7. Reactive Power Compensation in the Four Load Quadrants

7.1.1 Technical Consideration

Please refer to figure 11 for a better understanding of the following text. In electrical systems referred exclusively to consumed active energy, reactive energy is controlled only in quadrants I and II of the illustrated coordinate system.

This means that the vector P (active power) can only have a positive sign. Only vector Q can have both signs, namely "+" for inductive and "-" for capacitve reactive power. In the former case, reactive energy is extracted from the network, while in the latter case reactive energy is returned to the network.

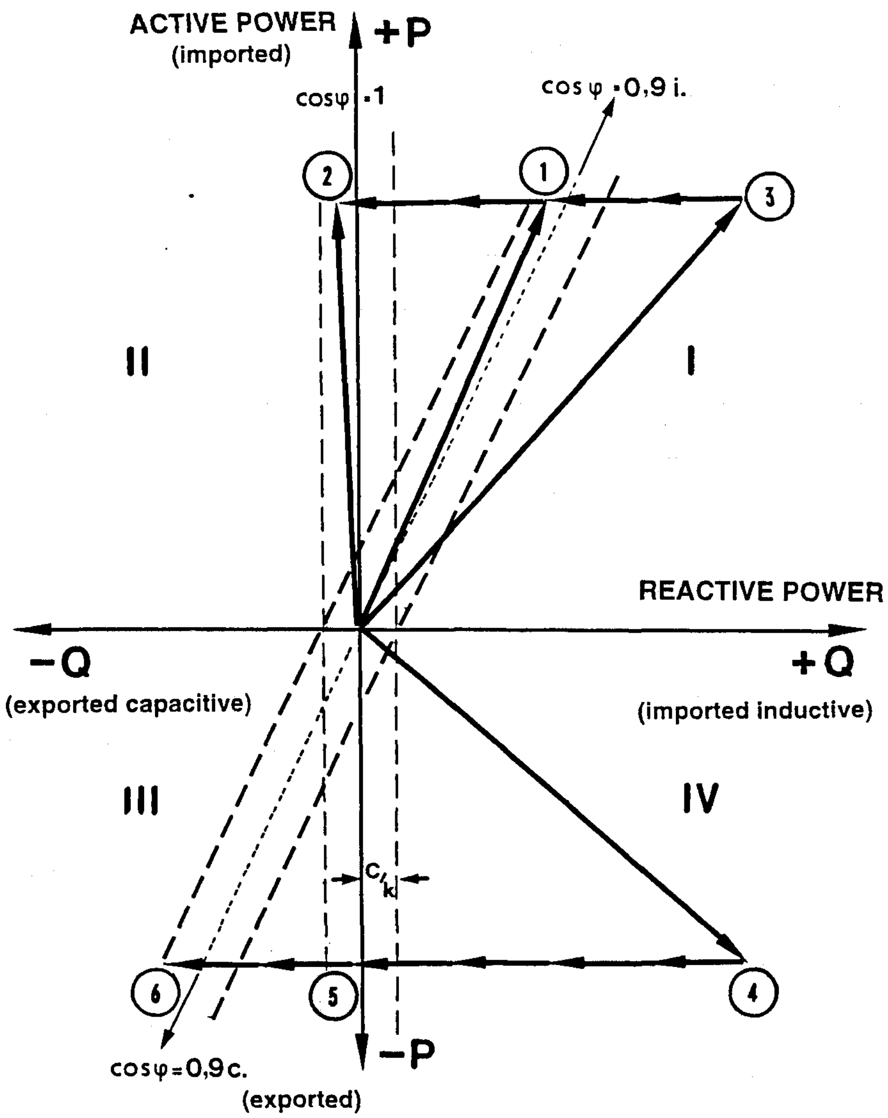


Figure 11

Two different target power factor setting lines (cos φ setting on the reactive power control relay), namely cos φ = 0,90 inductive and cos φ = 1 are shown in the coordinate system. The broken lines on either side of the vector line indicate the response thresholds set on the control relay. Thus, two strips are produced whose areas symbolize the "dead range" or "range of insensitivity". If a load vector, e.g. (1) falls into such a set range, the relay has compensated properly. This applies to load case 3, which compensates with one capacitor stage to approx. 0,92 inductive (1) and with four capacitor stages to approx. 0,99 capacitve (2) depending on the cos φ value set on the control relay.

If, however, active energy is fed back from the system concerned into the public mains by an existing generator, control is displaced to quadrants III and IV of the coordinate system.

As far as the amounts are concerned (apparent current), the same load case has been chosen for an easier understanding, but referred to generator operation (load vector 4). At the same time, it can be seen clearly that compensation is symmetrical when cos φ = 1 is set on the control relay (5), i.e. also only 4 capacitor stages suffice for compensation.

The difference between motor and generator operation does not become clear until the target power setting on the control relay deviates from 1. In generator operation, a relay set to cos φ = 0,90 inductive compensates to cos φ = 0,90 capacitive (6), needing 6 capacitor stages to do this.

This knowledge is indispensable in order to enable selection of the corresponding reactive power control relay. For mixed operation (generator/motor), therefore, it is recommended to set the cos φ to unity to obtain symmetrical compensation. When settings deviate from cos φ = 1, the mirror-image control response on reversal of the active load must be taken into account. If a control relay is to compensate to cos φ = 0,9 inductive in generator mode, it will want to compensate to 0,9 capacitive in motor mode and vice versa.

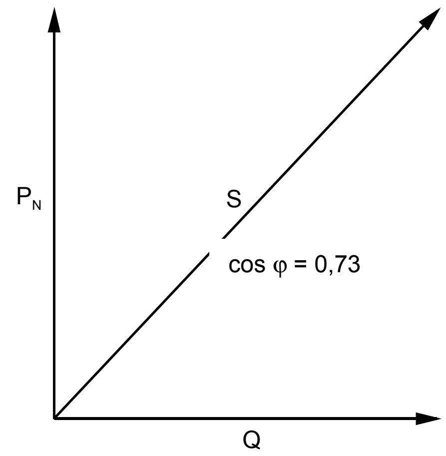
It is useful to set target cos φ = 1 not only for technical but also for commercial reasons (see next chapter 7.1.2).

Referring to the measuring point "incoming supply", Figure No. 12 shows some unusual power factors that could occur with generator operation. The present power factor can scatter over all four quadrants from 1 to 0 inductive, and again over 1 (feedback) to 0 capacitive!

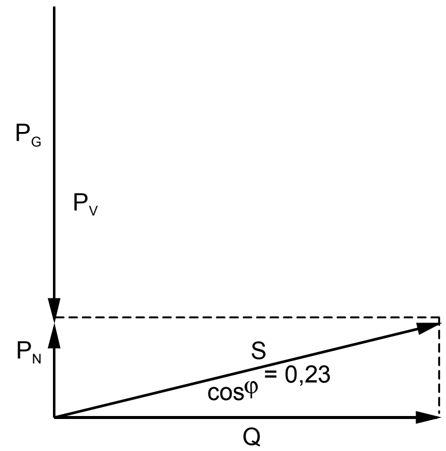
As mentioned in chapter 6.1, power factor cos φ is not helpful to gain an insight into the existing quantity of reactive power!

Variation of Power Factor on Import and Export of Power

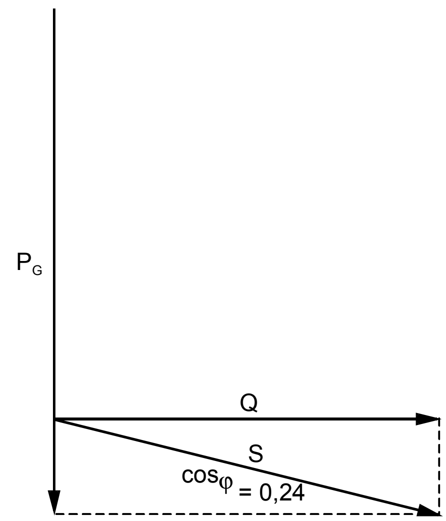
Case a): All power imported



Case b) Power partly supplied
by Generator(s)



Case c) All Power supplied
by Generator(s) and
Power Export



Measuring point: Current Transformer at Main Incomer or at Metering Point

Figure 12: Power Factors in Four-Quadrant-Operation (Import/Export of Power)