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Analysis of the significance and method of improving power factor

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ABSTRACT. *This paper explains the significance of improving the power factor. It is an important technical parameter in the power system and an important means for energy saving and efficiency improvement. Taking the fluorescent lamp experiment as an example, the improved circuit makes the experiment easy to measure and analyze, and shows the method of improving the power factor of the circuit.*

KEYWORDS: *power factor, shunt capacitance, active power, reactive power, phasor*

1. Introduction

In teaching of "Electric and Electronic Foundation", many students have difficulty understanding power factor. In this paper, the function of improving the power factor is analyzed in detail, and the fluorescent lamp lighting circuit is taken as an example to improve the circuit, enhance the flexibility of the experiment. Deepen students' understanding of the improvement of power factor.

2. Definition of power factor`

In an AC circuit, the cosine of the phase difference between voltage and current is called the power factor($\cos\varphi$). $\cos\varphi$ is numerically equal to P/S, where P is the active power, S is the apparent power. And the reactive power is used for energy exchange, and Its symbol is Q.

The relationship between active power, reactive power, and apparent power is:

$$S=\sqrt{P^2+Q^2}, \qquad P=S\cos\varphi=UI\cos\varphi, \qquad Q=S\sin\varphi=UI\sin\varphi$$

3. The significance of improving power

3.1 Increasing power factor can improve equipment utilization

It is well known that the capacity of a power supply device is determined based on the rated voltage U_N and rated current I_N, and its rated apparent power is $S_N=U_NI_N$. It indicates that the maximum active power of the device is allowed to be output. If $\cos\varphi=1$, then $P=U_NI_N\cos\varphi=U_NI_N=S_N$. At this time, the capacity of the power source is all converted into active power, so the power supply device is fully utilized. If $\cos\varphi<1$, then $P=U_NI_N\cos\varphi$. The output power is less than its capacity, and the power supply device is not fully utilized.

3.2 Increasing power factor can reduce line loss, reduce system voltage loss, and improve power quality

Noted that $P=UI\cos\varphi$, then $I=P/U\cos\varphi$.When P and U are certain, $I\propto 1/\cos\varphi$.

Since the transmission line has resistance, when P and U are certain, $I\propto 1/\cos\varphi$.The lower the power factor, the greater the current I through the line and the greater the power consumed on the line resistance. Inevitably, voltage loss will occur, power quality will be seriously degraded, the life of electrical equipment will be affected, and the quality of enterprise products will decline.

That is to say, by increasing the power factor, the current I can be made smaller, the loss of electric energy on the transmission line can be reduced, the diameter of the transmission line conductor can be reduced, the conductor material can be saved, the system voltage loss can be reduced, and the power supply quality can be improved.

3.3 Improve power factor can reduce enterprise electricity expenses

In order to promote users to improve the power factor, the power sector has set a method for industrial users to adjust the electricity bill according to the monthly average power factor.

The power factor adjustment electricity fee basis and standard is the document "Power Factor Adjustment Electricity Fee Measures" issued jointly by the former Ministry of Water Resources and Electricity and the State Price Bureau in 1983.

First of all, according to the power factor of the user in the current month, in accordance with the "power rate adjustment of electricity rate increase and decrease checklist", to find out the percentage increase or decrease of the total electricity bill for the user. The percentage increase or decrease is increasing the electricity bill and deducting the electricity bill.

Table1 Power factor adjustment meter with 0.90 as the standard value

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Reduce electricity bill	Actual power factor	0.9	0.91	0.92	0.93	0.94	0.95-1.00							
	Monthly electricity bill reduced by %	0	0.15	0.3	0.45	0.6	0.75							
Increase electricity bill	Actual power factor	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.8	0.79	0.78	0.77
	Monthly electricity bill increased by %	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5
Increase electricity bill	Actual power factor	0.76	0.75	0.74	0.73	0.72	0.71	0.7	0.69	0.68	0.67	0.66	0.65	
	Monthly electricity bill increased by %	7	7.5	8	8.5	9	9.5	10	11	12	13	14	15	
Power factor from 0.64 and below, every 0.01% reduction, electricity costs increase by 2%														

Power factor adjustment electricity bill = total electricity bill × increase or decrease percentage.

4. Method of improving power factor

4.1 To increase the natural power factor, means taking measures to reduce the reactive power without any compensation device. It is the most economical way to improve the power factor.

4.1.1 Choose the right asynchronous motor model and capacity

Reasonable use of electric motors. Reduce the reactive power consumption of the load, so that it can run at full load as much as possible to achieve the purpose of improving the natural power factor.

4.1.2 Select the transformer that matches the load

According to the optimal load factor, the transformer is reasonably selected to improve the natural power factor.

4.1.3 Ensure the quality of the motor

The air gap between the stator and the rotor of the asynchronous motor is the main factor that determines the need for more reactive power in the asynchronous motor. When the air gap between the stator and the rotor increases or the stator coil decreases, the excitation current increases. Result in increased reactive power and reduced power factor.

4.1.4 For motors with large capacity and no need for speed regulation, synchronous motors should be used as much as possible.

4.2 Manual compensation of power factor

Manual compensation, also known as reactive power compensation, is to install some devices capable of providing reactive power near the load, so that the reactive power is compensated locally and the power factor is effectively improved. The most common method is to shunt capacitors on inductive loads.

Take the fluorescent lamp circuit as an example, based on Figure.1, replace the current meter of the original circuit with a parallel socket and switch, and replace the capacitance with the parallel connection of the capacitors. As shown in Figure.2.

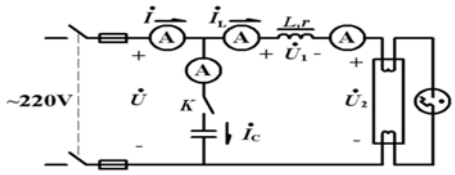

Figure. 1 Circuit without capacitor

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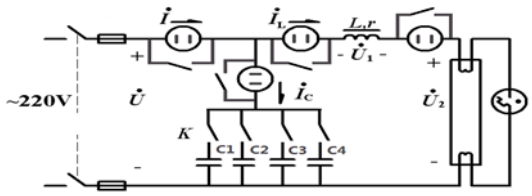

Fig. 2 Improved circuit with capacitor added

The benefits of the improved circuit are: 1) It can be powered. 2) Saving the number of ammeters and reducing the cumbersomeness of the intermediate process of measurement. 3) Parallel connection of capacitors, it can be observed that the power factor changes with the change of capacitance. You don't have to power off each time, change the value of the capacitor, then connect the line and measure again. 4) The mode of this assembled circuit is close to the engineering circuit, and in teaching, it is beneficial for students to speed up the process of linking theory with reality.

Draw the equivalent circuit diagram of Figure 2. As shown in Figure.3.

Set $\dot{U}$ as the reference phasor, the vector diagram of each phasor is shown in Figure.4, which is simplified to Figure.5.

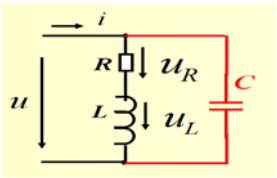

Fig.3 Equivalent circuit diagram

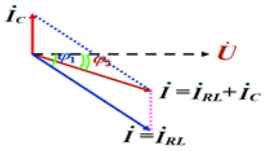

Fig.4 Phasor diagram

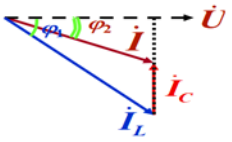

Fig.5 Phasor diagram

It can be obtained from Figure.5, $\cos\varphi_2 > \cos\varphi_1$. After the capacitor is connected, the voltage and current of the original load are unchanged, the power factor is increased, and the total current of the circuit is reduced.

But what happens when the shunt capacitance changes?

Through experimental measurements, we get the data shown in the table.2 below.

Table.2 The effect of the change of capacitor C on the circuit

Table.2 The effect of the change of capacitor C on the circuit							
Capacitance value	measurements						
	P(W)	U(V)	I(A)	I_L (A)	I_C (A)	cos(φ)	Remarks
0	32.4	216.7	0.299	0.3	0	0.5	Unconnected capacitor
C1 (1uf)	31.91	216.8	0.246	0.3	0.07	0.61	Under compensation
C2 (2.2uf)	37.27	216.8	0.191	0.3	0.152	0.79	
C3(4.3uf)	32.47	217	0.164	0.3	0.293	0.93	Reasonable compensation
C4(6.5uf)	37.65	217	0.247	0.3	0.444	0.61	Overcompensation

From the Table.2 , as the shunt capacitance C increases from C1 to C3, the voltage, current, and power factors of the load do not change, but the power factor of the entire circuit is improved. As the capacitance increases to C4, compensation phenomenon occurred, and power factor decreased.

After the general power factor is increased to 0.95, it is more difficult to raise it upwards. It requires a large capacitor and is prone to overcompensation.

5. Conclusion

In this paper, the function of improving the power factor is analyzed in detail, and the fluorescent lamp circuit is taken as an example to improve the circuit and enhance the flexibility of the experiment, so that students can easily measure the

results and analyze the experimental results. Enable students to deepen their understanding of power factors. The improvement of the power factor of the fluorescent lamp lighting circuit provides energy saving for the enterprise. Through this experiment, it is conducive to cultivating students' ability to analyze and solve problems. Make them the application-oriented technical talents that companies need.

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