**ADEDEJI FAROUQ ADEDOTUN**

**17/ENG04/001**

**ELECTRICAL ELECTRONICS ENGINEERING**

**ELECTRICAL MACHINES**

**SECTION A: THEORETICAL FRAMEWORK**

1. **Develop the theoretical framework required for the correction of the power factor for a multi - sectioned industrial complex from to where ; ; ; and to determine the kVAR rating of the capacitor and the magnitude of the capacitor (C) in farads required to correct the power factor of the complex. USE APPROPRIATE PHASOR DIAGRAMS.**

**Solutions:**

Θ1> θ2

P1=P2

Q1>Q2

S1>S2



kVAR supplied by p.f correction equipment= Qcap= Q1 -Q2

Qcap= kVAR1- kVAR2

Qcap= P2(tan Θ1-tan θ2)

Recall Q= V2/XC

Therefore XC=V2/ Qcap

Also for capacitors; XC= 1/2πfC

Therefore C= 1/2πfXC

**2) What determines the power factor of the Dangote Cement Factory at Abajana, Kogi State?**

The power factor of Dangotes Cement Factory at Abajana, Kogi State is determined by both the Apparent power (S) in KVA and the Working power (P) in KW, in other words by Dividing the working power by the apparent power.

The amount of inductive loads needed for the cement operations affect the power factor at the Obajana plant. Inductive loads such as induction motors used to drive the fans, coolers, rotary kilns e.t.c These motors need reactive power to sustain their magnetic fields, therefore the more reactive power is spent, the less true power is used from the apparent power supplied by the coal, gas and LPFO power plants supplying the industry.

For a more practical and effective method; it is known that the power factor of dangotes cement factory varies along the time. So, only typical values are obtained, potentially, the highest and lowest values of these parameters (Apparent and Working power). To acquire information about the power factor, connect an energy analyzer with the recording capacity. Then, analyzing the obtained data in typical days of the factory; should give the potential values needed to obtain the power factor.

3) **The power factor (pf) of Eleme Petrochemical Industry Port Harcourt is given as ; what is the state of the pf of the complex when ; and . Draw the respective Phasor diagrams**.

**Solution:**

Recall that, the power factor is the cosine of the phase difference between voltage and current. It is also the cosine of the angle of the load impedance.

Power factor= = cos

From the question, it can be deduced that, =

Where, the power factor angle is equal to the angle of the load impedance if V is the voltage across the load and I is the current through it.

Evidently;

,

At,

It is a purely resistive load; the voltage and current are in phase, so that and the state of the power factor is **unity.** Fig. 2b

At,

It is an inductive load; the current lags the voltage so it is a **Lagging power factor**. Fig. 2a

At,

It is a capacitive load; the current leads the voltage so it is a **Leading power factor.** Fig. 2b



![A close up of a map

Description automatically 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4) **For ; Write an expression for P and Q respectively with units in W and VAR. What does P and Q represent.**

**Solution:**

At,

It is an inductive load; the current lags the voltage so it is a **Lagging power factor**. From Fig.2a it can be deduced that:

Using the formula for a right-angle triangle;

VA =

Expressing it in complex form:

VA =

Also:

tan =

Where; P= Real power measured in Watt(W).

Q= Reactive power measured in Volt-Amperes reactive (VAr).

5) **Justify the need for power factor correction to ABUAD and PHCN or an IPP**.

There will be reduced charges on the electricity bills as industries or institutions as big as ABUAD are charged for reactive power when the power factor drops below a certain level

There will be improved voltage.

Electric cables will carry less load.

Sustainable development is achieved as the carbon footprint is minimized.

Considering ABUAD’S College of Engineering; having various well-equipped laboratories, if the power factor is low, this will shorten the life-span of equipment’s, leading to excessive cost for replacing/ repairing. ABUAD as a school having numerous individuals, from the non-academic staff- academic staff and also the students, the rate of power consumption is very high. The higher the portion of reactive power, the lower the power factor; Note, if the reactive power component is reduced and phase angle through compensation; the apparent power vector reduces in length, resulting in lower electricity consumption and energy charges. In other words, saving cost and consumption.

1. **Why is Q needed in an industrial complex with numerous induction motors?**

The reactive power is needed because it is related to the energy needed to maintain the motors internal magnetic field. In an induction motor, the rotor field always lags behind the stators field, so the induction motor always consumes reactive power due to the magnetization current.

**SECTION B: APPLICATION OF THEORETICAL FRAMEWORK**

1. **An industrial load absorbs 5 MVA at a pf of 40% capacitive at 6kV. To improve the pf up to 85% capacitive, determine Q and C of the required capacitor. State how the correcting equipment will be integrated into the industrial power network for this load.**

**Solution:**

1. *Preamble:*

Apparent power (S) = 5MVA

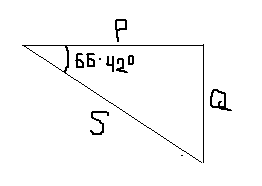
Voltage = 6KV

Initial power factor= 40%=0.4 leading

Improved power factor=85%=8.5 leading

Where; power factor=

Diagrammatic representation:



Where , S= 5Mva

P=

-Q=

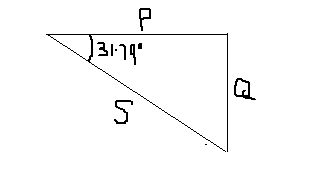
.

: when improving the power factor,

Therefore; where

Power factor=

Diagrammatic representation



=

=

.

Where,

,

Obtaining the value for C;

Recall; C=

Note: standard frequency in Nigeria = 50Hz

C=

C= - 515.4\*10-6 Farads

**7b) State how the correcting equipment will be integrated into the industrial power network for this load.**

From the question, it is stated that the industrial power network is operating on a capacitive load, it can be concluded that it will have a leading (capacitive) power factor; which means that the correcting equipment (capacitor of the minimal size ( -515.4)) which will be integrated in parallel to the industrial power network. This industrial power requires a minimal capacitor because it already deficient with leading VARs (it operates at a lagging PF) and thus this deficient power network will absorb the leading VARs and tend to improve its lagging PF to unity.

1. **An industrial load absorbs 5 MVA at a pf of 40% inductive at 6kV. To improve the pf. Up to 85% inductive, determine Q and C of the required and necessary capacitor. State how the correcting equipment will be integrated into the industrial power network for this load. How different are the values of Q7 and Q8 in terms of magnitude and type of pf correction?** *Preamble:*

Apparent power (S) = 5MVA

Voltage = 6KV

Initial power factor= 40%=0.4 lagging

Improved power factor=85%=8.5 lagging

Where; power factor=

Diagrammatic representation:



Where, S= 5Mva

P=

Q=

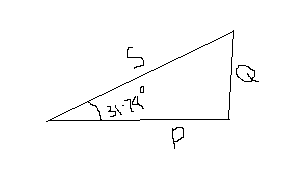
.

: when improving the power factor,

Therefore; where

Power factor=

Diagrammatic representation



Where :

=

=

.

Where,

,

Obtaining the value for C;

Recall; C=

Note: standard frequency in Nigeria = 50Hz

C=

C=295\*10-6 Farads

*From the example used, it has been proven that when correcting a power factor, the following conditions must be met:*

**8b) State how the correcting equipment will be integrated into the industrial power network for this load.**

From the question, it is stated that the industrial power network is operating on an inductive load, it can be concluded that it will have a lagging (inductive) power factor; which means that the correcting equipment (capacitor of the appropriate size (295)) which will be integrated in parallel to the industrial power network as demonstrated in Fig 1b.

**8c) How different are the values of Q7 and Q8 in terms of magnitude and type of pf correction?**

* Observing values in terms of magnitudes; with the same supplied voltage, the capacitor needed in Q7 is minimal ( and is less required compared to that of Q8 having a high capacitive value of (. Also, the Qcap of the capacitive load is more reactive tending towards the negative ( than that of inductive load which is tending towards positive (.
* The type of power factor correction used is AUTOMATIC POWER FACTOR CORRECTION.

1. **The National Universities Commission (NUC) Complex in Abuja has a total load of 100kW. It is powered by a 415 V, three phase, 4 wire power supply. The power factor is 0.85lagging and NUC desires to avoid the payment of penalties for this poor power factor. What Should the facility manager advise NUC management to do? If an improved pf of 0.95 lagging is desired, determine the magnitude of the required Q and C.**

Solution:

1. The facility manager should advice the NUC management to improve the power factor of the installations. If this is optimized, the payment penalties for low power factor will be reduced and at least 20% of the monthly electricity bill will be saved. Not only will that be saved, the rate of electricity consumption will also be lowered.
2. *Preamble:*

Real power (P) = 100kW

Voltage phase = 415V

Initial power factor=0.85 lagging

Improved power factor=0.95 lagging

Where; power factor=

Where, P= 100KW

S=

Q=

.

: when improving the power factor,

Therefore; where

Power factor=

Where :

=

=

.

Where,

,

Obtaining the value for C;

Recall: C=

Note: standard frequency in Nigeria = 50Hz

C=

C=537.9\*10-6 Farads

1. **Undertake a comparative analysis as an Electrical Power Management Consultant and use techno – economic facts and data to advice a client (Globacom Nigeria Ltd) requiring a 20kW induction motor to power its intended fruit juice factory from motor choices given the following details:**

|  |  |  |
| --- | --- | --- |
| **Motor/parameters** |  |  |
| **kW** | **20** | **20** |
| **Phases** | **3** | **3** |
| **Line Voltage** | **415** | **415** |
| **pf** | **0.85** | **0.95** |
| **S** |  |  |
| **Q** |  |  |
| **PREVIOUS METER READING (kWhr)** | **23,000** | |
| **NEW METER READING (kWhr)** | **25,000** | |
| **kWhr charge** | **#55/kWhr** | |
| **Demand(kW) Charge** | **#35/kW** | |
| **Capacity (kVA) Charge** | **#70/kVA** | |
| **Reactive Power (kVAR) Charge** | **#25/kVAR** | |

**Justify clearly your choice of recommended motor.**

**Solution:**

As an Electrical Power Management Consultant, I would recommend Motor M2.

Justifying this:

There is a wide range of barrier that affect the implementation of motor systems efficiency measures, including operating issues that affect decisions regarding allocation of resources. In other to power a fruit juice factory, an effective motor, as well an economic utilization of power supply is required. And for this, I have recommended M2 for the following reasons:

1. **From the calculated values below, it can be deduced that (M2) has a lower reactive power which will not only reduce the problems of low power factor, cables and windings of the motor insulation failure and direct tripping of the motor but also reduce the utility bill charged per reactive power (**this can be seen from the below calculations)**.**

Given the details in the table above:

* Load 20kW at a PF of 0.85 (M1):

The reactive power can be calculated as : Q=P tan

Q = 20\*= 12394.88 KVAr

The cost of reactive power is given as : 12394.88\*#25/kVAR = #309,872 .

* Load 20kW at a PF of 0.95 (M2):

The reactive power can be calculated as: Q=P tan

= 20\*

= 6573.68.

The cost of reactive power is given as: 6573.68\*#25/kVAR = #164,342.

1. **The apparent power which is the most useful power has to be of low operating cost and reasonable consumption: knowing that the KVA is most considered when billing. It can be observed from the calculations that M2 has a lower cost in apparent power than M1.**

Given the details in the table above:

* Load 20kW at a PF of 0.85 (M1):

The Apparent power can be calculated as:

= P/Cos (

=

= 23529.411 VA

The cost of Apparent power is given as: 23529.411\* #70/kVA = #1,647,058.77

* Load 20kW at a PF of 0.85 (M1):

The Apparent power can be calculated as:

= P/Cos (

=

= 21052.63VA

The cost of Apparent power is given as: 21052.63\* #70/kVA = #1,473,684.1

1. **Poor power factor means drawing more power from the electricity network to do the same amount of work. Therefore, the cables need to be larger and this will cost more money. Also, low power factor can cause losses in the motor parts, increase in heat gain and reduce the life span of the motor. So, M2 with a high-power factor has been recommended to prevent the above issues.**