# Reactive power compensation

## 1. Purpose of the exercise:

Familiarization with reactive power compensation, performed using a compensation device controlled by a reactive power regulator with the function of a network parameters analyzer.

## 2. Tasks to be completed:

- To program the regulator,
- To measure parameters before and after compensation,
- To prepare phasor diagrams and power triangles,
- To conclude the conducted exercise.

## 3. Theoretical introduction

Reactive power compensation identifies the source of inductive or capacitive reactive power in the circuit, electrical installation, and the appropriate selection of the compensating element.

The relationship that allows us to determine the ratio of active to reactive power is determined based on the power triangle (Figure 1), where:

Q – active power

S – apparent power

P – reactive power

An important parameter on which reactive power compensation is based is the power factor:

$$cos\,\varphi = \frac{P}{S} \qquad (1)$$

Most electricity suppliers use $tan\,\varphi$ specifying the power factor as:

$$tan\,\varphi = \frac{Q}{P} \qquad (2)$$

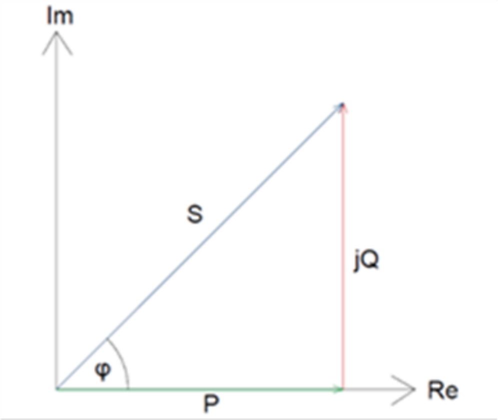


Figure 1 Power triangle

An increasing number of electricity consumers have problems with additional charges resulting from reactive energy consumption exceeding the limit set in the contract with the supplier. An additional fee for the consumption of inductive reactive energy may be incurred by almost every consumer using such devices that draw inductive reactive energy from the grid for proper operation. Among them, the following can be distinguished:

- electric motors;
- transformers;
- injection molding machines;
- welders;
- chillers;
- air conditioners.

There are more and more cases of penalties for the consumption of capacitive reactive energy. Most often, it takes place in office buildings whose lighting is based on low-quality LED luminaires. The problem of capacitive reactive energy primarily concerns consumers using:

- capacitor banks,
- luminaires with capacitors,
- inverters,
- electronics,
- extensive LV networks characterized by high cable capacity.

**Calculation of fees for excessive consumption of reactive energy**

Fee for inductive reactive energy consumption:

$$O_b = k \cdot C_{rk} \cdot \left(\sqrt{\frac{1+\varphi}{1+\varphi_0}} - 1\right) \cdot A \qquad (3)$$

Fee for capacitive reactive energy consumption:

$$O_b = k \cdot C_{rk} \cdot A_b \qquad (4)$$

where:

$O_b$ - fee for excess reactive energy in PLN

k - multiple of the $C_{rk}$ price set in the tariff for low-voltage consumers, it is usually 3, and for medium-voltage consumers, it is 1

$C_{rk}$ - average selling price of electricity on the competitive market as of the date of approving the operator's tariff

$tan\ \varphi_0$ - power factor by the contract (usually 0.4)

$tan\ \varphi$ - power factor resulting from the reactive energy consumed

A - active energy consumed 24 hours a day or for the time zone in which reactive energy consumption is controlled.

**Selection of proper reactive power compensation**

In order to properly adjust the reactive power compensation method, you should:

- take into account the specificity of the industry (it is worth getting acquainted with typical solutions and using the experience gained during the commissioning of reactive power compensation systems in already existing, similar facilities),
- perform a precise power balance, taking into account: the power of devices, their natural cosine, and the coefficient of simultaneity,
- and precisely specify whether the given receiver is linear or not. If it is not, its spectrum of higher harmonics should be known.

Additionally:

- take into account the dynamics of changes in reactive power consumption
- determine whether the receiver is powered from one, three, or only two phases.

Having all the data:

- separate lists should be prepared with a division into linear, non-linear, static, and dynamic receivers, and the ratios of these powers should be calculated,
- if the calculated values of the power ratio will be 10-20% of the power of the linear receivers, then, depending on the short-circuit power of the system, we can assume that the designed system meets typical conditions and the designed system will be based on standard batteries,
- suppose the calculated values of the power ratio exceed 20% of non-linear receivers. In that case, reactive power compensation should be selected, choosing dynamic batteries, follow-up batteries, and battery systems with regulators - appropriate for this type of compensation.

**Battery operation in an environment of higher harmonics**

Detuning from resonant powers may not be sufficient if the measurements performed show a high content of higher harmonics in the supply network. Also, if at the design stage, it results from the analysis of installed receivers. The risk of overloading the battery beyond the permissible value is very high. In this case, other preventive measures should be taken, including:

- connecting the choke in series with the capacitor,
- moving the battery to another part of the system.

**Elimination of transient current overloads**

At the design stage, it should be checked whether it is possible to connect a capacitor bank to a battery operating in parallel in the network.

When the battery is connected to other, already energized capacitor banks, transient current overloads of high amplitude and high frequency may occur. Current overloads also apply to multi-segment batteries, where another battery section is connected to the energized one.

In order to reduce transient current overloads to the size corresponding to the capacitor and its equipment, it is necessary to connect the capacitors through a resistor (resistor switching) or by installing chokes in the power supply circuit of each battery section.

The peak value of current overloads resulting from switching activities is recommended to be limited and not exceed the maximum value of 100xIn (RMS value).

## 4. Guidance questions - check yourself

- Do you know the methods of reactive power compensation selection?
- Do you know what the reactive power factor is and what it is used for?
- Can you list and describe the methods that can be used when there is a problem with harmonics in the circuit?
- Can you discuss adding another battery or switching on another capacity when one is already working in reserve?

## 5. Exercise program

**Measurement station:**

The exercise will be performed on a station with a NOVAR 2600 Power Factor Controller by KMB System.

This device works on an innovative hardware platform with improved precise and continuous control of all required parameters in a three-phase system. The analyzer is fully automatic with a very intuitive installation process.

Depending on the model, it offers up to 18 relay outputs to control single-, two- or three-phase power capacitors or shunt reactors. In addition to the functions of the automatic power factor controller, the device also includes the functions of a network parameter analyzer.

The meter can store data with an additional 512 MB of internal memory. The archives can be downloaded to a computer, which will allow the analysis of the course of the compensation process using the dedicated Envis application.

The built-in, four-quadrant energy meter can record active and reactive power. It fits data up to 3 different user-defined tariffs.

A large, high-resolution display brings the information you need to the screen. All displayed parameters can be configured according to the user's needs. Novar 2600 can monitor parameters online using the Envis application or other SCADA systems. This model has a wide range of communication options, such as:

- USB
- RS485
- Ethernet

**The course of the exercise:**

A. Start the regulator and the dedicated Envis application. Identify opportunities for online compensation on the job.

B. Select the compensator based on capacitive and inductive elements available at the stand.

C. Select experimental RLC elements based on inductive and capacitive reactive power compensation to obtain compensator operation.

D. Preparation of protocols, obtaining results in vector diagrams of currents, voltages, and the power triangle before and after compensation.

E. Analyze the influence of the controller's tg and cos phi settings.

F. Analyze the effect of three-phase and single-phase compensation strategies in a three-phase installation.