الريان للهندسة الكهربائية والاستشارات والتدريب

Alrayan For Electrical Engineering, Consultation And Training

Training Session For Port Sudan Electrical Engineers

Power Factor Correction

Concept , Advantage and Practical Cases

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Power Factor Correction

Concept , Advantage and Practical Cases

Session Outlines :

1. Three phase power equations (P – Q – S).
2. Power Triangle .
3. Power factor equation.
4. How capacitors are used to improve the power factor .
5. How power factor correction decreases generators and transformers loading.
6. Reactive power flow through a grid.
7. How power factor correction decreases grid total losses.
8. How low power factor penalty is calculated according Sudan utility (SEDC).
9. How the automatic power factor correction controller operates.
10. How to choose the best location to add capacitors in a grid.
11. How to use Etap software to simulate power factor correction cases.

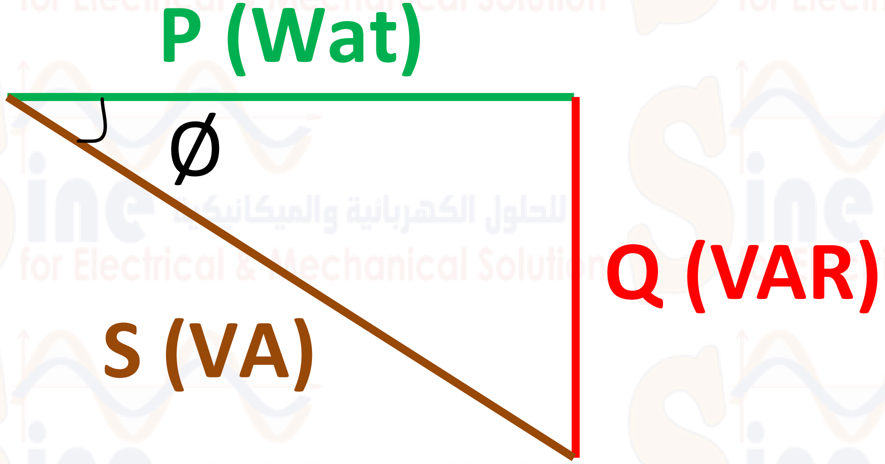
Electrical Power Triangle

* Below is the famous three phase electrical power equations which forms what is called **the power triangle**.

$$P=\sqrt{3}*V_L*I_L*\cos \varnothing \quad (\text{Wat})$$

$$Q=\sqrt{3}*V_L*I_L*\sin \varnothing \quad (\text{VAR})$$

$$S=\sqrt{3}*V_L*I_L \quad (\text{VA})$$



P = Active Power (القدرة الفعالة)

Q = Reactive Power (القدرة الرد فعلية)

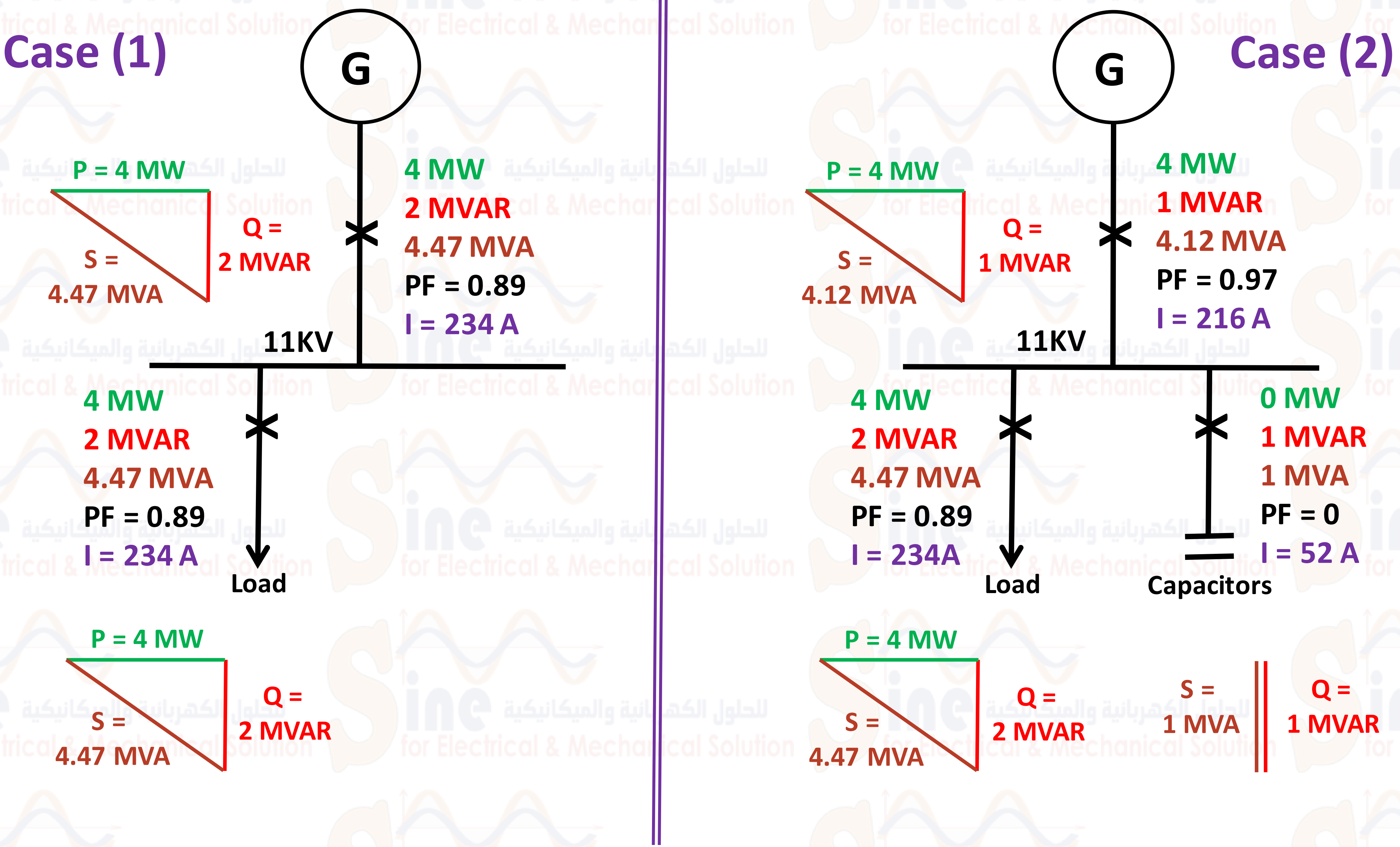
S = Apparent Power (القدرة الظاهرية)

$$S = \sqrt{(P^2 + Q^2)}$$

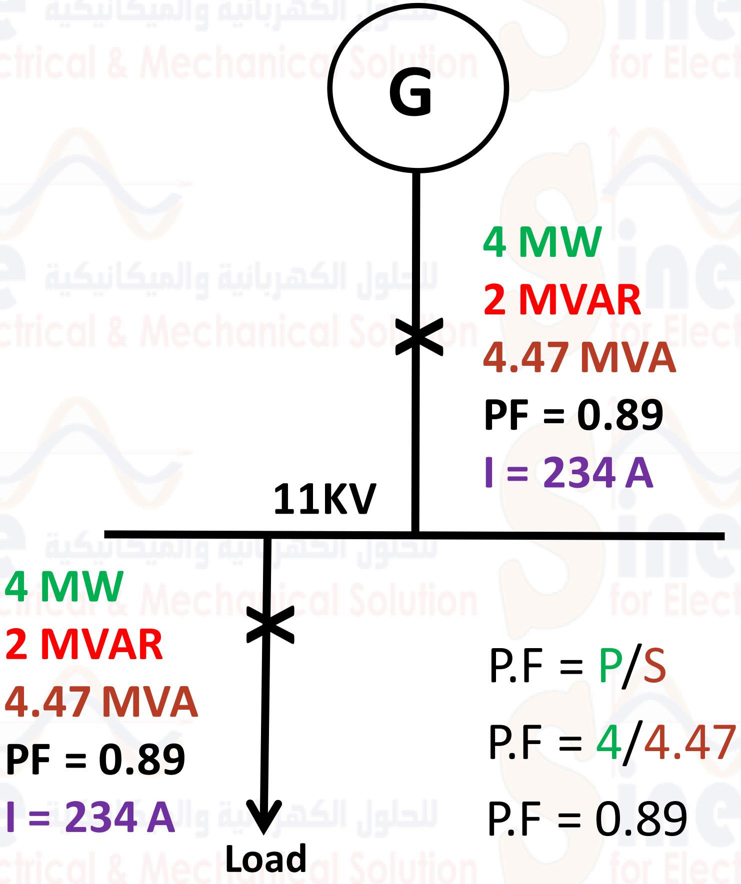
$$P.F = P/S$$

$$P.F = \cos \varnothing$$

The Effect Of Adding Capacitors



Current And Power Factor Calculations



$P.F = P/S$

$P.F = 4/4.47$

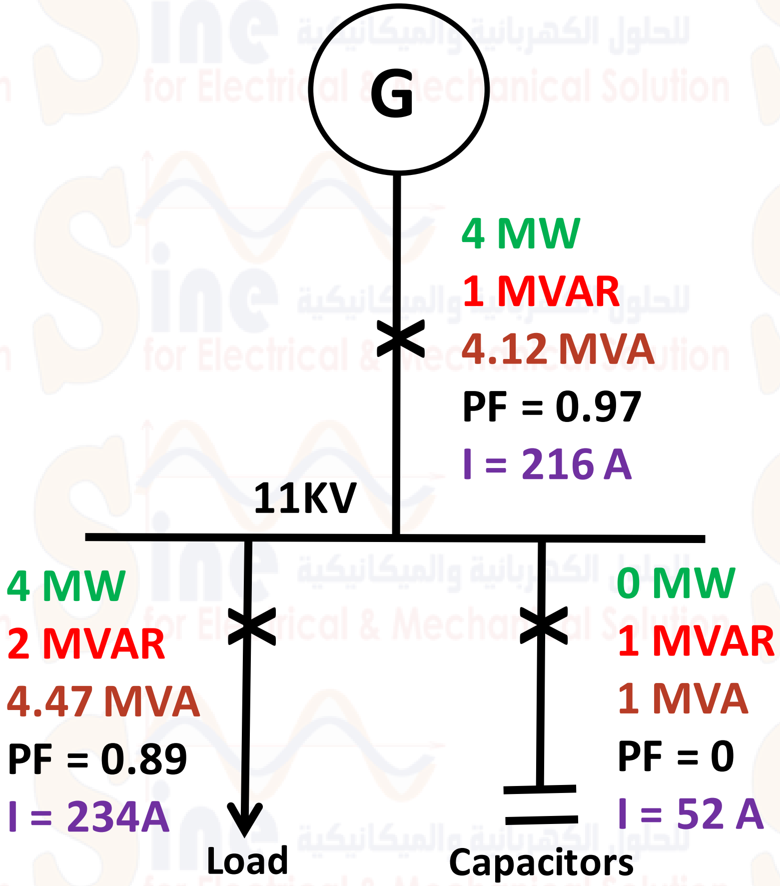
$P.F = 0.89$

$S = \sqrt{3} * V_L * I_L$

$I_L = S/\sqrt{3} * V_L$

$I_L = 4.47 * 10^6/\sqrt{3} * 11 * 10^3$

$I_L =$ **234 A**



$Q = \sqrt{3} * V_L * I_L * \sin Ø$

$I_L = Q/\sqrt{3} * V_L * \sin Ø$

$I_L = 1 * 10^6/\sqrt{3} * 11 * 10^3 * \sin 100$

$I_L =$ **52 A**

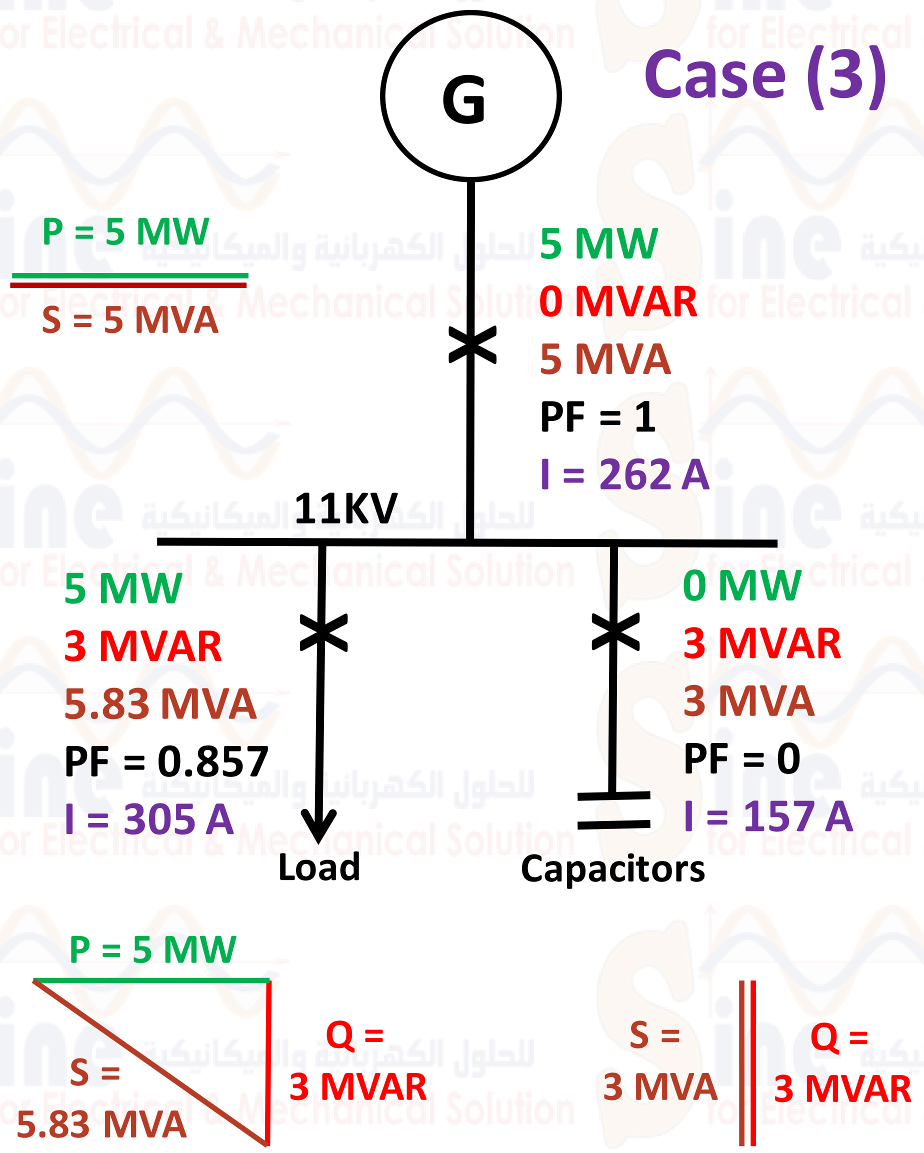
$S = \sqrt{3} * V_L * I_L$

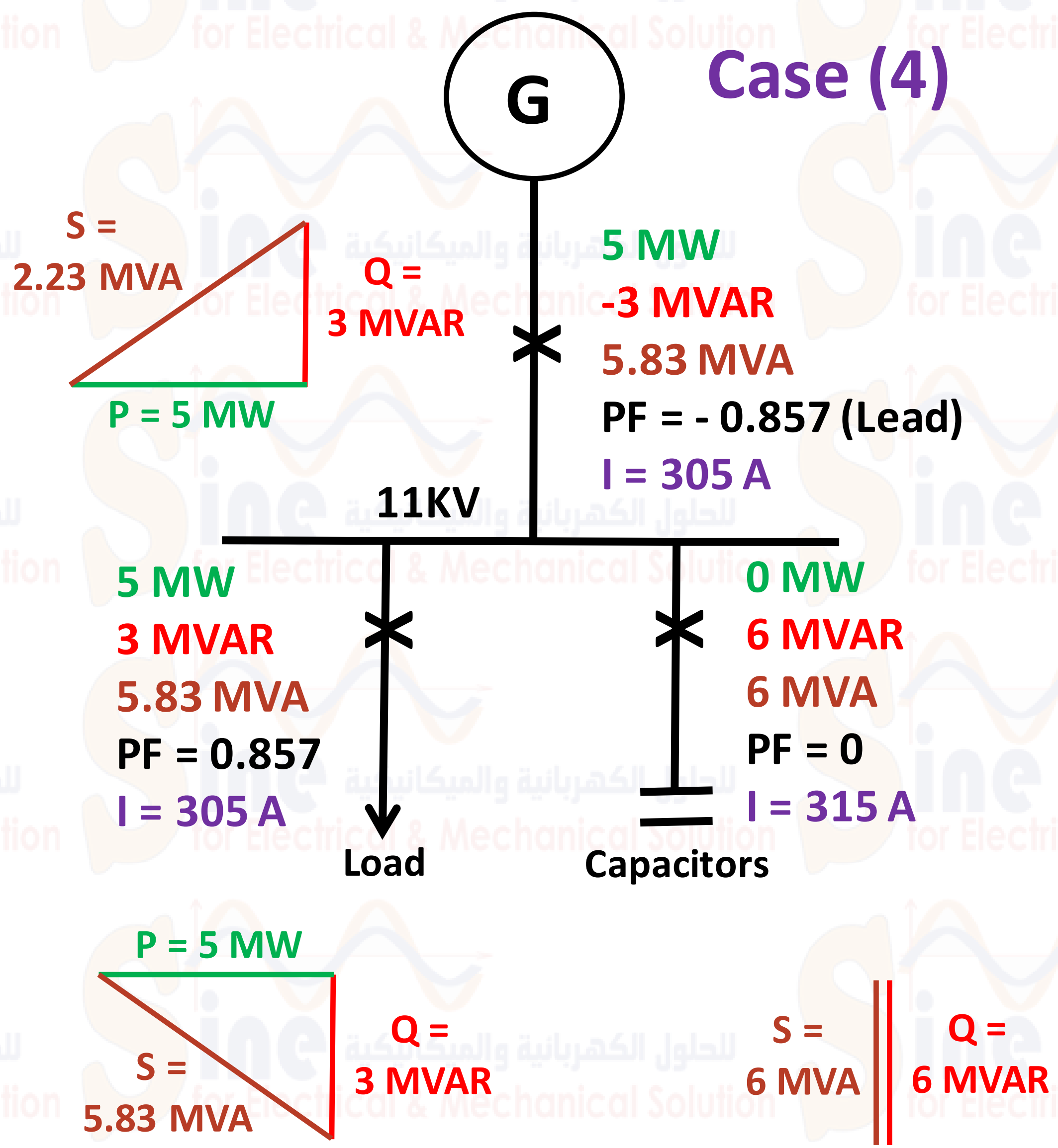
$I_L = S/\sqrt{3} * V_L$

$I_L = 1 * 10^6/\sqrt{3} * 11 * 10^3$

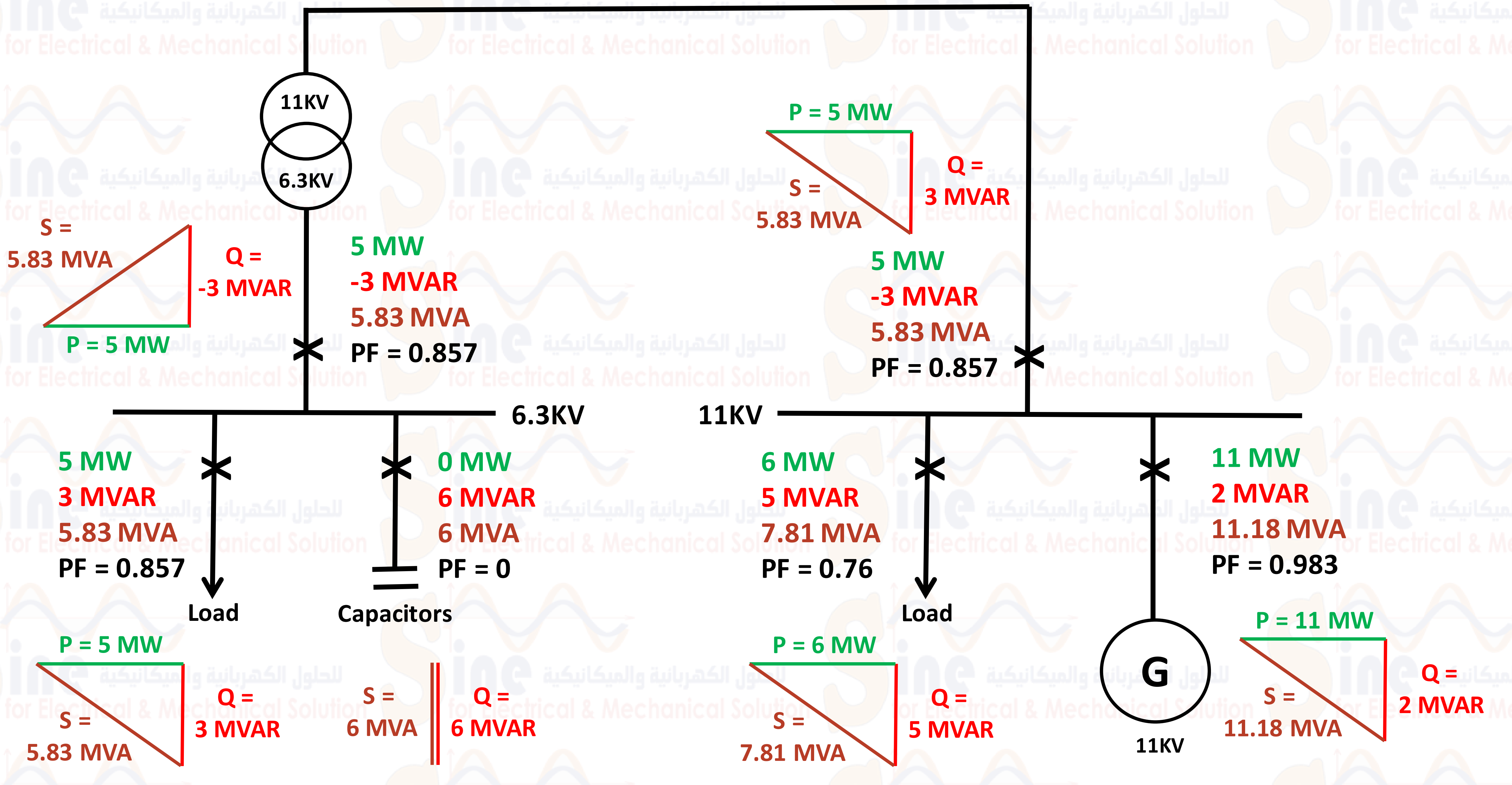
$I_L =$ **52 A**

The Effect Of Adding Capacitors More Than Load Requirement

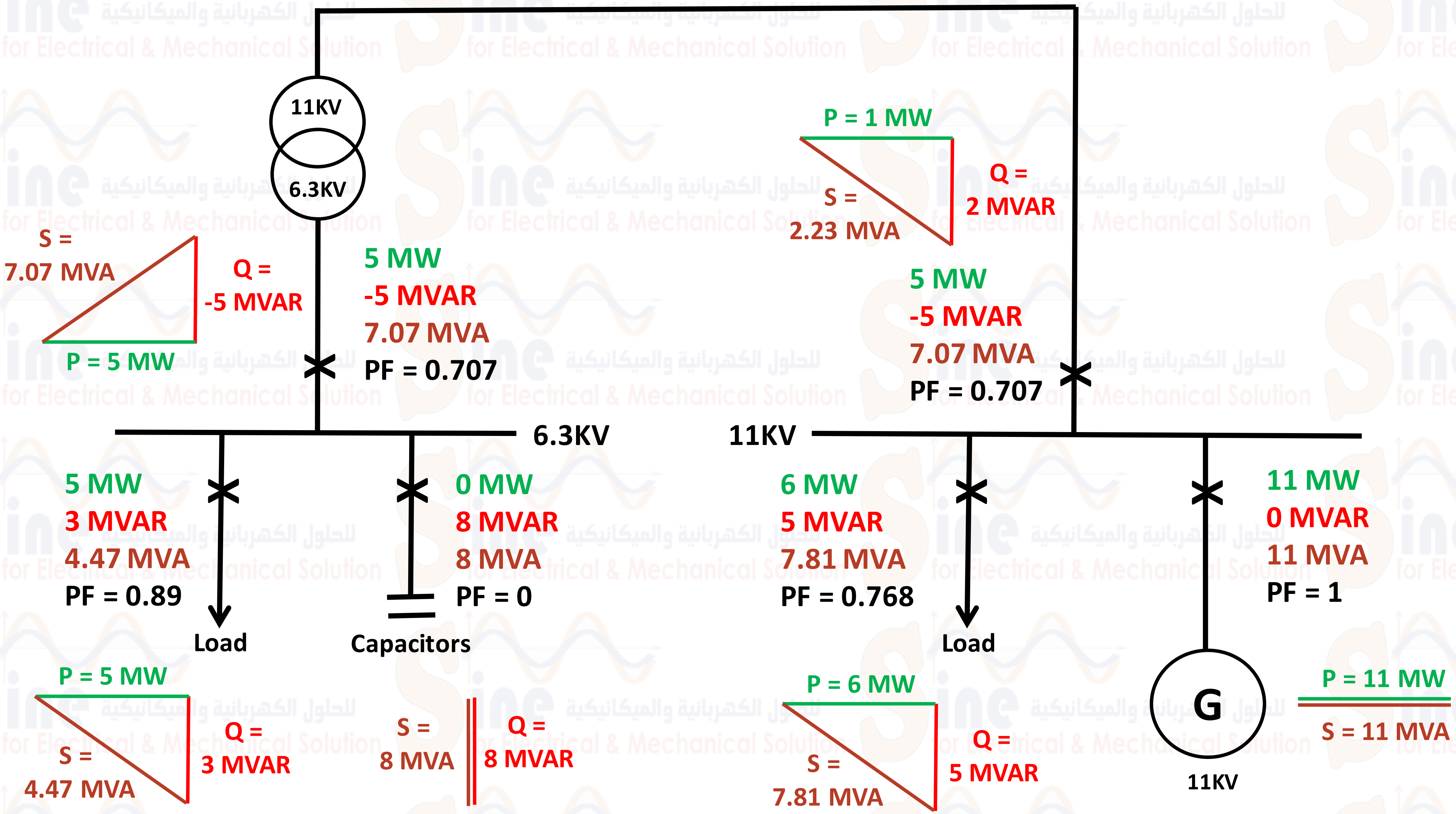




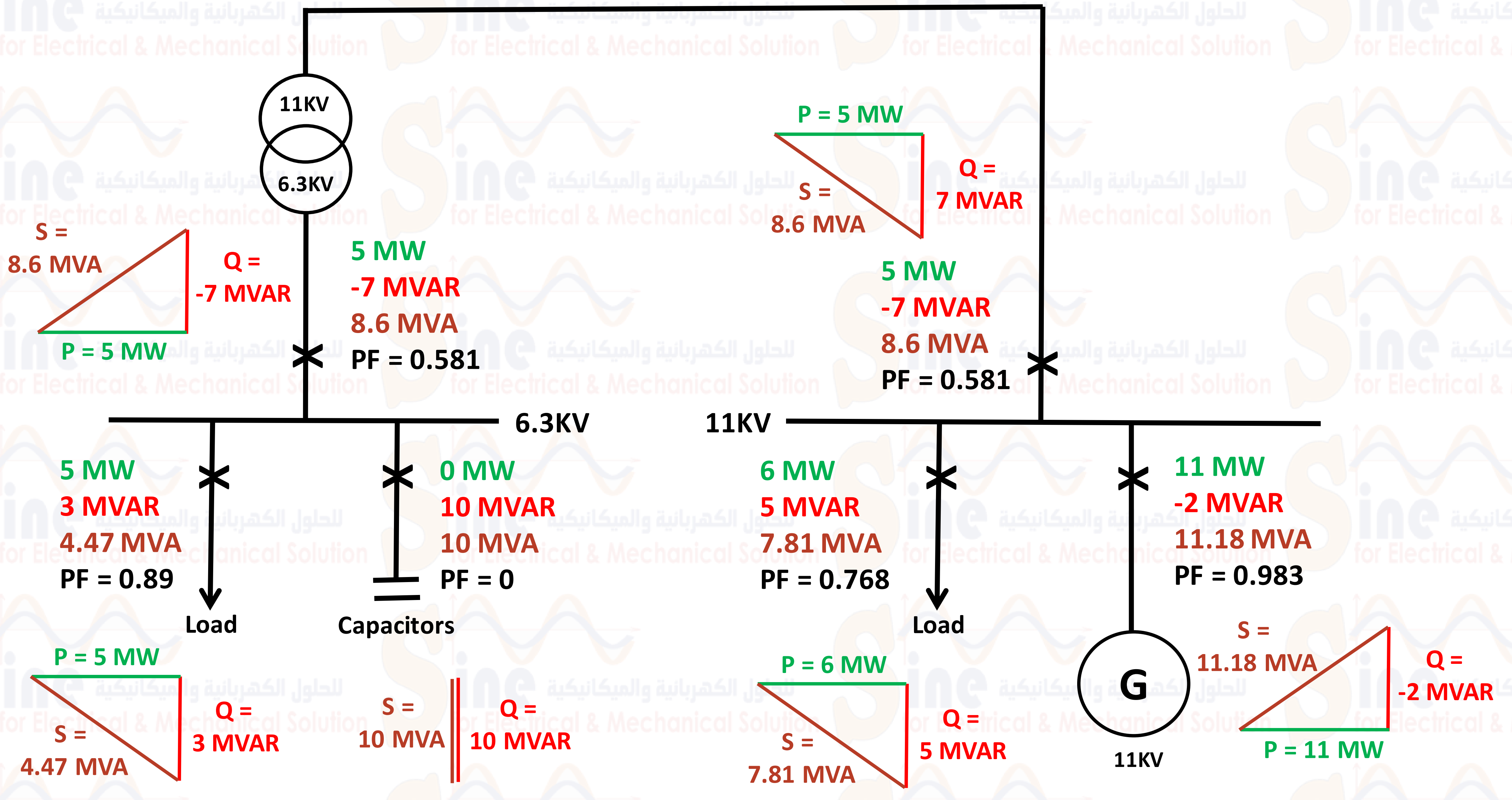
Reactive Power Flow Through The Grid



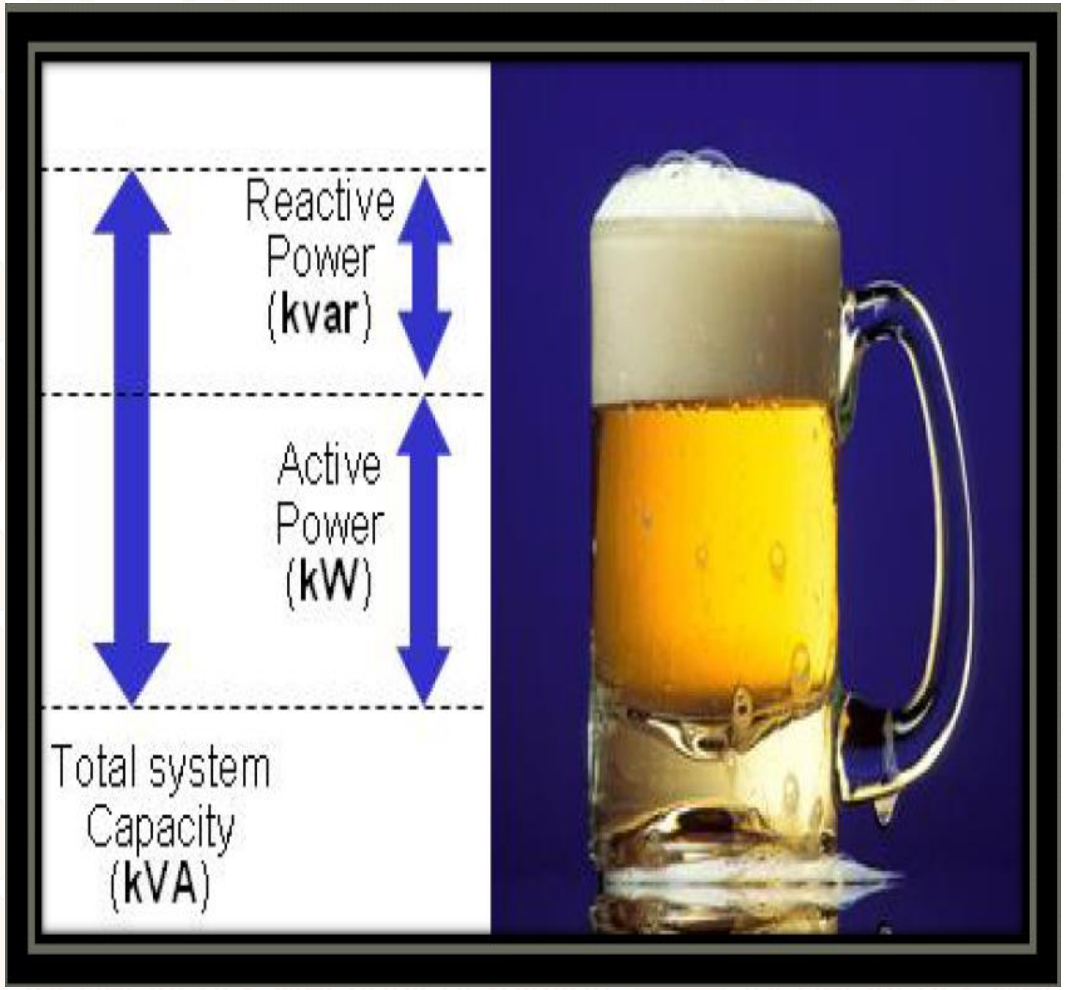
The Effect Of Adding Capacitors



The Effect Of Adding Capacitors

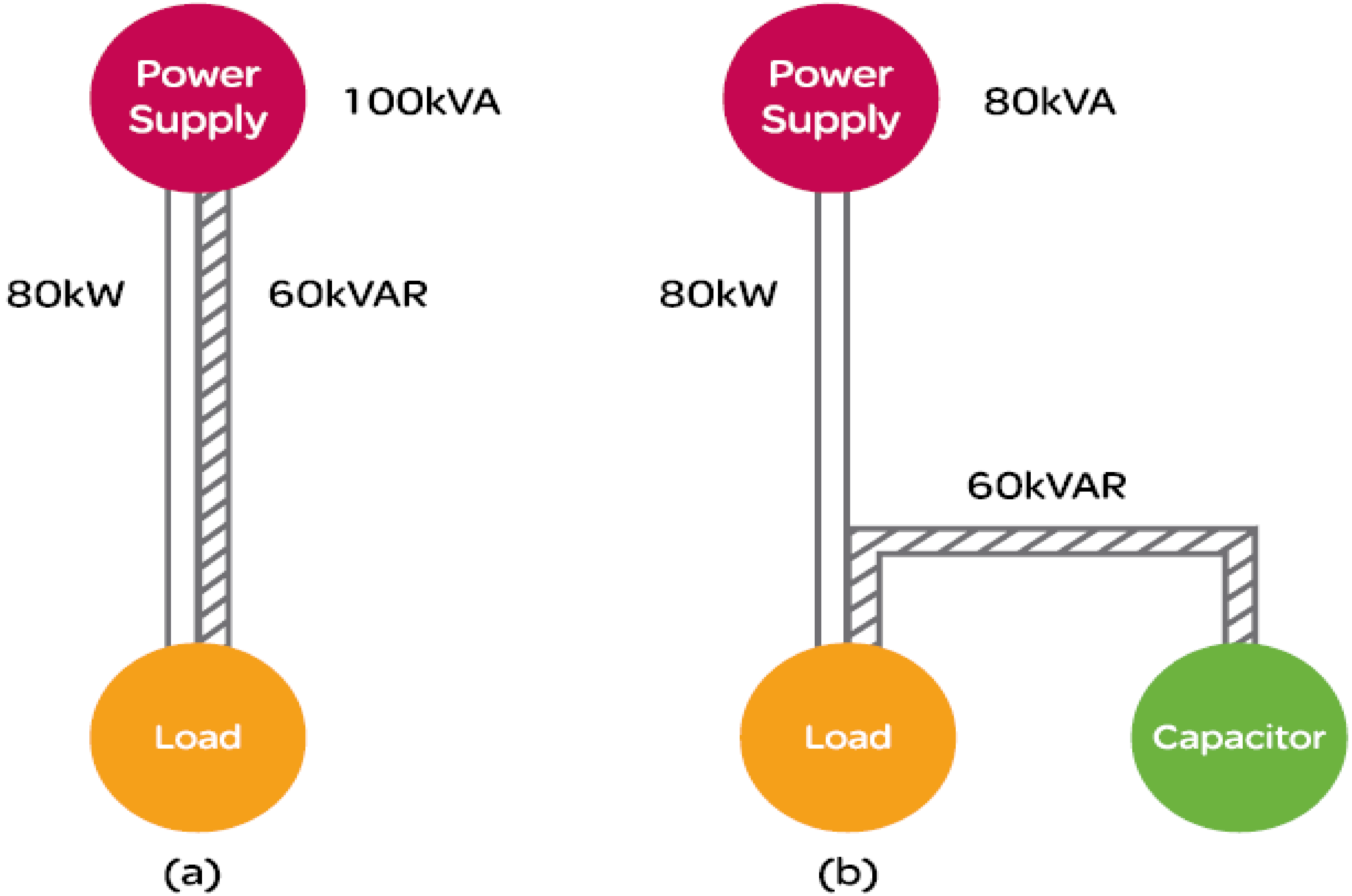


Power Factor Correction



- We can simulate the reactive power by the foam in a cup of SHAMPION .
- The foam fill the upper part of the cup and if we want to empty the whole flask we need a cup larger than this cup .
- So the increase of KVAR increases the total system capacity KVA .

Power Factor Correction



Power Factor Correction

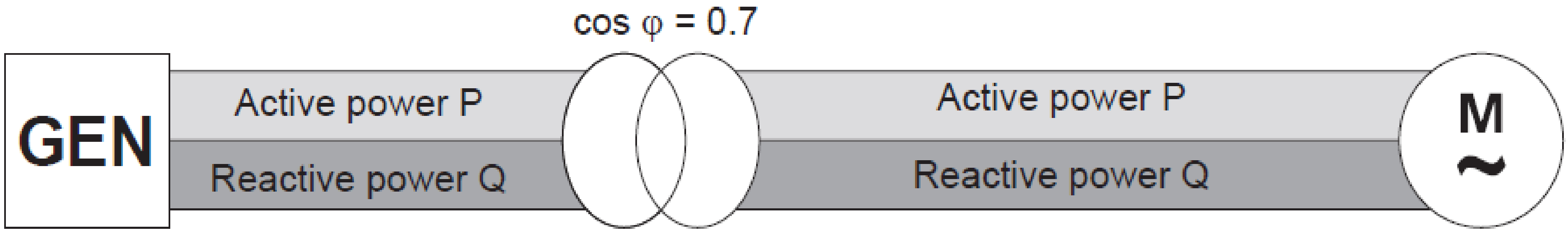
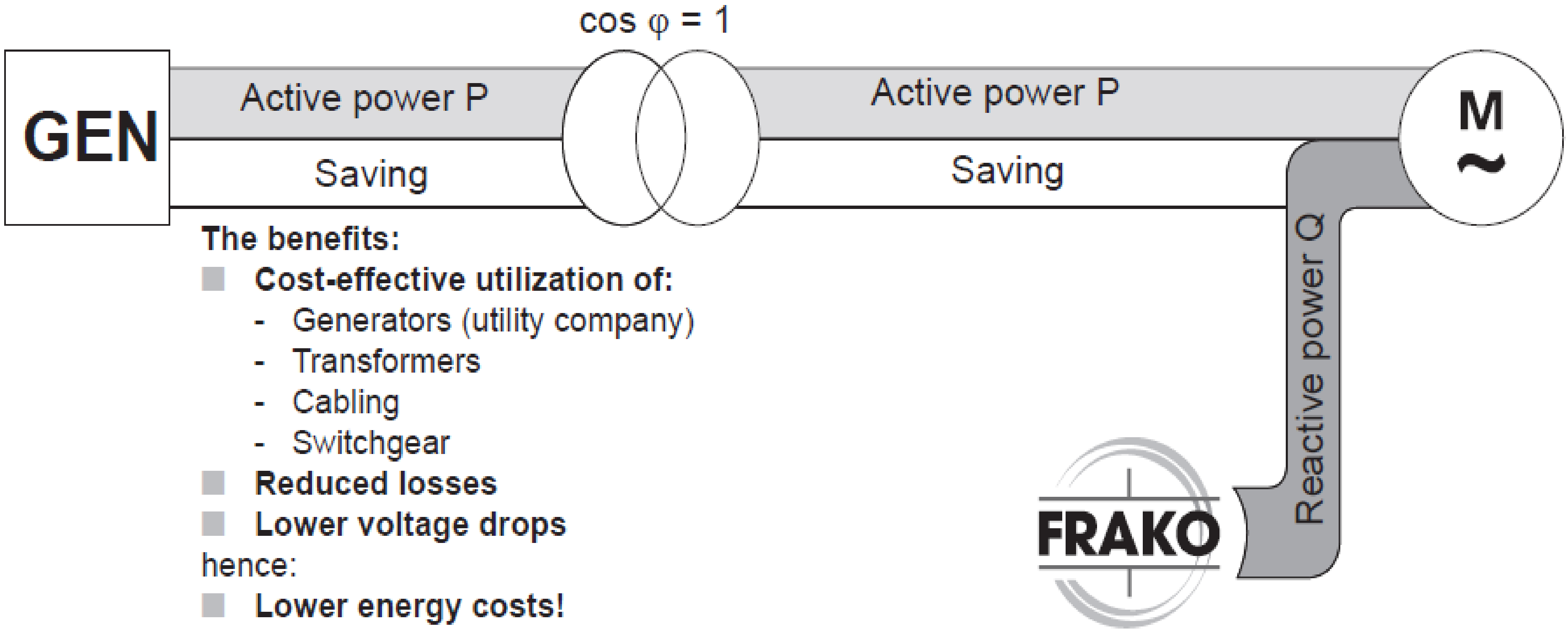


Fig. 6 Active and reactive power in the power distribution system: without PFC



The benefits:

- **Cost-effective utilization of:**
  - Generators (utility company)
  - Transformers
  - Cabling
  - Switchgear
- **Reduced losses**
- **Lower voltage drops**

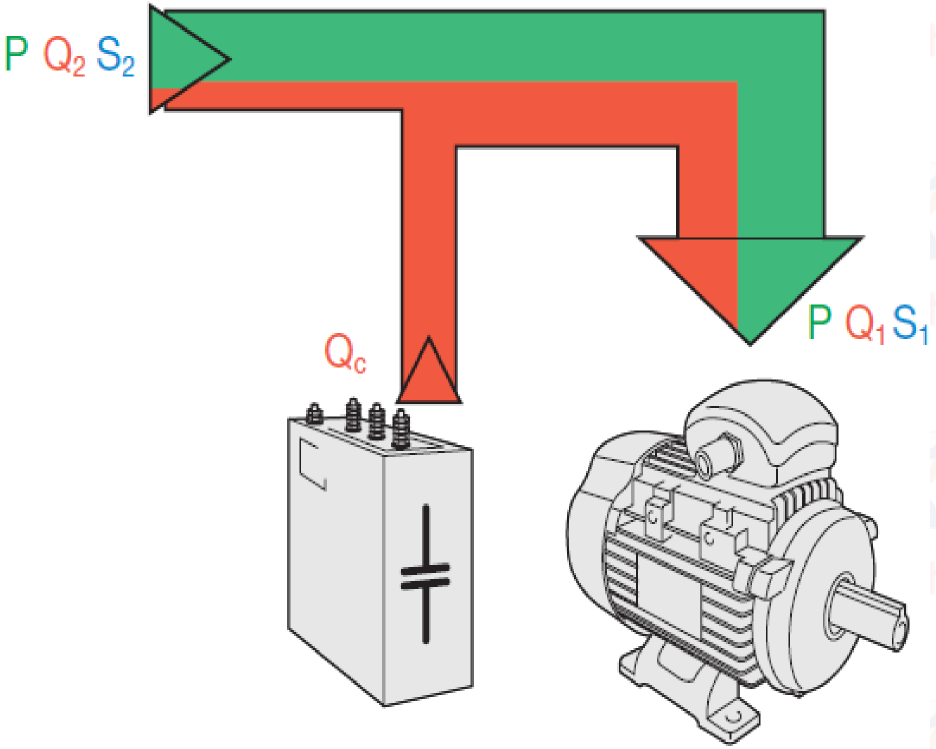
hence:

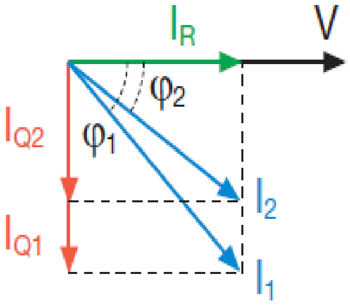
- **Lower energy costs!**

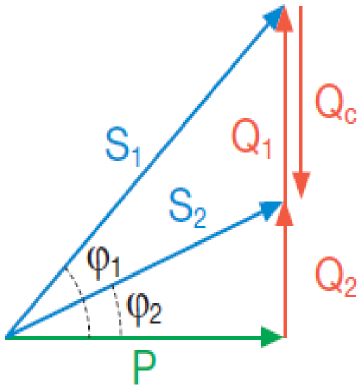
Power Factor Correction

where:

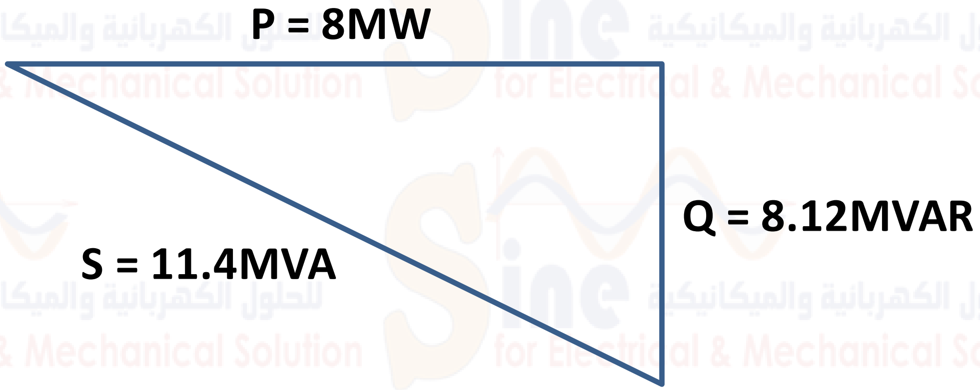
- P is the active power;
- Q_1, φ_1 are the reactive power and the phase displacement angle before power factor correction;
- Q_2, φ_2 are the reactive power and the phase displacement angle after power factor correction;
- Q_c is the reactive power for power factor correction.



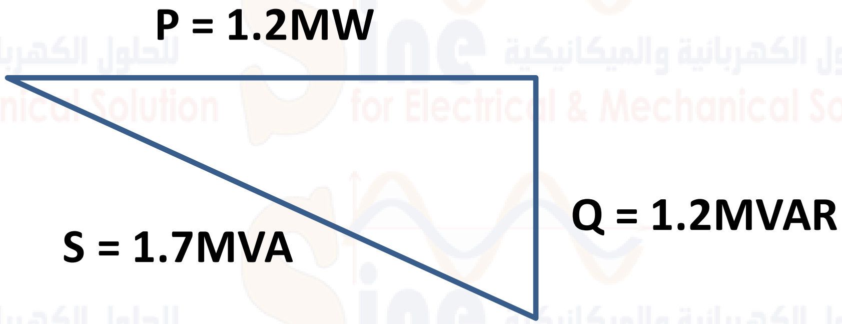




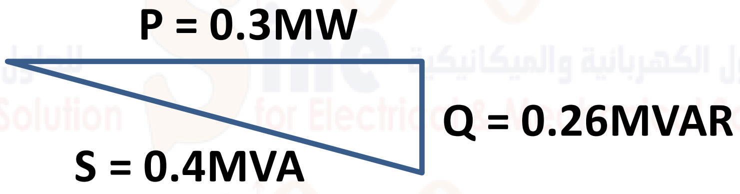
Same PF With Different MVAR Value



PF = P/S
= 8MW/11.4MVA
= 0.7



PF = P/S
= 1.2MW/1.7MVA
= 0.7



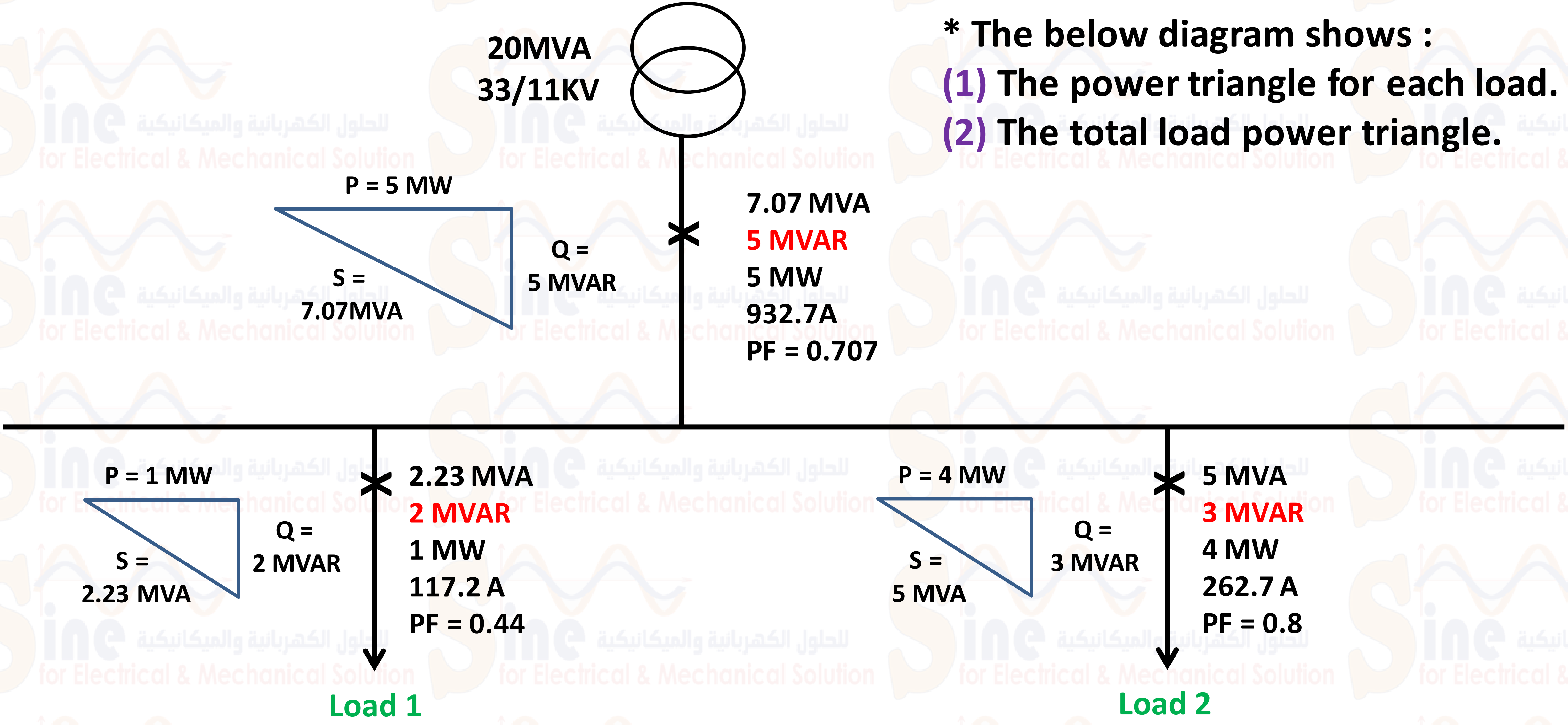
PF = P/S
= 0.3MW/0.4MVA
= 0.7

Electrical Power Triangle

* The below diagram shows :

(1) The power triangle for each load.

(2) The total load power triangle.



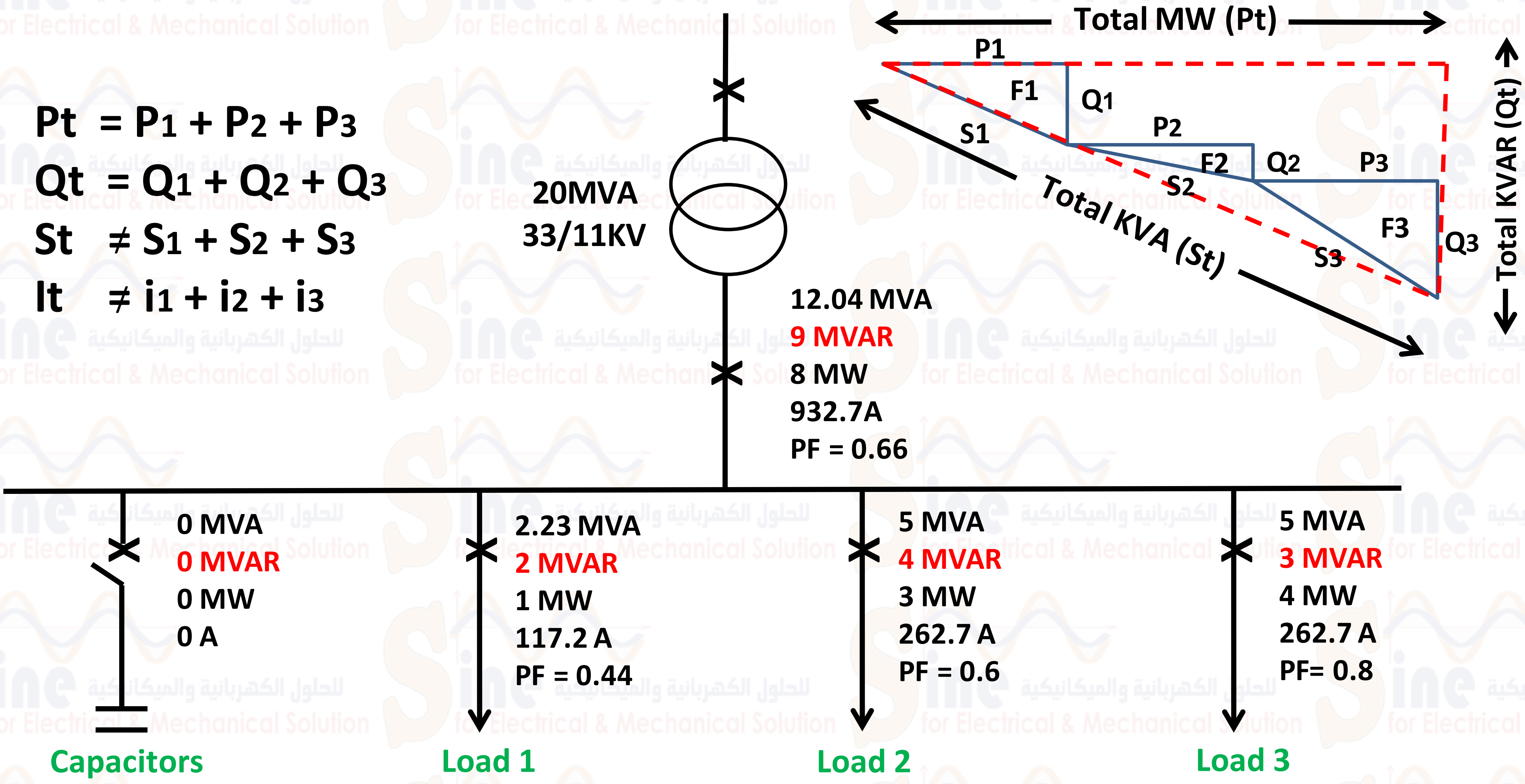
Three Phase Power Summation

$$Pt = P_1 + P_2 + P_3$$

$$Qt = Q_1 + Q_2 + Q_3$$

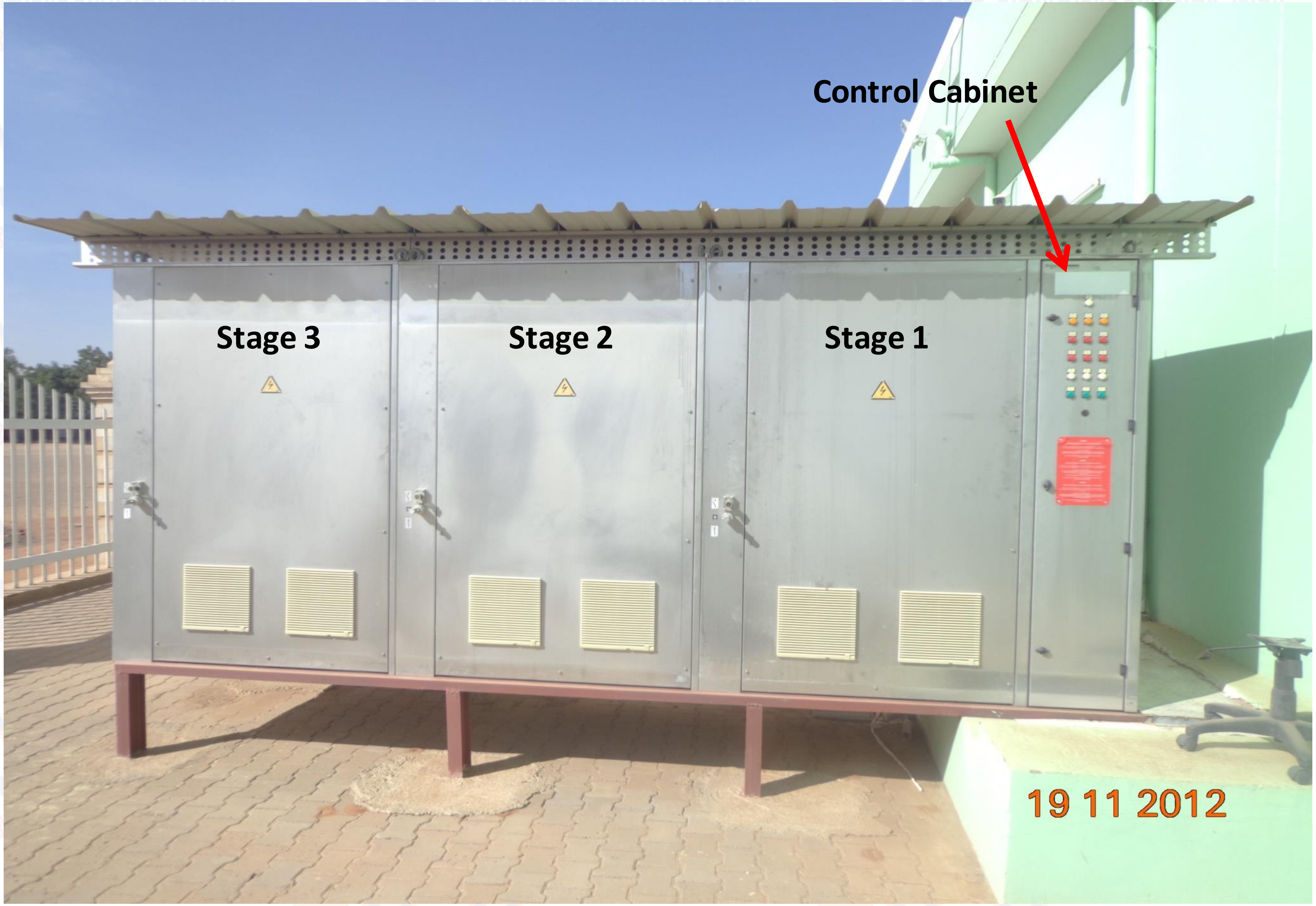
$$St \neq S_1 + S_2 + S_3$$

$$It \neq i_1 + i_2 + i_3$$

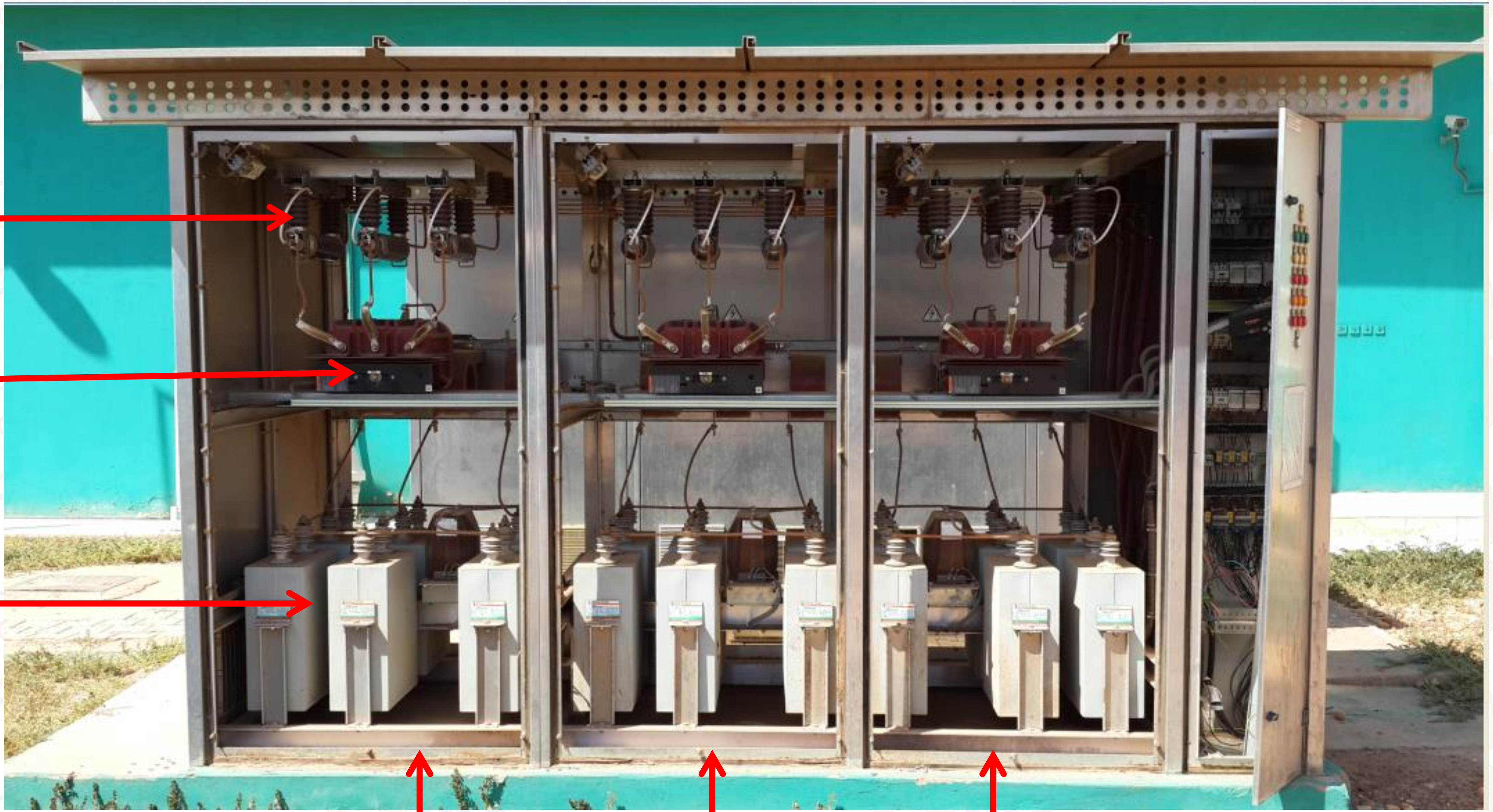


Medium Voltage Capacitor Bank (11KV)

Power Factor Correction



4500KVAR/11KV Capacitor Bank

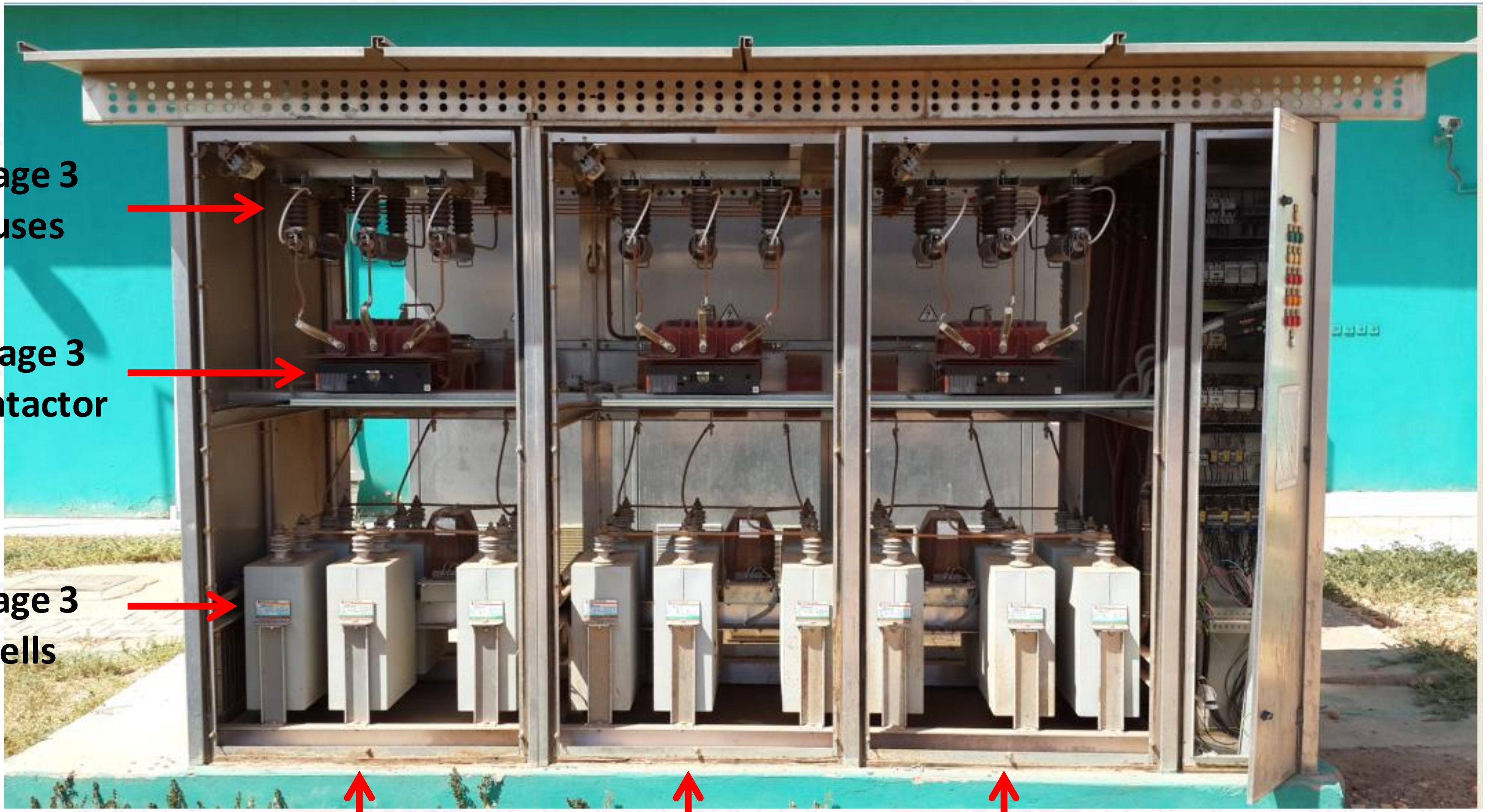


4500KVAR/11KV Capacitor Bank

Stage 3
Fuses

Stage 3
Contactor

Stage 3
Cells



Stage 3

Stage 2

Stage 1

Power Factor Correction Controller

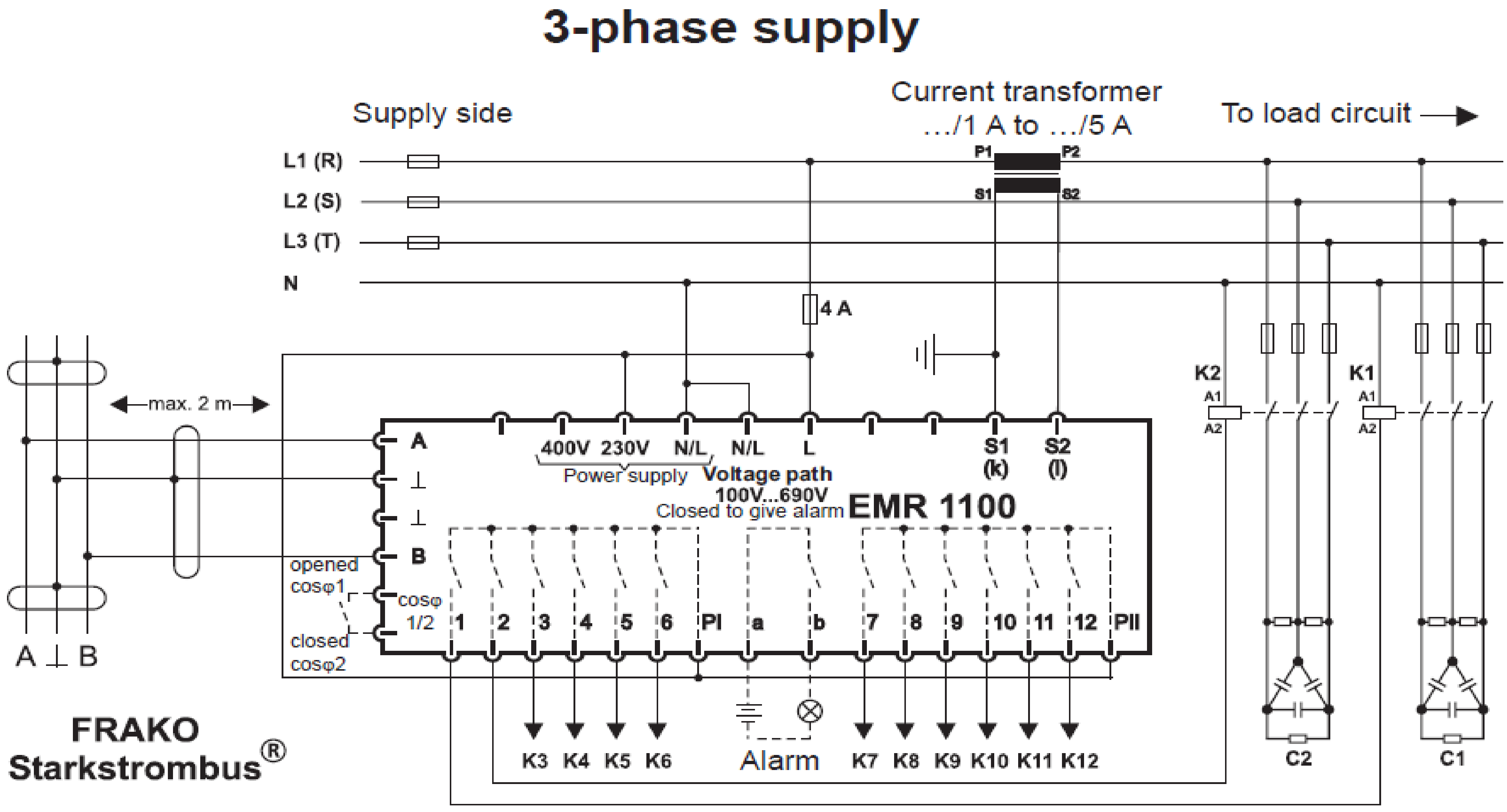
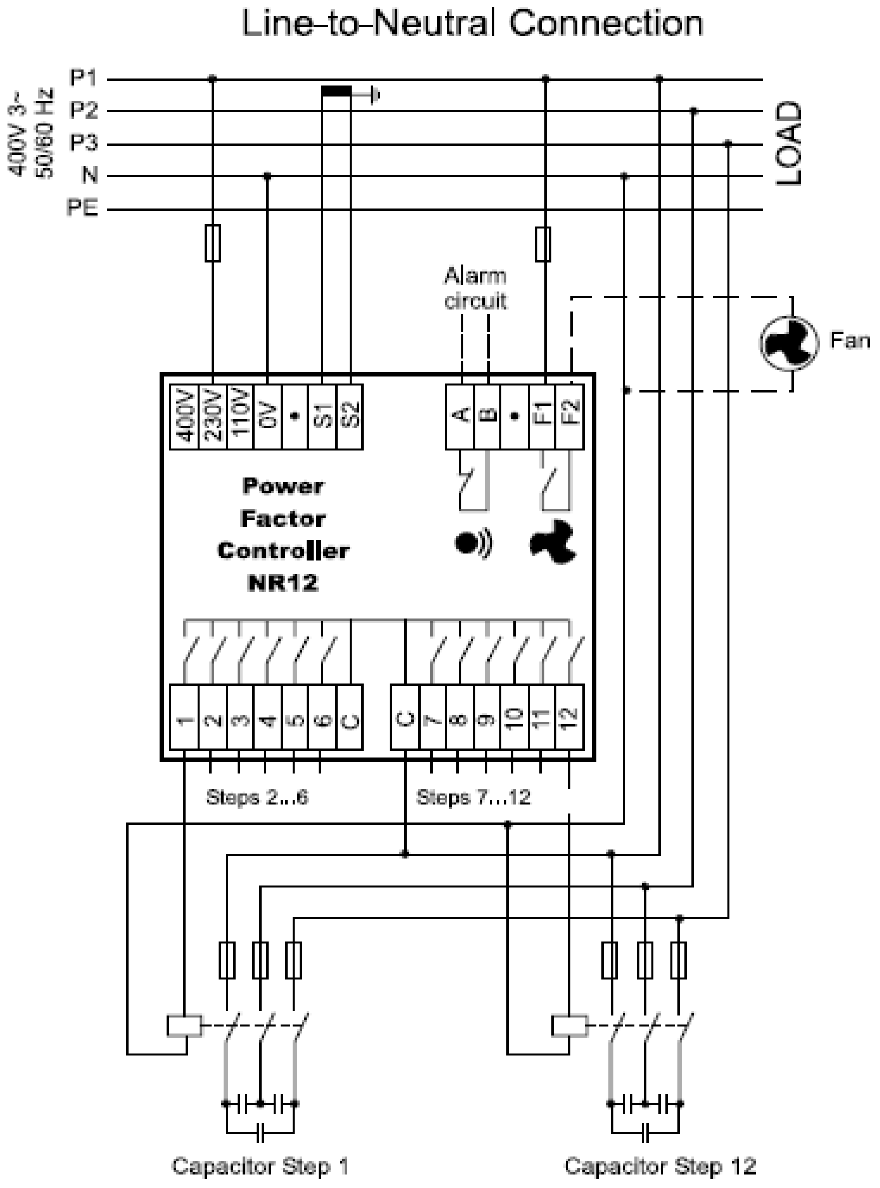
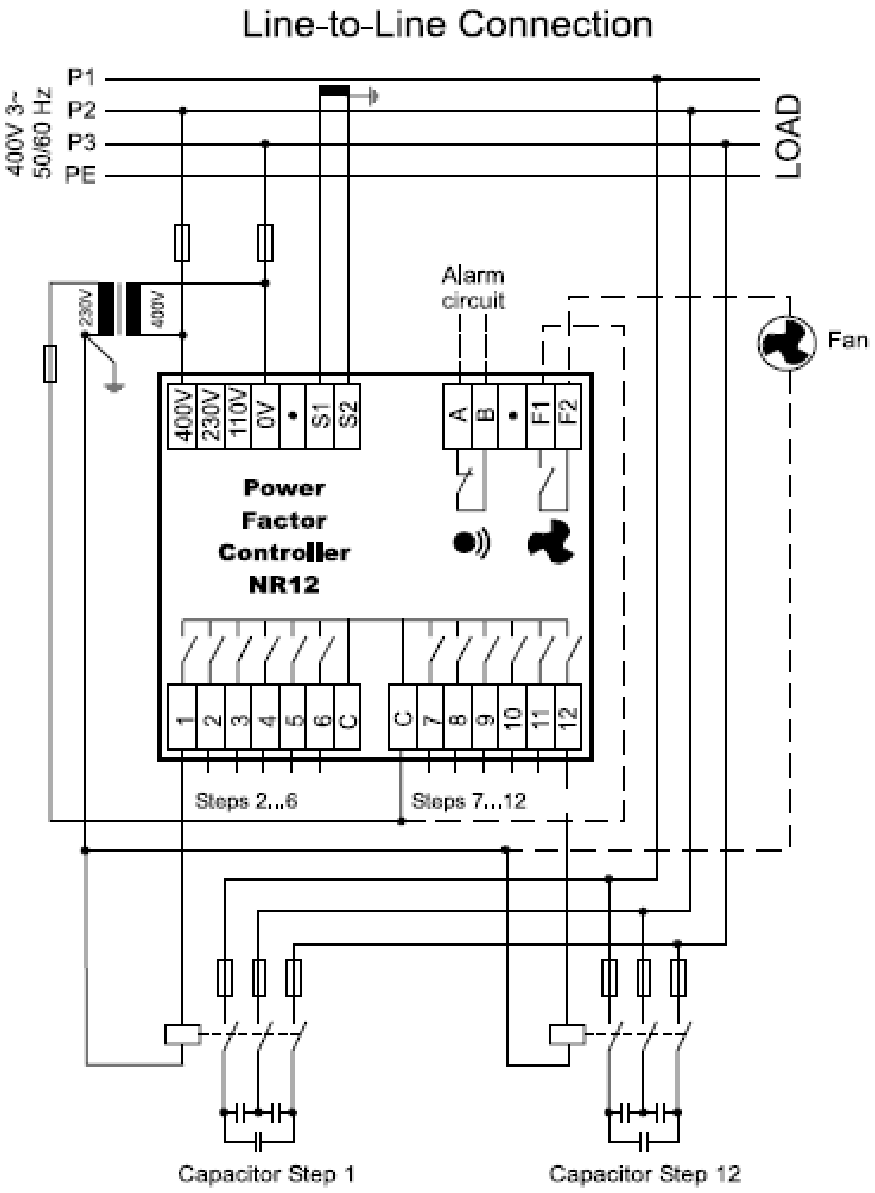


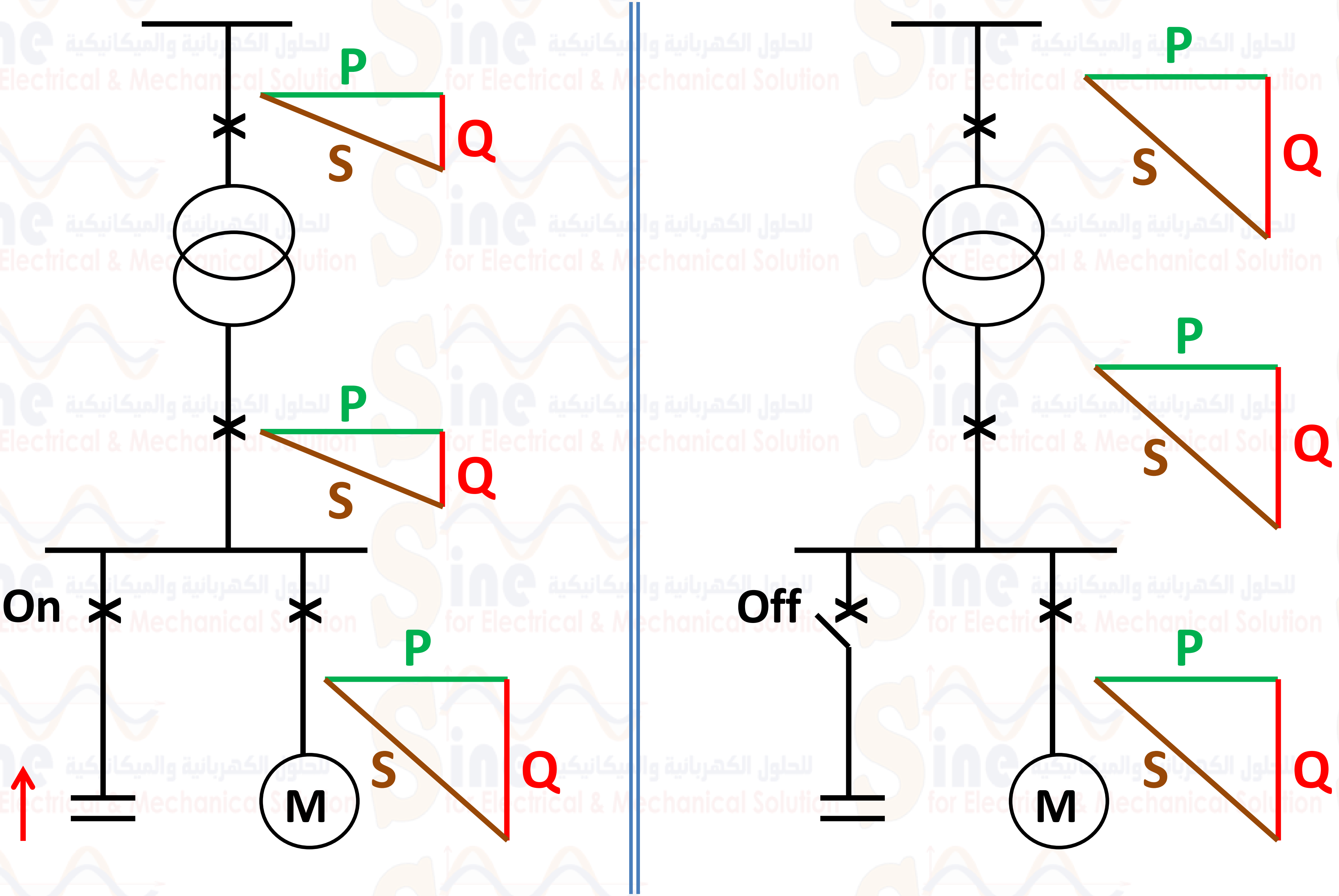
Fig. 22 Typical PFC system circuit

Power Factor Correction





Power Factor Correction-Basic Concept



Power Factor Correction

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<tr><th>RIGHT CONNECTION</th><th colspan="2">WRONG CONNECTIONS</th></tr>
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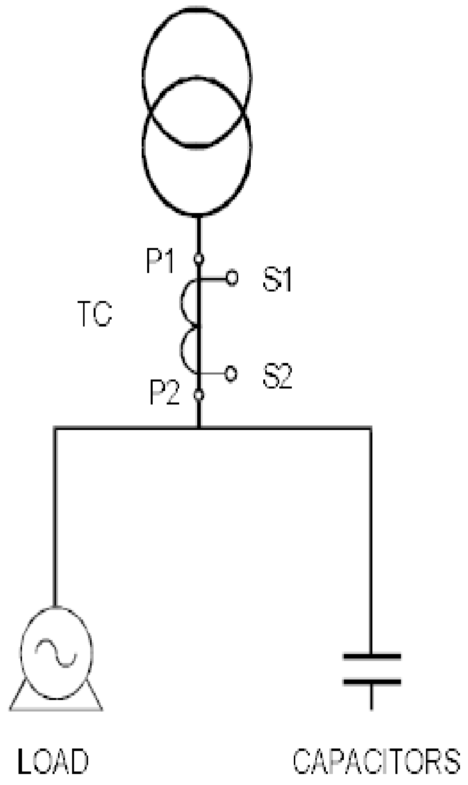
<td>
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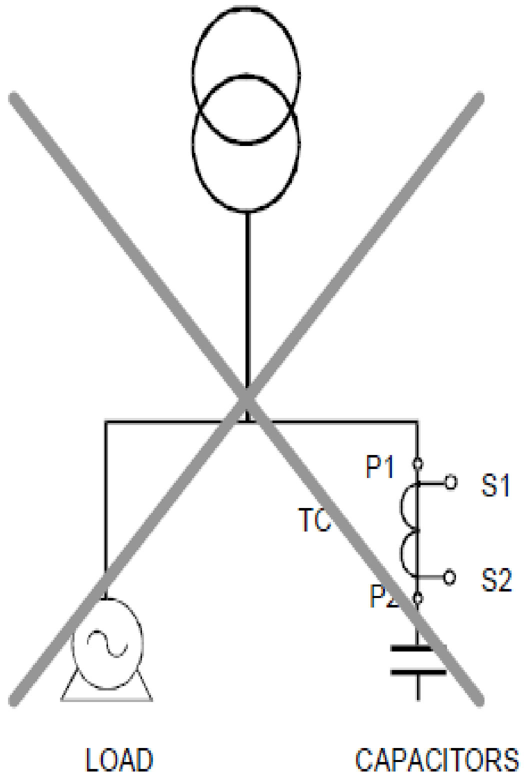
<td>
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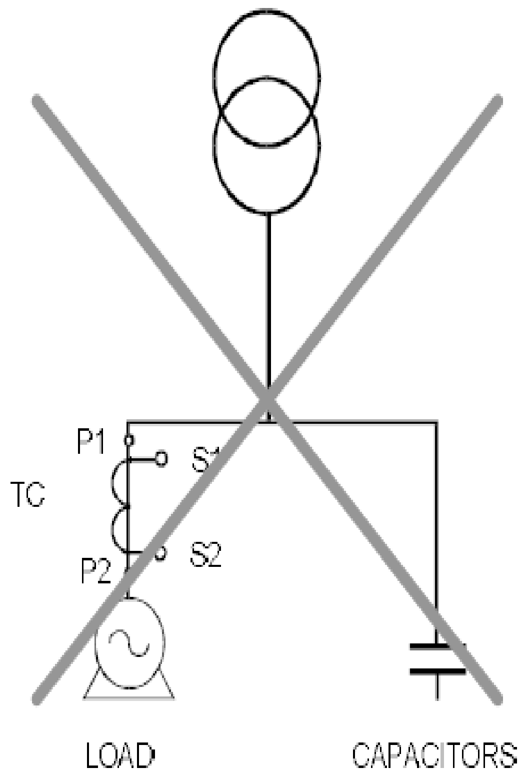
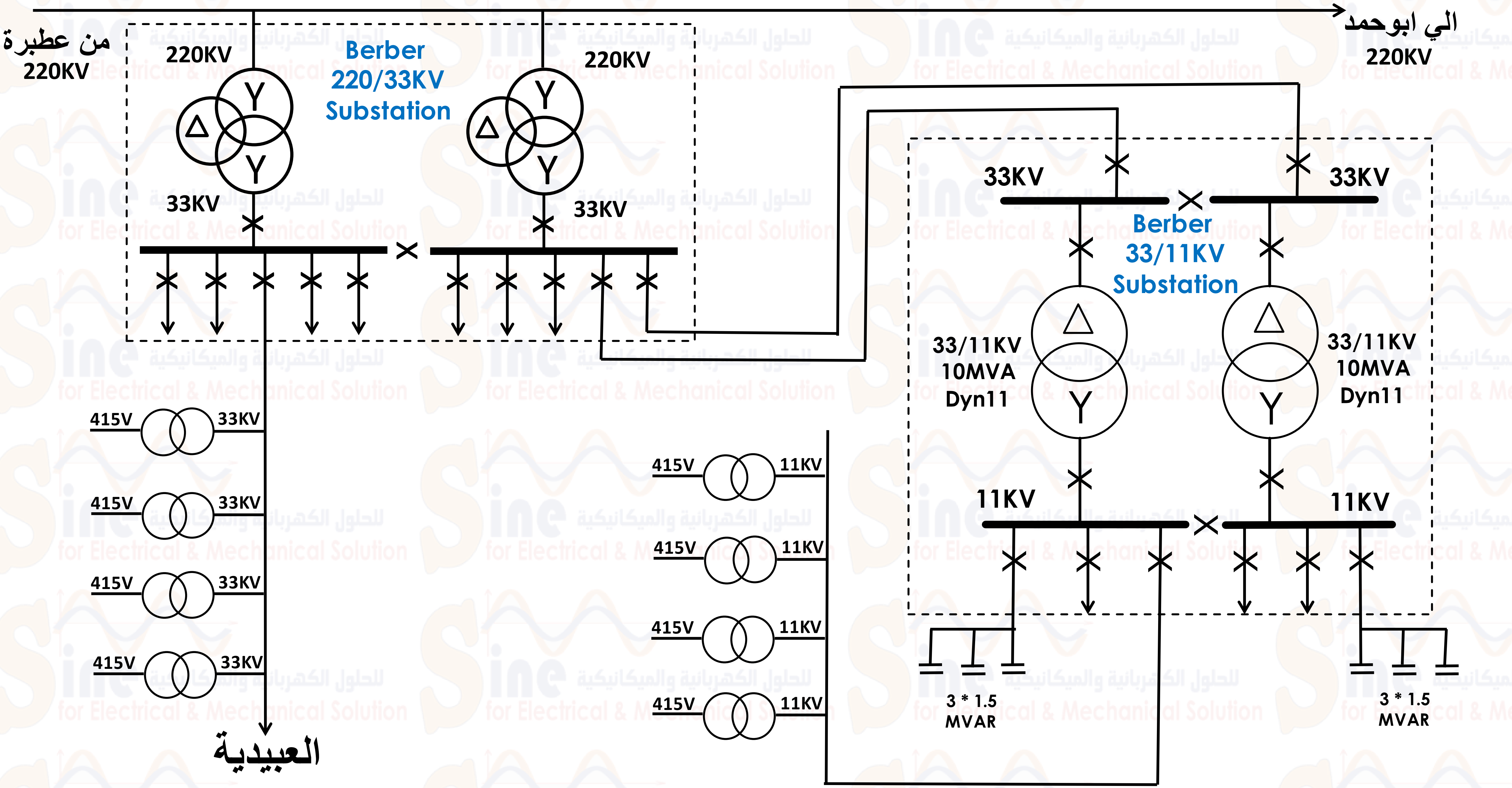
<td>
</td>
</tr>
<tr>
<td>The CT measures the whole current of loads + capacitor bank. In case of malfunction check that the CT is not shortcircuited</td>
<td>If CT is placed in this position, NONE of the CAPACITOR STAGES WILL CONNECT.
The equipment does not regulate properly.</td>
<td>If CT is placed in this position ALL THE CAPACITOR STAGES WILL CONNECT.
WARNING! This situation may cause overcompensation, resonance and overcurrent</td>
</tr>
</table>

Berber Area Grid



Low Power Factor Penalty (Sudan Practice)

PF = 1

لا توجد غرامه

PF = 0.95

4 جنيه لكل كيلوفار

PF = 0.90

5 جنيه لكل كيلوفار

PF = 0.85

8 جنيه لكل كيلوفار

PF = 0.80

10 جنيه كيلوفار

How to Convert From VAR to Farad

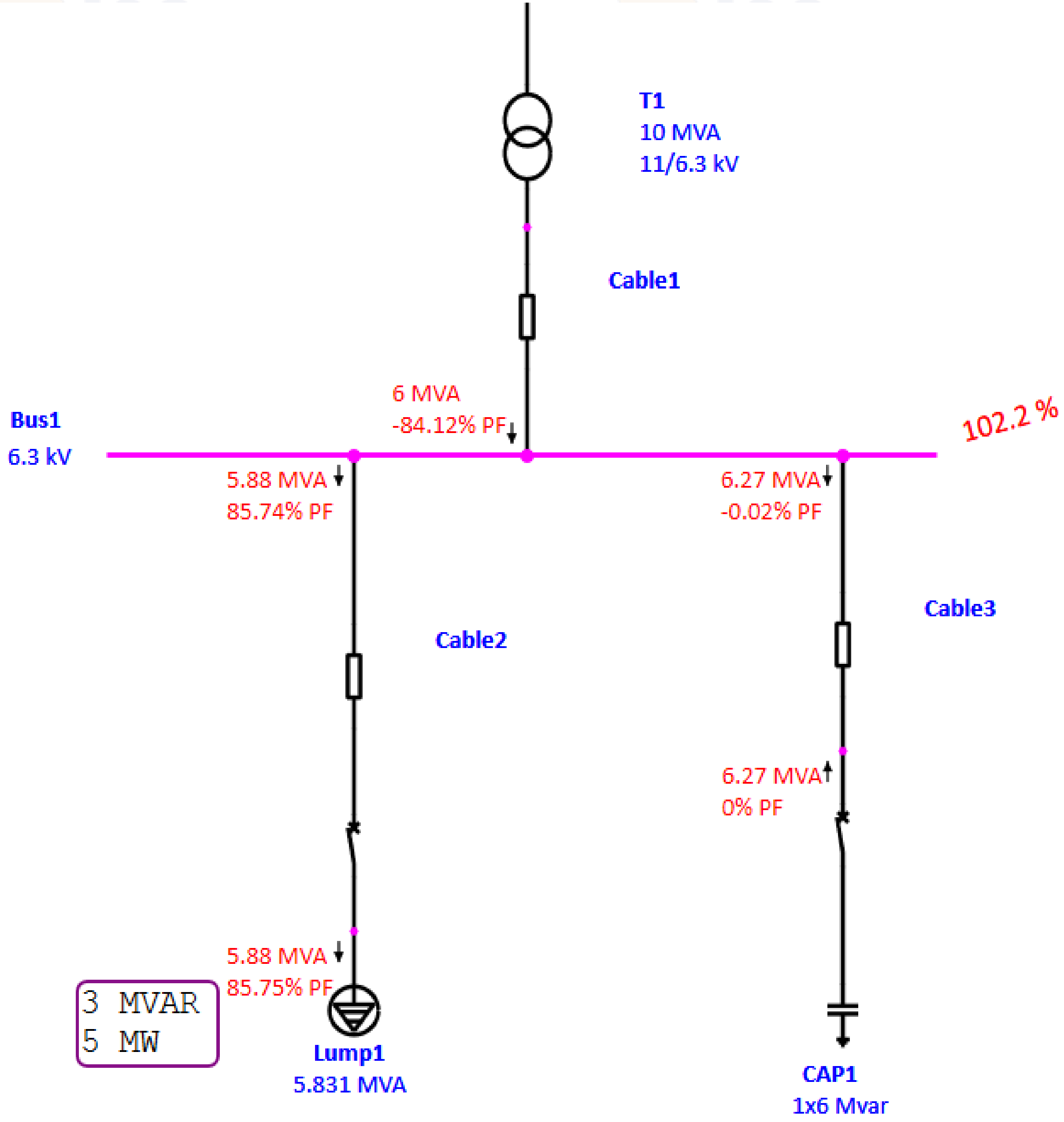
- The important formula that connect between VAR and CAPACITANCE is :

$$VAR = 2 * \pi * f * C * V^2$$

- **V** is the voltage applied to the terminal of the capacitor cell and it is written on the nameplate.
- On the next slide is a name plate and you find that :

$$250*10^3 = 2*\pi*50*20.084*10^{-6}*6432^2$$

Reactive Power Flow Through The Grid



$$S = \sqrt{(P^2 + Q^2)}$$

$$S = \sqrt{(5.05^2 + 3.24^2)}$$

$$S = 6 \text{ MVA}$$

$$P.F = 5.04/5.689$$

$$P.F = -\ 0.8416 \text{ (Lead)}$$