Power supply of industrial enterprises

Laboratory work

Study of the reactive power compensation methods

The objective of the work is

- to study purpose of the reactive power;
- to understand physical sense of the reactive power compensation;
- to research effect of condensers, load coefficient value of a motor on reactive power consumption;
- to study compensation methods.

After execution of work student should

- know: physical meaning of reactive power compensation; sources of reactive power; methods to reduce consumption of reactive power; initial parameters for calculation of the capacity of compensation equipment;
- be able: to select a method for the reactive power compensation; to calculate the capacity of compensation equipment; to draw diagrams of reactive and active power consumption; to calculate power factor.

The most of the alternative current receivers are reactive power consumers, such as asynchronous motors, transformers, reactors, power lines, welding transformers and so on.

One of the main reasons of the excess reactive power consumption in industrial enterprises is underload and open-circuit duty of asynchronous motors.

Transportation of the reactive power through power system causes negative effects:

1. Additional power losses in elements of the power system occur:

$$\Delta S = \frac{P^2 + Q^2}{U^2} Z .$$

2. Voltage losses in power net elements increase:

$$\Delta U = \frac{PR + QX}{U} .$$

3. Active power carrying capacity of power system elements decrease while total power is constant:

$$P = \sqrt{S^2 - Q^2} .$$

There are two groups of methods to reduce reactive power transportation.

1. Without use of compensation equipment.

2. With use of special compensation equipment that should be technically and economically proved.

In the first group of measures are:

- to increase the load of asynchronous motors;
- to use open-circuit arresters to avoid open-circuit operational modes of equipment;
- to replace asynchronous motors with load rate lower than 60 % by motors with lower capacity;
- to replace or to switch off temporary transformers with load factor lower than 30 %;
- to replace when possible asynchronous motors by synchronous.

As compensation equipment static condensers, synchronous motors (in generator mode with overexcitation), banks of capacitors could be used. This equipment produces reactive power and allows reducing supply of it from power system.

Plan

1. Measure parameters of active and reactive power consumption by asynchronous motors in different operational modes according to Table 1. Duration of each measurement (1 – 3 min) is given by lecturer.
2. calculate energy consumption.

Active power consumption:

$$W = \frac{K_{CT} \cdot K_{VT}}{1750} n_W \text{, kWt·h,}$$

reactive power consumption:

$$V = \frac{K_{CT} \cdot K_{VT}}{1750} n_V \text{, kvar·h,}$$

where K_{CT}, K_{VT} – transformation coefficients for current transformer and voltage transformer;

n_W, n_V – quantity of active and reactive energy meter turns.

3. Calculate average consumption of active power:

$$P_a = \frac{W}{T} \text{, kWt,}$$

where T – duration of power consumption measurement, h.

4. Calculate average consumption of reactive power:

$$Q_a = \frac{V}{T} \text{, kvar.}$$

5. Define power factor:

$$\cos\varphi = \frac{P_a}{\sqrt{P_a{}^2 + Q_a{}^2}}.$$

6. Define reactive power factor:

$$tg\varphi = \frac{Q_a}{P_a}.$$

7. Calculate capacity of static capacitors for full compensation of reactive power:

$$Q_{comp} = Q_a = P_a \cdot tg\varphi .$$

8. Results of calculation have to be written down into table.

Table 1. Presentation of results of experiments and calculations.

Operation duty	Results of experiments				Results of calculations						
			Quantity of electricity supply meter turns		Energy consumption		Average power consumption				
	cosφ	I, A	n_w	n_v	W, kWt·h	V, kvar·h	P_a, kWt	Q_a, kvar	cosφ	tgφ	Q_{comp}, kvar
1. AM1 open-circuit											
2. AM1 open-circuit+ compensation											
3. AM1 load											
4. AM1 load+ compensation											
5. AM2 open-circuit											
6. AM2 open-circuit+ compensation											
7. AM2 load											
8. AM2 load+ compensation											

9. Analyze results of experiments and calculations, make conclusions about effect of operational duty of equipment on reactive power consumption, possibilities and purpose of reactive power compensation in each case.

Report contents

Title, objective, functions of compensation of the reactive power, brief characteristic of compensation methods, table with results of measurements and calculations, example of calculation, conclusions.

Quiz

1. What kinds of equipment are suppliers of reactive power?
2. What equipment is consuming of reactive power?
3. The purpose of reactive power compensation.
4. The purpose and measures to reduce reactive power supplying.
5. How does operational mode of asynchronous motor effect on reactive power consumption?
6. What is physical meaning of reactive power compensation?

Further reading

1. Справочник по электроснабжению и электрооборудованию. / Под ред. А.А. Федорова. – М.: Энергоатомиздат, 1986. – 508 с.