LV – PFC Basics

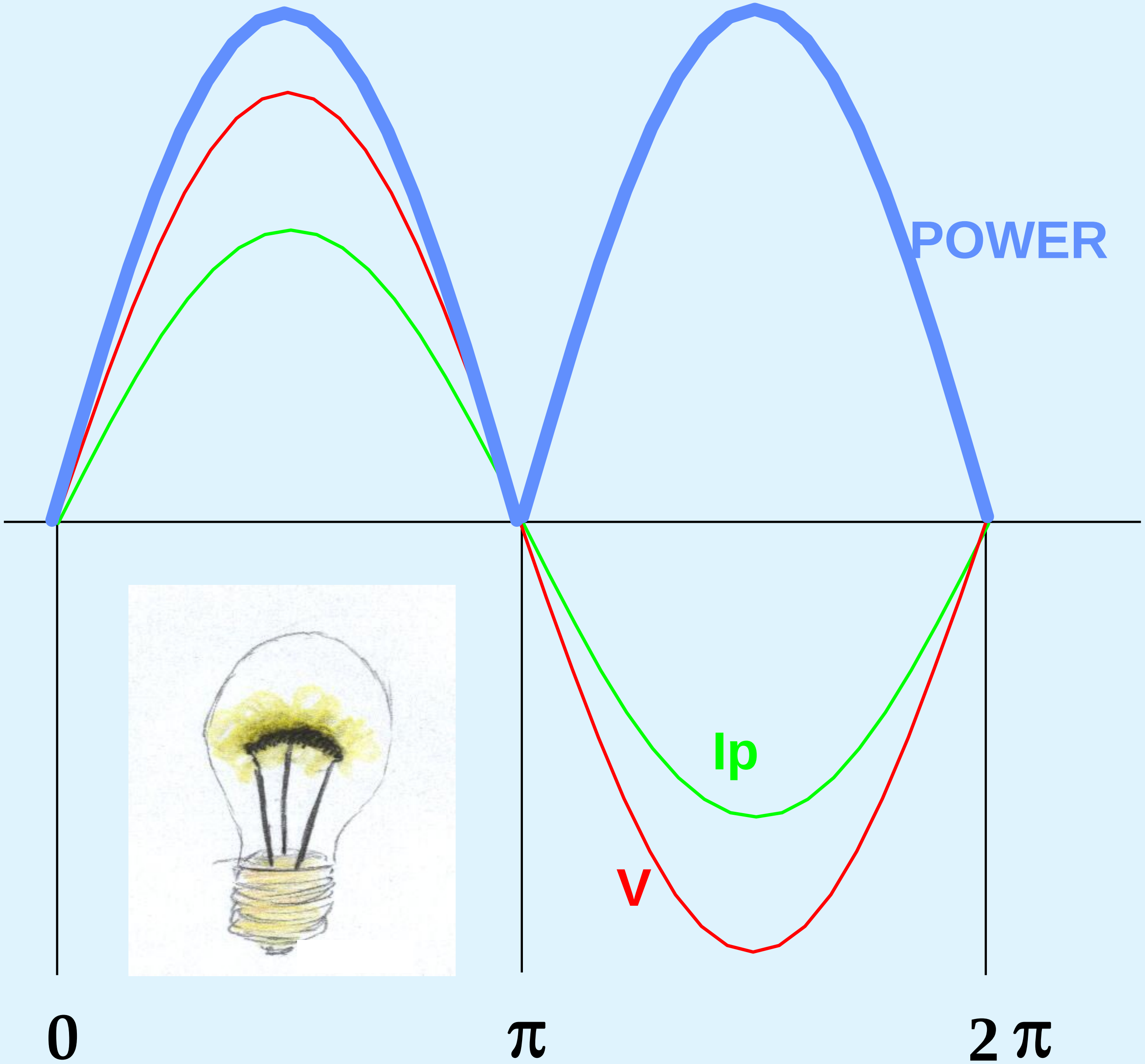
What are the different types of loads?

Ohmic loads
Lighting bulbs
Iron
Resistive heating

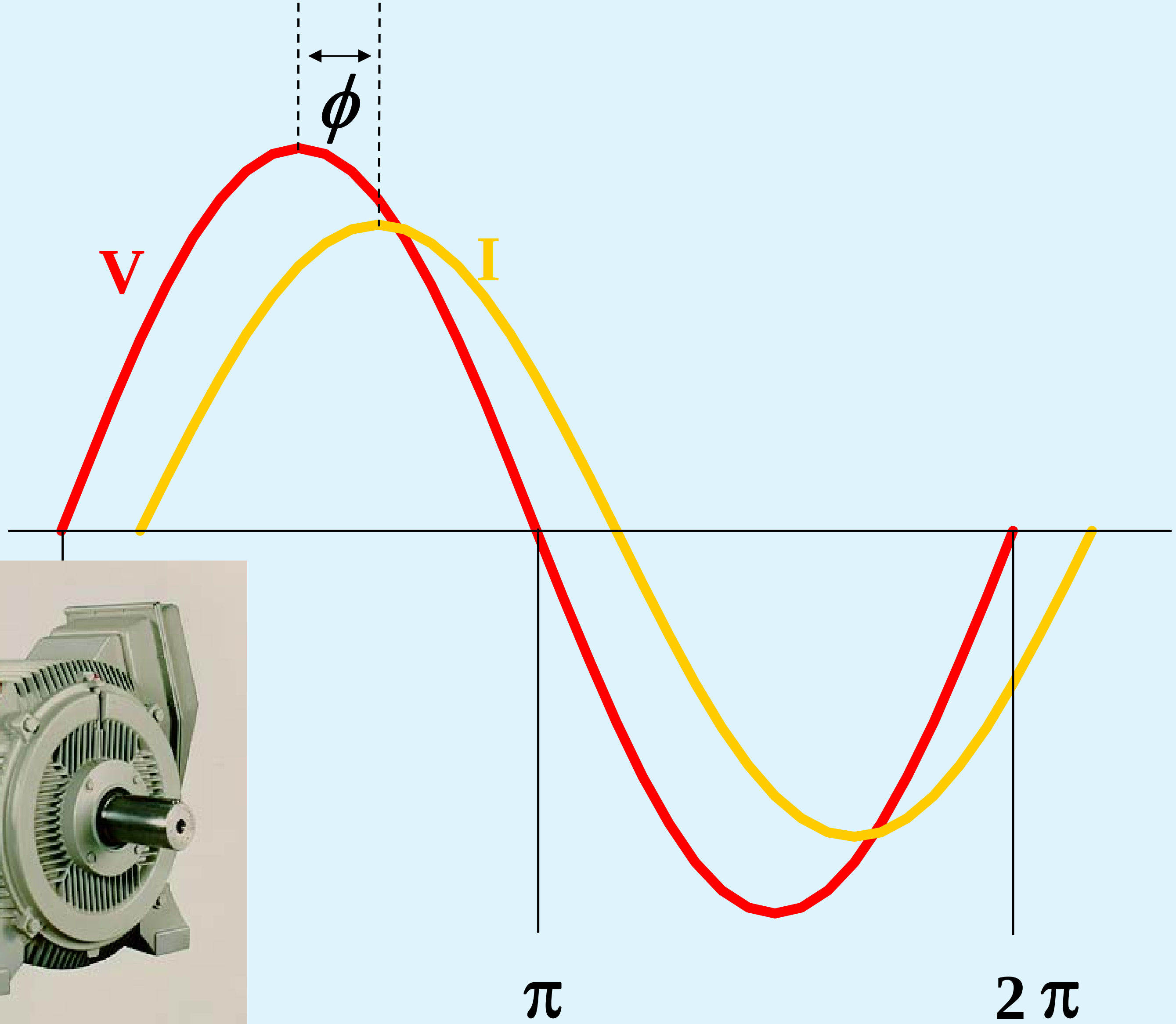
Capacative loads
Capacitors
Underground **cables**
Over **excited** synchronous generators

Inductive loads
Electrical Motors
Transformers
Reactors/chokes
Overhead lines
Under excited Synchronous generators
Discharge lamps
Power electronic

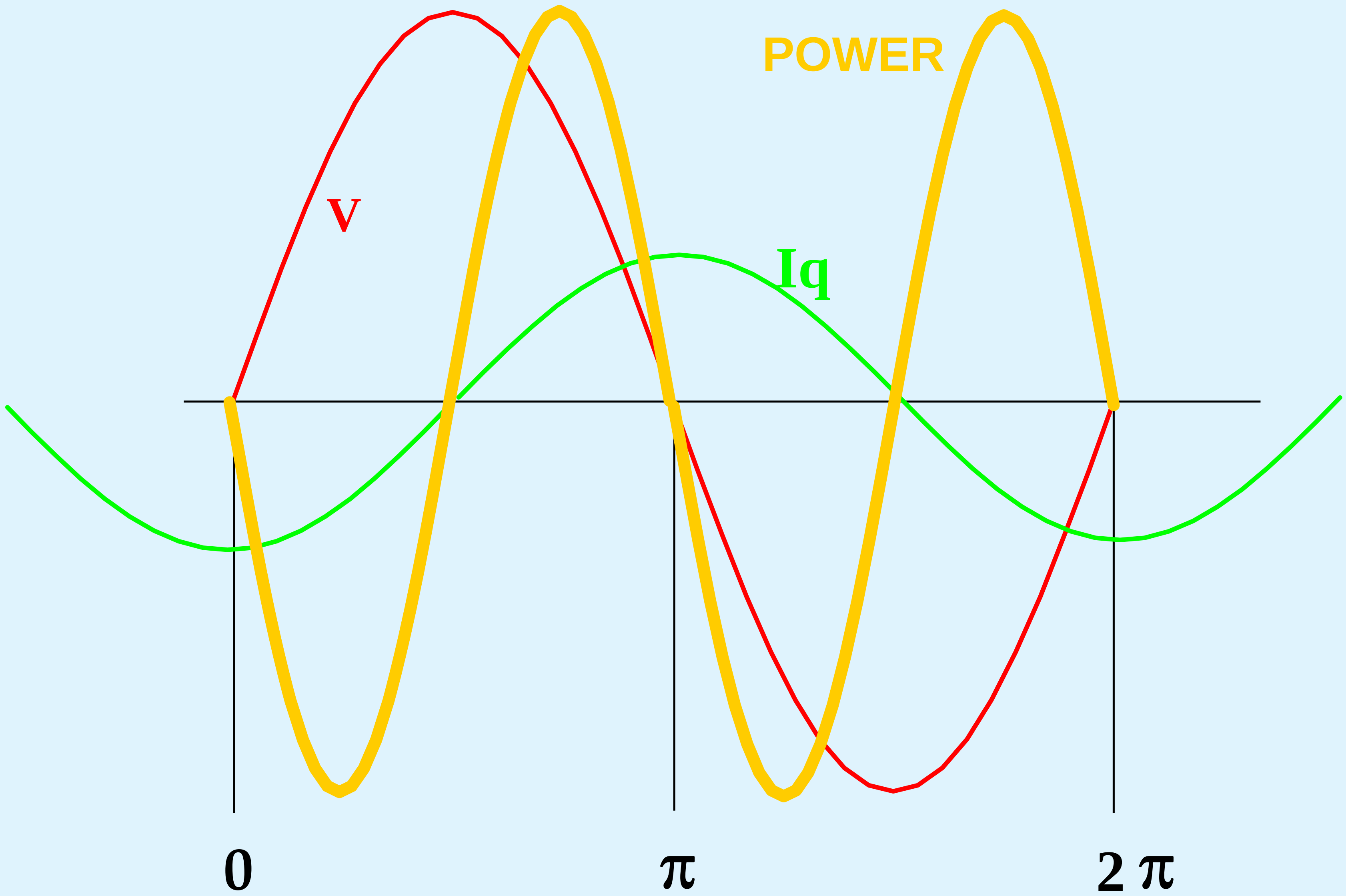
Real Power (kWh)



PhaseShift V and I



Reactive Power (kVAr)

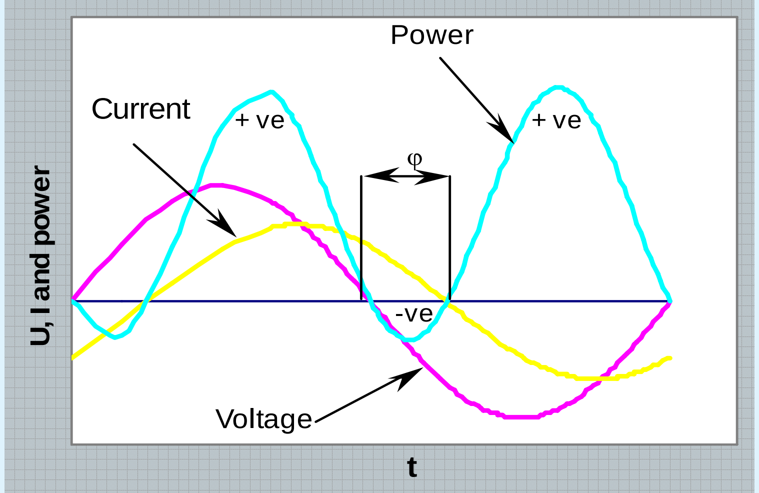


What is the power factor?

Power factor = cosφ

cos-phi = P (kW) / S (kVA)

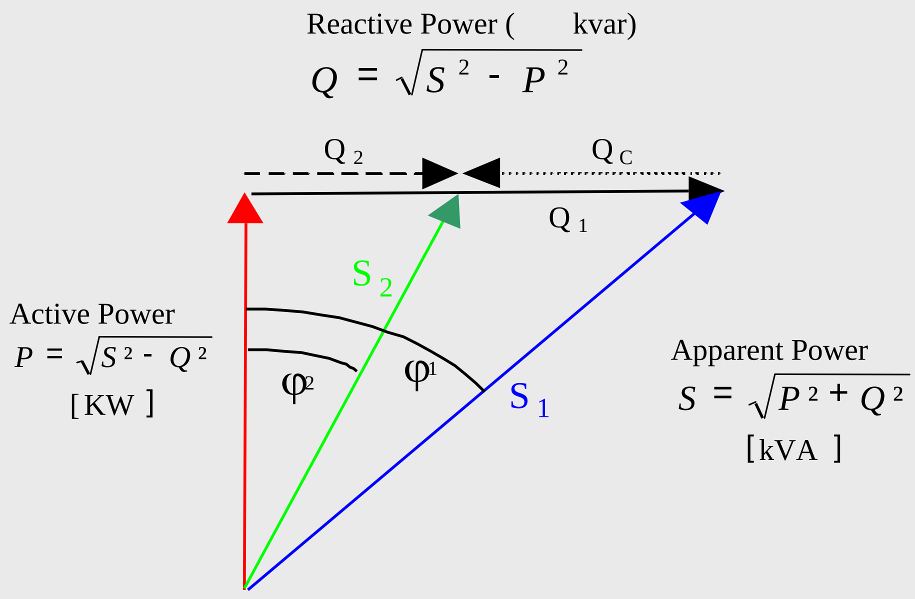
Phase shift



Factory	Typical uncompensated PF
Breweries	0,6..0,7
Butcher's	0,6..0,7
Cement plant	0,6..0,7
Compressor	0,7..0,8
Cranes	0,5..0,6
Drying-Plants	0,8..0,9
Machinery, big sized	0,5..0,6
Machinery, small sized	0,4..0,5
Plywood	0,6..0,7
Sawmill	0,6..0,7
Steel factory	0,6..0,7
Suggar	0,8..0,85
Tobacco	0,6..0,7
Water pumps	0,8..0,85

Three different types of electrical power

- S = Apparent Power
- P = Active Power
- Q = Reactive Power

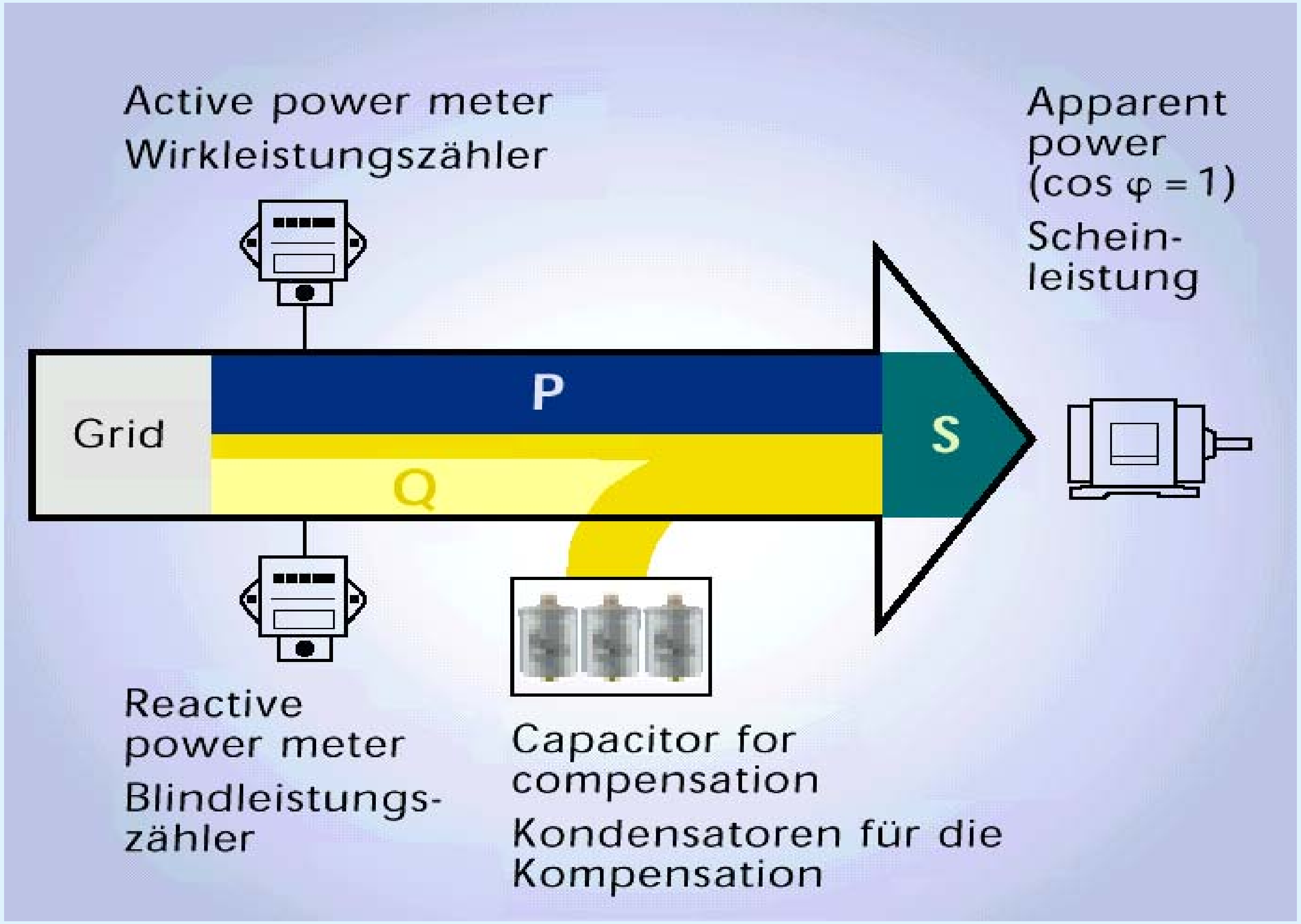


$\cos\varphi = P/S$
$\sin\varphi = Q/S$
$Q = S \sin\varphi$

$Q = P \tan\varphi$

φ = phase displacement angle
S_1 = uncompensated apparent power
S_2 = compensated power with capacitors for compensation

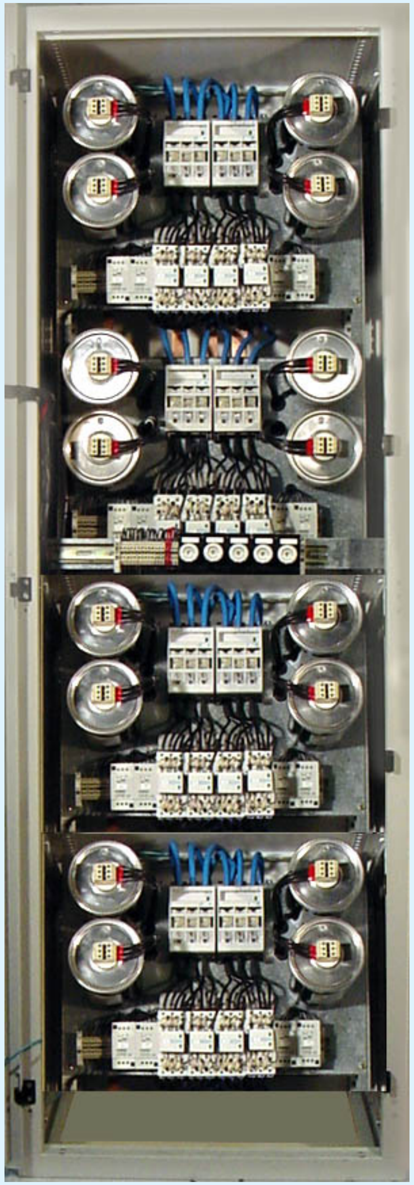
Principle of PFC



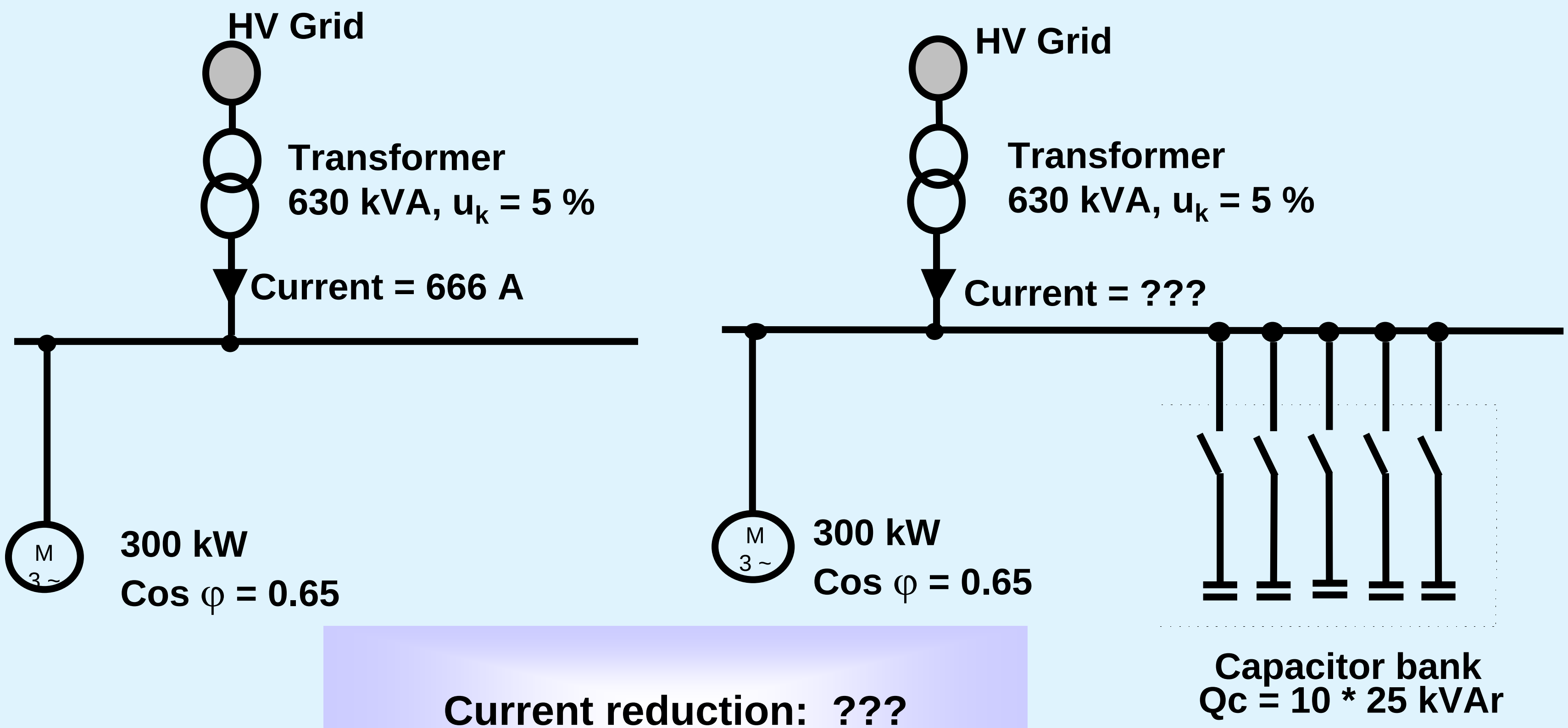
What are the benefits of Power Factor Correction?

- Reduction of electricity bill (power factor penalties)
- System kVA- release
- Reduction of ohmic losses, voltage drops
- Power Quality improvement (voltage sags…)
- Higher kW loading (utilization) of transmission and distribution equipment and/or smaller dimensioning of this equipment (cable, transformer, bus bars,...)

Example of a PFC System



Example: Current reduction in main supply cable?

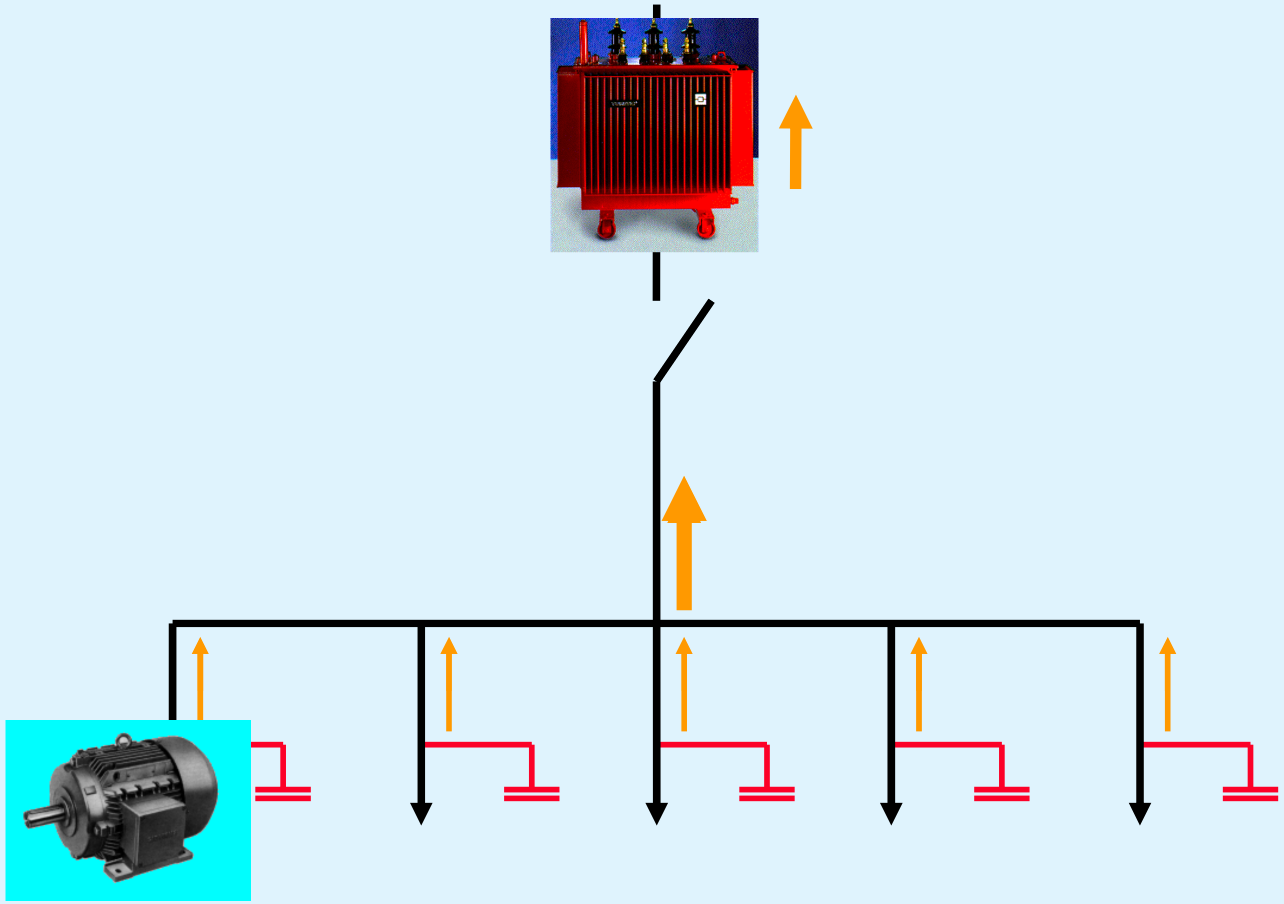


Current reduction: ???

Types of PFC/PQS

- **Individual PFC**
- **Group PFC**
- **Centralized PFC**
- **Mixed PFC**
- **Dynamic PFC**
- **De-tuned harmonic filter**
- **Tuned harmonic filter**
- **Active filter**

Methods of PFC: 1. Individual (fixed) Compensation



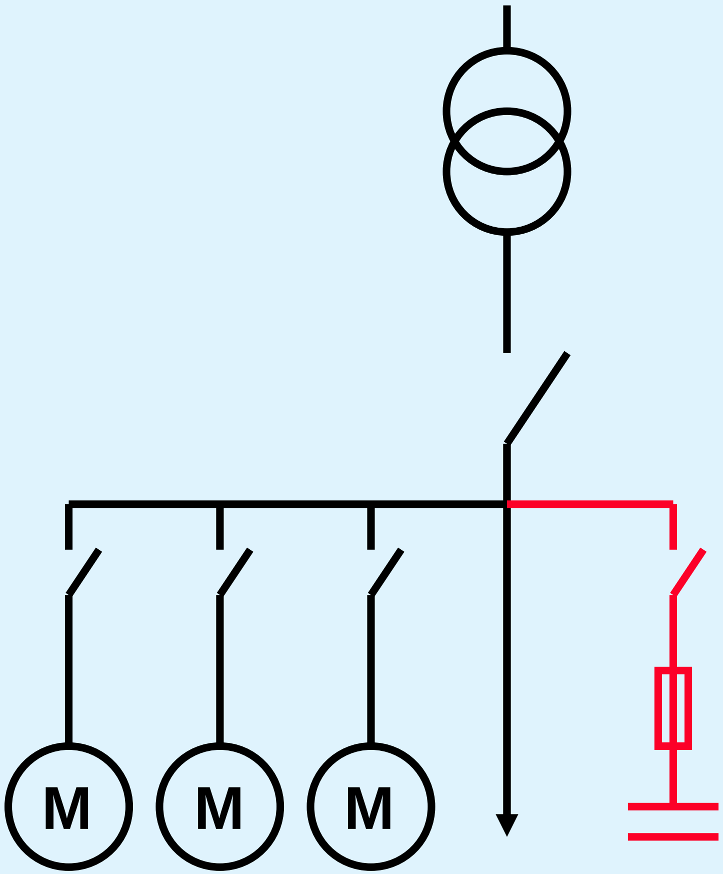
<u>Advantages at a glance</u>

- kvar produced on the spot
- Reduction of line losses
- Reduction of voltage drops
- Saving of switch gear

<u>Disadvantages</u>

- Many small capacitors are more expensive than one central one
- Low utilization factor of capacitors for equipment not often in operation

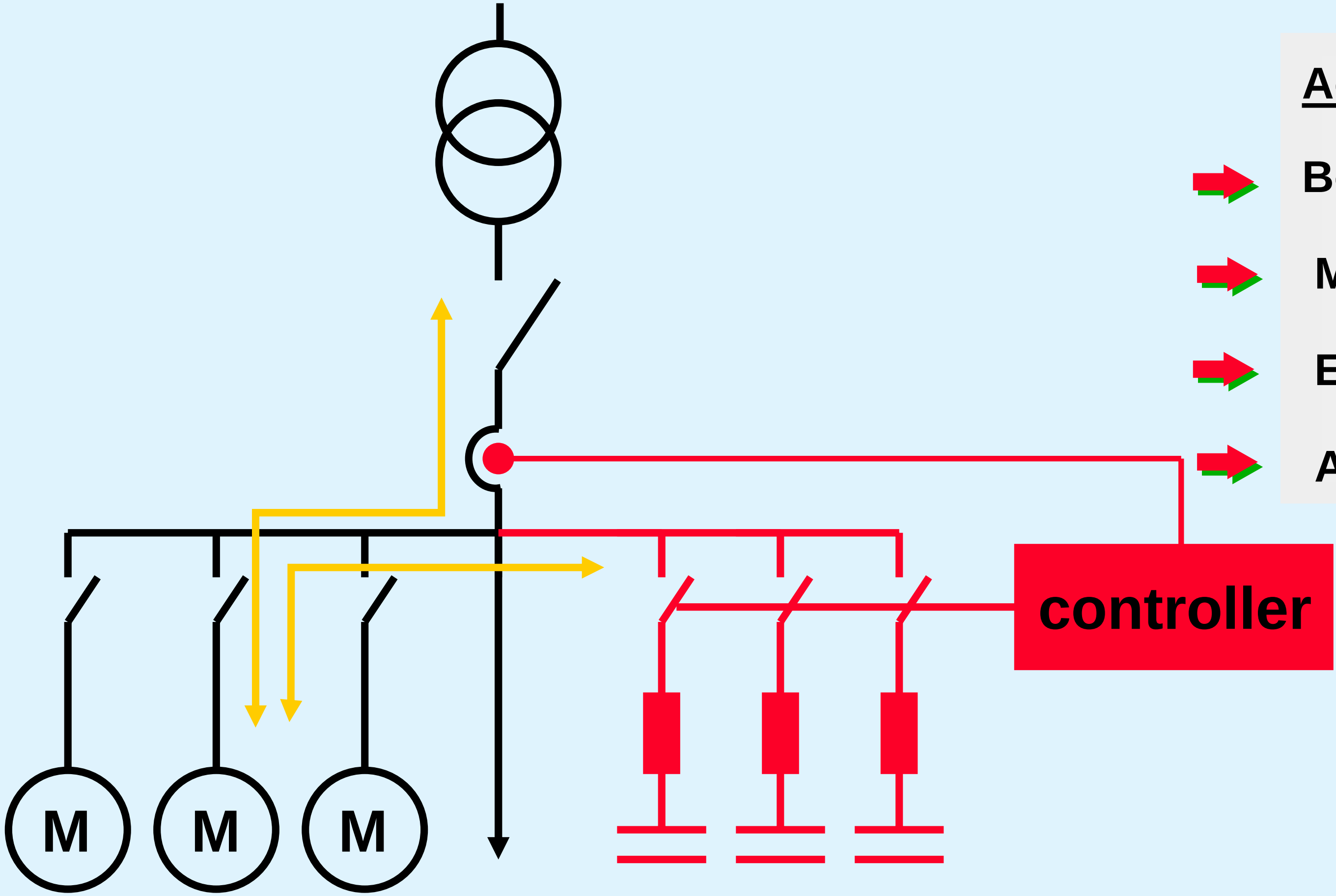
Methods of PFC: 2. Group Compensation



Advantages at a glance

- Reduction of capital investment
- Loses reduced in distribution lines
- Voltage drops reduced in distribution lines
- Higher utilization factor of capacitors

Methods of PFC: 3. Centralized Compensation



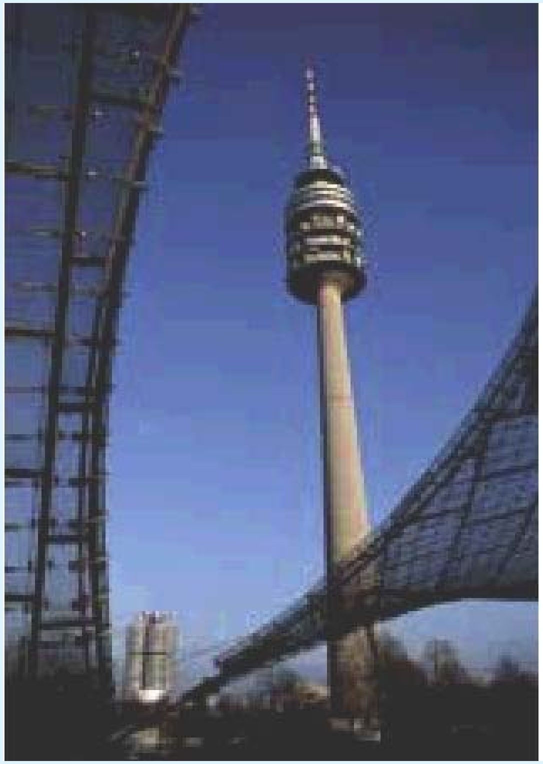
Advantages at a glance

- Best utilization of the capacitors
- Most cost effective solution
- Easier supervision
- Automatic control

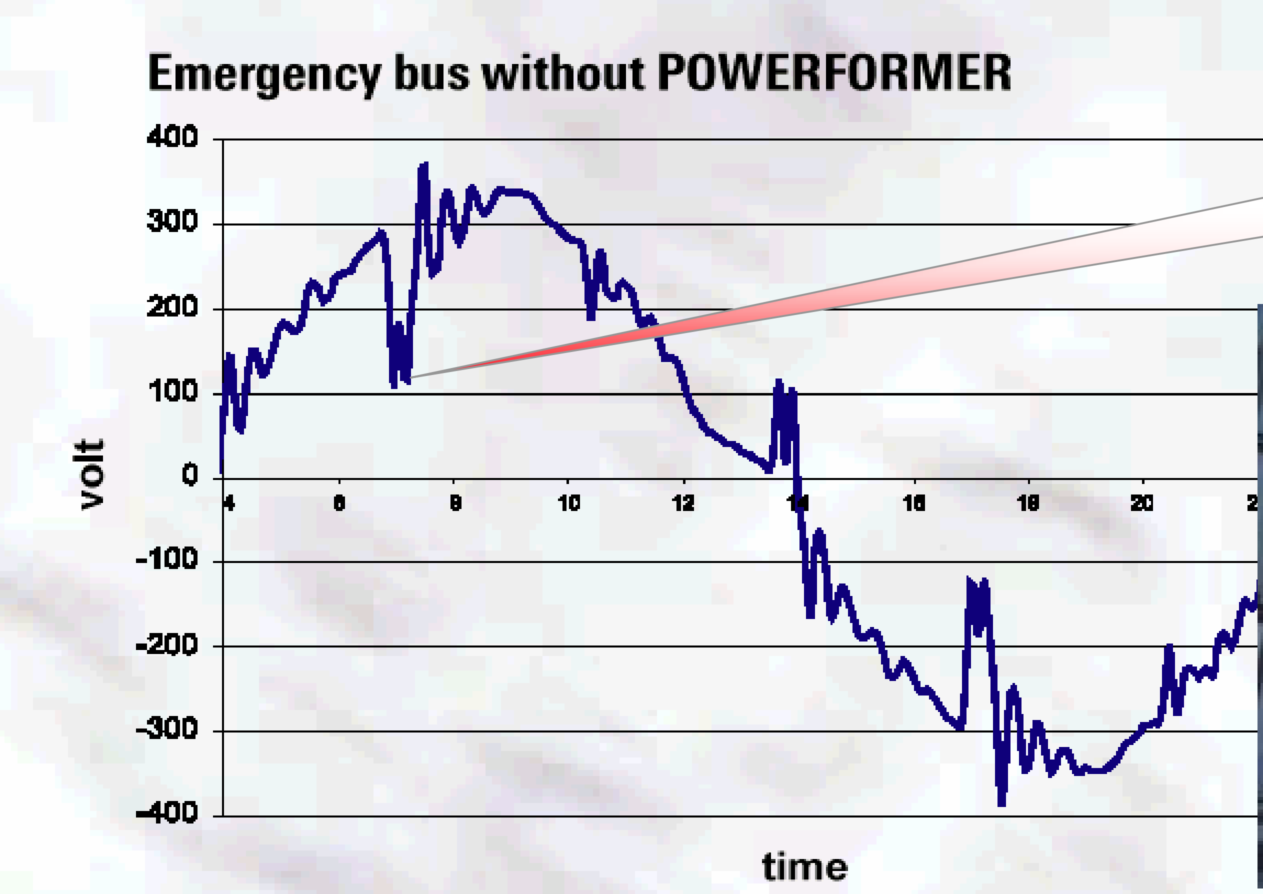
Methods of PFC: 4. Dynamic PFC

Advantages of dynamic PFC at a glance

- Real time power factor correction; e.g. essential for cranes or lifts
- Smooth switching of capacitors, avoids inrush current
- Less problems with power quality, such as voltage sags
- Voltage stabilizing
- Longer life cycle of capacitor banks

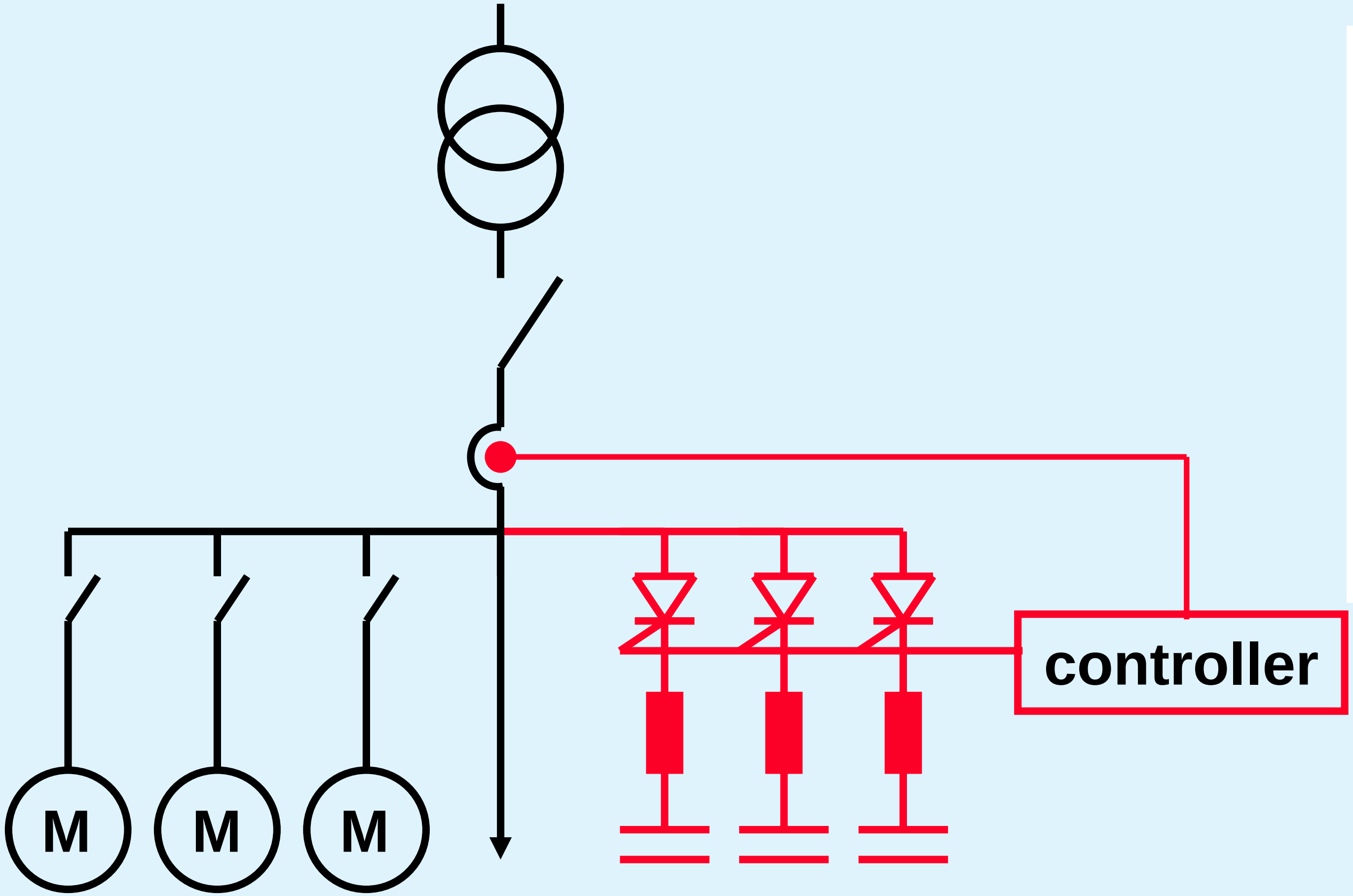


Methods of PFC: 4. Dynamic PFC



Voltage sags due to high inrush currents

Methods of PFC: 4. Dynamic PFC



TARGET
ZIEL $\cos\varphi = 0.96$

Q

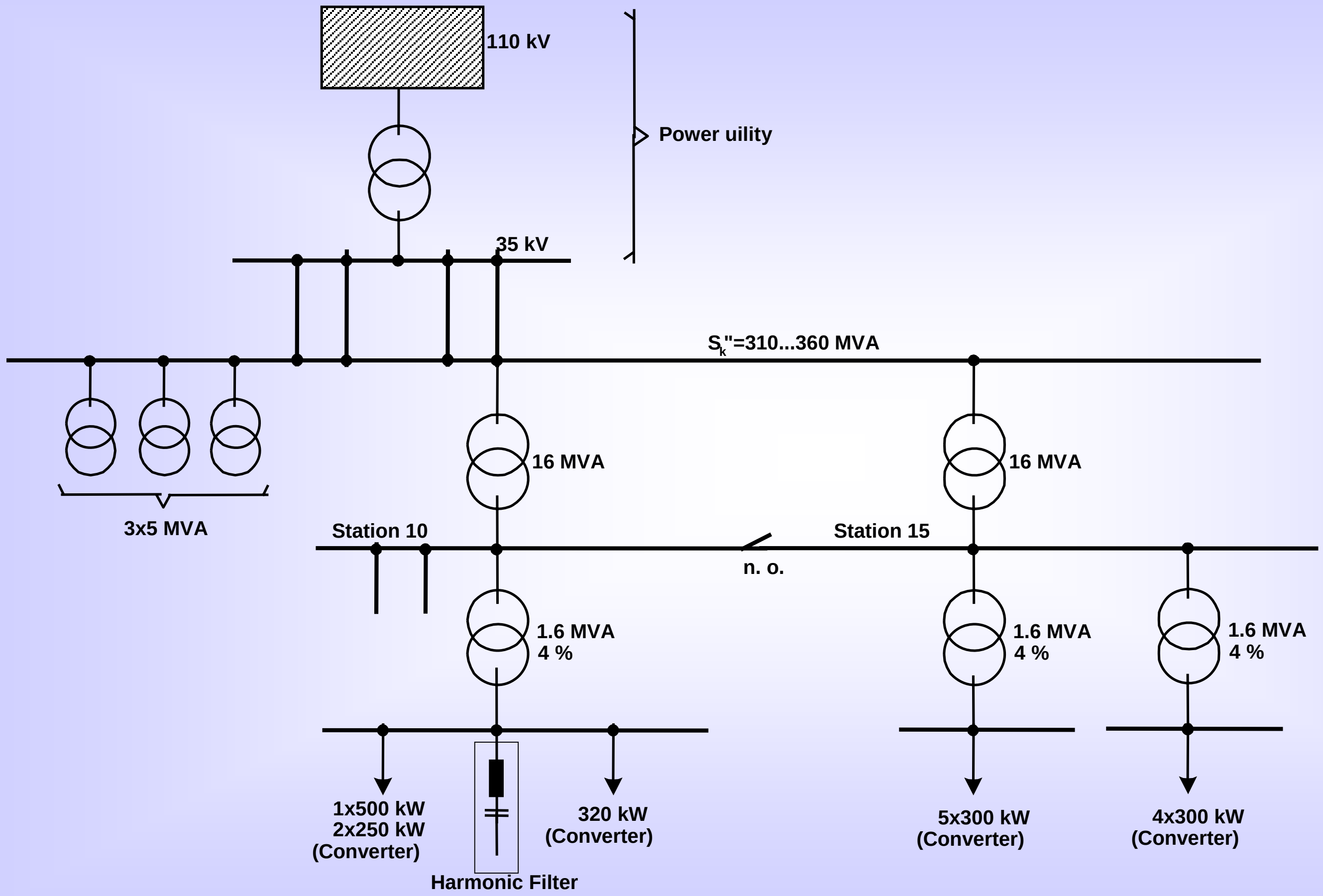
$\cos\varphi \leq 1$

$Q_c = P_{mot} * F_{tab} = [kvar]$

$30 * 0.88 = 26.4$ kvar

current (ACTUAL) vorhandener (IST) tan φ	cos φ	achievable (TARGET) gewünschter (ZIEL) cos φ 0,80	0,82	0,85	0,88	0,90	0,92	0,94	0,96	0,98	1,00
		Faktor F									
3,18	0,30	2,43	2,48	2,56	2,64	2,70	2,75	2,82	2,89	2,98	3,18
2,96	0,32	2,21	2,26	2,34	2,42	2,48	2,53	2,60	2,67	2,76	2,96
2,77	0,34	2,02	2,07	2,15	2,23	2,28	2,34	2,41	2,48	2,56	2,77
2,59	0,36	1,84	1,89	1,97	2,05	2,10	2,17	2,23	2,30	2,39	2,59
2,43	0,38	1,68	1,73	1,81	1,89	1,95	2,01	2,07	2,14	2,23	2,43
2,29	0,40	1,54	1,59	1,67	1,75	1,81	1,87	1,93	2,00	2,09	2,29
2,16	0,42	1,41	1,46	1,54	1,62	1,68	1,73	1,80	1,87	1,96	2,16
2,04	0,44	1,29	1,34	1,42	1,50	1,56	1,61	1,68	1,75	1,84	2,04
1,93	0,46	1,18	1,23	1,31	1,39	1,45	1,50	1,57	1,64	1,73	1,93
1,83	0,48	1,08	1,13	1,21	1,29	1,34	1,40	1,47	1,54	1,62	1,83
1,73	0,50	0,98	1,03	1,11	1,19	1,25	1,31	1,37	1,45	1,63	1,73
1,64	0,52	0,89	0,94	1,02	1,10	1,16	1,22	1,28	1,35	1,44	1,64
1,56	0,54	0,81	0,86	0,94	1,02	1,07	1,13	1,20	1,27	1,36	1,56
1,48	0,56	0,73	0,78	0,86	0,94	1,00	1,05	1,12	1,19	1,28	1,48
1,40	0,58	0,65	0,70	0,78	0,86	0,92	0,98	1,04	1,11	1,20	1,40
1,33	0,60	0,58	0,63	0,71	0,79	0,85	0,91	0,97	1,04	1,13	1,33
1,30	0,61	0,55	0,60	0,68	0,76	0,81	0,87	0,94	1,01	1,10	1,30
1,27	0,62	0,52	0,57	0,65	0,73	0,78	0,84	0,91	0,99	1,06	1,27
1,23	0,63	0,48	0,53	0,61	0,69	0,75	0,81	0,87	0,94	1,03	1,23
1,20	0,64	0,45	0,50	0,58	0,66	0,72	0,77	0,84	0,91	1,00	1,20
1,17	0,65	0,42	0,47	0,55	0,63	0,68	0,74	0,81	0,88	0,97	1,17
1,14	0,66	0,39	0,44	0,52	0,60	0,65	0,71	0,78	0,85	0,94	1,14

Single line diagram essential for system study



Frequently asked questions

- What is the thumb rule for selection of kvar size for motor fixed compensation?
- How to find the active load of a motor for calculating the capacitor size?
- In factories with many loads it is problematic to calculate the required capacitor output during planning status.

  1) Why?

  2) How to select a suitable kvar size?
- When to select:

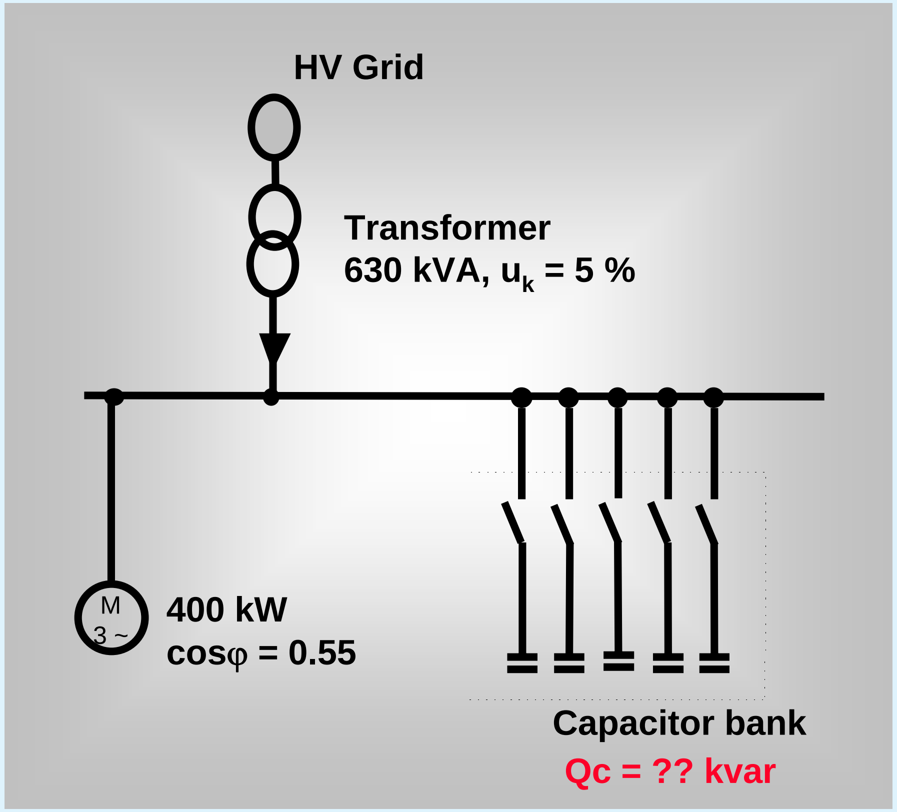
  A) Fixed B) Group C) Centralised - compensation

Example

Question:

- A textile factory with a total load of 400 kW shows an actual power factor of 0.55 (phi=56.6°)
- The local power utility asks for a target PF=0.98 (phi=11.5 °)

What capacitor output is required to avoid surcharges for low PF?



Example

Solution:

- Qc = P * (tang phi1 - tang phi 2) = 400*(tan (56.5) - tan(11.5)) = 523 kvar

  (where phi1 is the phase angle of existing power factor and phi2 is the phase angle of target power factor)

- We recommend a capacitor bank design: 25 kvar + 10 steps of 50 kvar

- Depending on types of loads, e.g. frequency converters,

  a de-tuned capacitor bank should be used