVA maximum demand and the initial cost of static loss-free capacitors as 10 $/kVAR. The annual interest and depreciation charges total 15 %.

It is required t calculate:

a. The most economical power factor, cos ϕ*.
b. The kVAR rating of the required capacitors.
c. The annual net saving.
d. The time taken to save the initial cost of the capacitors.

Solution:

a. The most economical power factor

$C = 10 \times 0.15 = 1.5$ \$/year /kVAR.

$\alpha = 6$ \$/kVA m.d.

The most economical power factor phase angle is

$\phi^* = \sin^{-1}(C / \alpha) = 14.4775^o$.

Hence, the most economical power factor = $\cos \phi^* = 0.97$ lagging.

b. The kVAR rating of the required capacitors

PFC size = $P_D (\tan \phi - \tan \phi^*)$ kVA

$= 700 \times 0.7 (\tan 45.5730 – \tan 14.4775)$

$= 374$ kVA.

c. The annual net saving

The annual net saving = $\alpha P_D (1/\cos \phi - 1/\cos \phi^*) – C P_D (\tan \phi - \tan \phi^*)$ \$/year

$= 6 \times 700 \times 0.7 (1/0.7 – 1/0.97) – 1.5 \times 700 \times 0.7 (\tan 45.5730 - \tan 14.4775)$

$= 609$ \$/year.

e. The time taken to save the initial cost of the capacitors

= Capacitor cost / annual net saving

= Capacitor kVAR rating x initial cost of capacitors / annual net saving

$= 374 \times 10 / 609$

$\cong 6.2$ year.

EXAMPLE 3: SPECIFIED CAPACITOR KVAR BASED CORRECTION

A load of 700 kVA m.d. at 0.7 PF lagging is to be corrected by connecting a 370 kVAR static capacitor in parallel as shown in Fig. E3. The capacitor losses are 5 watts/kVAR.

It is required to calculate:

a. The kVA m.d. after correction.
b. The annual net saving taking the annual tariff as 6$/kVA m.d. and the annual interest and depreciation charge on initial cost of the capacitor 555 $.

Assume that the capacitor is permanently connected to the supply and the energy costs 0.833 cent/kWh.

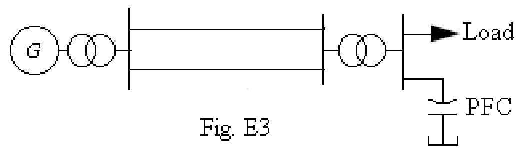

Fig. E3

Solution

a. The kVA m.d. after correction

Based on Fig. 8

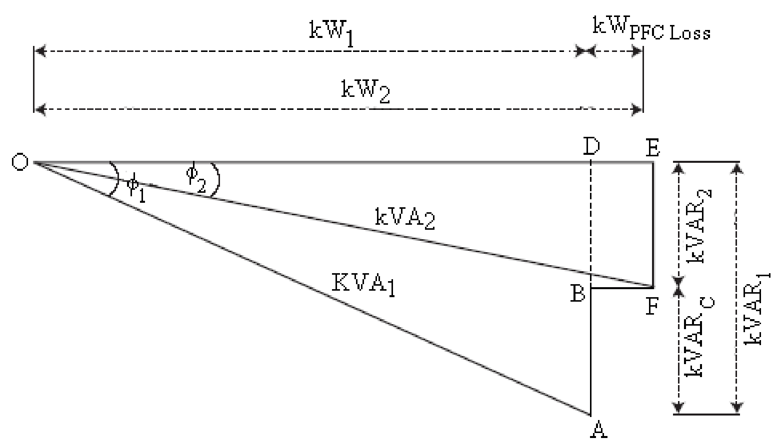

Fig. 8

Capacitor losses = DE

= 370 x 0.005 = 1.85 kW.

Phase angle before correction = $\phi 1 = 45.523^{o}$.

Load kW before correction = OD

= 700 x 0.7

= 490 kW

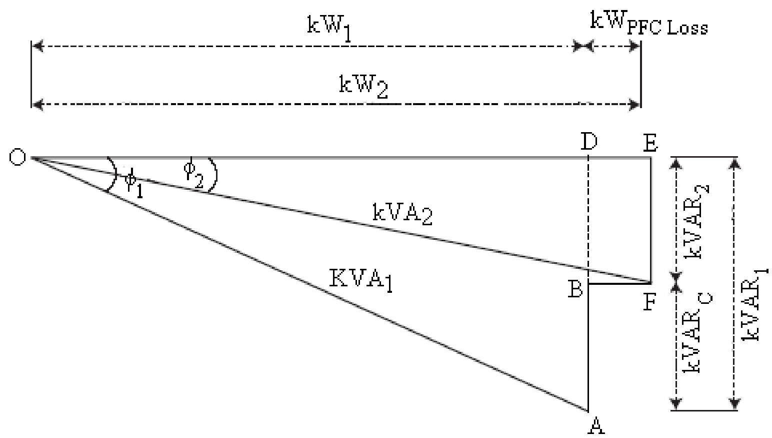

Fig. 8

Load kVAR lagging before correction = AD

= 490 tan ϕ1

= 500.1

kVAR lagging after correction = DB = EF = AD – BD

= 500.1 – 370

= 130.1

kW after correction = OE = OD + DE

= 490 + 1.85

= 491.85

kVA m.d. after correction = OF = $(OE^2 + EF^2)^{0.5}$.

= 509

b. The annual net saving

Reduction in kVA m.d. = OA – OF

= 700 – 509

= 191

Corresponding tariff saving = 191 x 6

= 1146 $/year

Increase in kW charge = DE x kWh cost x 8760 $/year

= 1.85 x 0.00833 x 8760

= 135 $/year

Annual net saving = reduction in kVA m.d. tariff – Increase in kW charge – The annual interest and depreciation charge on the initial cost of the capacitor $/year

= 1146 – 135 – 555

= 456 $/year.

Good Luck

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