The Principle of the Characteristics of Inductive Circuit Analysis and Research

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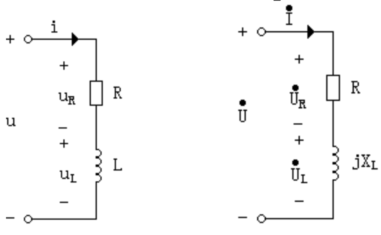
Abstract. The analysis and research inductive AC circuit characteristics for guidingthe use of inductive load equipment has practical significance. By combining experimental electrical theory to explain inductive AC circuit voltage and current relationships, power, influence electrical shunt capacitance of the circuit. For experimental phenomena, using the formula and phasor diagram method for inductive AC circuit characteristics are analyzed and studied. Concluded that: the inductive shunt capacitance of the AC power supply voltage circuit, the inductor voltage, the voltage resistance of the inductor current, active power constant; circuit current, capacitive current, reactive power and power factor to change; proper capacitance value can be increased in parallel power factor.

Introduction

Widely used in daily life and industrial and agricultural production has a lot of electrical equipment is inductive loads, such as the three-phase asynchronous motor, daylight lamps and lanterns of inductive circuit. Analysis and research on inductive circuit features for use perceptual load device has practical significance. Based on the fundamental theory of electrical engineering combined with experimental approach are the characteristics of the inductive communication circuit, and USES the method of formula and phasor diagram analysis of the experimental phenomenon, in the final conclusion. For the general electrical fans more profound understanding electrical phenomenon, correctly grasp the electrotechnics to offer help.

Relationship between voltage and current

Inductive circuit can be expressed in the resistance and inductance in series circuit, as shown in figure 1. By each element of current ? serial communication circuit, voltage and current instantaneous value relationship:



(a) (b)

Figure 1 resistor, inductor in series circuit

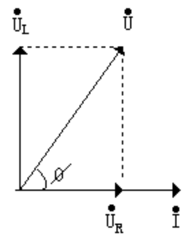


Figure 2 The voltage and current phasor diagram

$$u = u_R + u_L = Ri + L\frac{di}{dt} \quad (1)$$

Voltage and current phasor relationship:

$$\dot{U} = \dot{U}_R + \dot{U}_L = R\dot{I} + jX_L\dot{I} = (R + jX_L)\dot{I} = Z\dot{I} \quad (2)$$

The impedance:

$$Z = \frac{\dot{U}}{\dot{I}} = \frac{U\angle\varphi_u}{I\angle\varphi_i} = \frac{U}{I}\angle\varphi_u - \varphi_i = R + jX_L = \sqrt{R^2 + {X_L}^2}\angle\arctan\frac{X_L}{R} = |Z|\angle\varphi \quad (3)$$

Impedance model:

$$|Z| = \frac{U}{I} = \sqrt{R^2 + X_L{}^2} \tag{4}$$

Impedance Angle picture (phase difference between voltage and current):

$$\varphi = \varphi_u - \varphi_i = \arctan\frac{X_L}{R}, \quad （0<\varphi\leq 90^{o}） \tag{5}$$

Set the current: $i = I_m \sin\omega t$,The voltage $u = U_m \sin(\omega t + \varphi)$

As a reference to current phasor, voltage and current phasor diagram is shown in figure 2. By u, I instantaneous value expression and phasor diagram shows: voltage and current phase relationship is leading current φ, voltage that is: $\varphi_u = \varphi_i + \varphi$ 。

The relationship between the frequency of the voltage and current is the same frequency.

Power

Only in the inductive circuit resistance electric consumption, inductance don't consume electricity, have energy exchange between inductance and power supply. Resistance expressed in active power energy consumption of power, between inductance and power supply, said the scale of the exchange of energy with reactive power capacity of power supply in apparent power, power supply capacity into the proportion of the active power in power factor.

Instantaneous power:

$$p = ui = U_m I_m \sin(\omega t + \varphi)\sin\omega t \quad = UI\cos\varphi - UI\cos(2\omega t + \varphi) \tag{6}$$

Active power:

$$P = \frac{1}{T}\int_0^T pdt = \frac{1}{T}\int_0^T [UI\cos\varphi - UI\cos(2\omega t + \varphi)]dt = UI\cos\varphi \quad = U_R I = I^2 R = \frac{U_R^2}{R} \tag{7}$$

Reactive power:

$$Q = UI\sin\varphi = U_L I = I^2 X_L = \frac{U_L{}^2}{X_L} \tag{8}$$

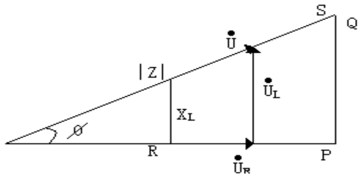
Apparent power:

$$S = UI = I^2|Z| = \frac{U^2}{|Z|} = \sqrt{P^2 + Q^2} \tag{9}$$

The power factor:

$$\cos\varphi = \frac{P}{UI} = \frac{P}{S} \tag{10}$$

Inductive circuit each impedance, voltage and the relationship between the power can be expressed in impedance, voltage and power triangle, respectively. In figure 2 voltage and current phasor diagram of three voltage $\dot{U}_R$ 、 $\dot{U}_L$ 、 $\dot{U}$ Form a triangle voltage, the voltage and the size of each side of the triangle, respectively and expand the current times, impedance and power triangle triangle, respectively. The triangle is similar impedance, voltage, power, the voltage vector triangle, triangle is shown in figure 3. By each triangle get the following corresponding relation, can make it easier for readers to analysis and memory between different impedance, the relationship between the voltage and power.

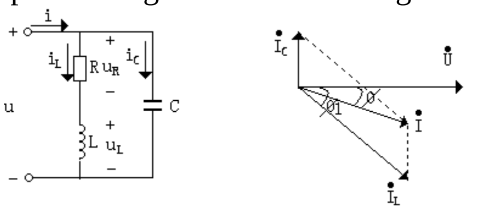


$$\begin{cases} R = |Z|\cos\varphi \\ X_L = |Z|\sin\varphi \\ |Z| = \sqrt{R^2 + X_L{}^2} \end{cases} \quad \begin{cases} U_R = U\cos\varphi \\ U_L = U\sin\varphi \\ U = \sqrt{U_R{}^2 + U_L{}^2} \end{cases} \quad \begin{cases} P = S\cos\varphi \\ Q = S\sin\varphi \\ S = \sqrt{P^2 + Q^2} \end{cases}$$

Figure 3 impedance, voltage, power triangle

The influence of shunt capacitance on the circuit

On both ends of inductive load parallel capacitor, it will affect the power factor of power supply or power grid, parallel capacitor can improve the power factor, appropriate circuit diagram and phasor diagram as shown in figure 4.



(a) circuit diagram (b) phasor diagram

Figure 4 capacitor with perceptual load in parallel to improve power factor

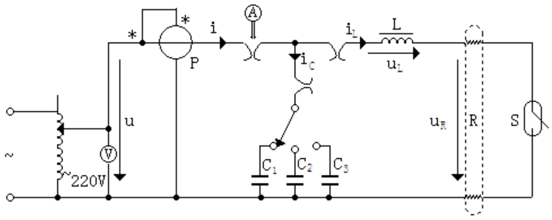


Figure 5 fluorescent lamp circuit experiment

After the inductive circuit shunt capacitance of the effect of various physical quantities in the circuit is as follows:

(1) the inductive load current $I_L = \frac{U}{\sqrt{R^2 + X_L{}^2}}$, power factor $\cos\varphi_1 = \frac{R}{\sqrt{R^2 + X_L{}^2}}$, active power $P = I_L{}^2 R$, resistance voltage $U_R = I_L R$ and inductance voltage $U_L = I_L X_L$ do not changes;

(2) the phase difference between the power supply voltage and line current changes (φ by $\varphi_1 \to \varphi$), the power factor of power change ($\cos\varphi$ by $\cos\varphi_1 \to \cos\varphi$), line current changes (I by $I_L \to I$), reactive power changes (Q by $I_L{}^2 X_L \to I_L{}^2 X_L - I_C{}^2 X_C$).

Inductive circuit in parallel capacitor after appropriate because of the phase difference between voltage and line current, So the power factor of power supply or power grid get bigger (as shown in figure 4 (b)), often adopt this method in engineering to improve the power factor of the inductive circuit, parallel capacitor of capacitance value can be used to launch the formula to calculate. In figure 4 (b) **:**

$$I_C = I_1 \sin\varphi_1 - I\sin\varphi = (\frac{P}{U\cos\varphi_1})\sin\varphi_1 - (\frac{P}{U\cos\varphi})\sin\varphi = \frac{P}{U}(\tan\varphi_1 - \tan\varphi)$$

And because of $I_C = \frac{U}{X_C} = U\omega C$

So $U\omega C = \frac{P}{U}(\tan\varphi_1 - \tan\varphi)$

driven $C = \frac{P}{\omega U^2}(\tan\varphi_1 - \tan\varphi)$

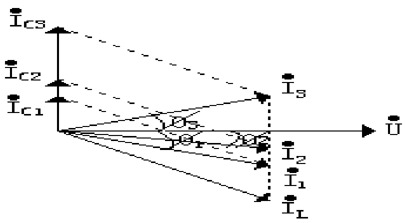


Figure 6 different perceptual load in parallel capacitance effects on total current

The result of the experiment and analysis

In order to verify the characteristics of the inductive circuit using fluorescent lamp circuit experiment, and the experimental results were analyzed. The experimental circuit as shown in figure 5, R in the figure as the daylight lamp, L for ballast, S for starter, from C_1 to C_3 capacitor, P for power meter (power factor and test), V for voltmeter, for A current meter. Using TKDG1 electrotechnics experiment device testing,as shown in the experimental data are shown in table 1.

Through the experimental data found the following phenomena:

(1) voltage power supply voltage, ballasts, ballasts for fluorescent tube voltage, current and active power in different shunt capacitance in the basic do not change;

(2) circuit current, capacitance current and power factor In different parallel capacitance in change. Is along with the rising of the shunt capacitance values, the changes of total current circuit, increase with the decrease of the first capacitive current increases, power supply power factor First

increases then decreases. And parallel 2.0μF , 4.7μF capacitor circuit is inductive, 6.7μF is capacitive capacitance in circuit in parallel. That is to improve the power factor of the inductive load must be parallel capacitance, appropriate if the shunt capacitance values are not proper power factor will drop.

Table 1 experimental data form

Shunt capacitance (uF)	Measuring physical quantities and values							
	U (V)	U_L (V)	U_R (V)	I (A)	I_L (A)	I_C (A)	P (W)	cosφ
0	220.1	182.5	93.9	0.387	0.389	0	37.7	L0.45
2.0	220.2	182.2	93.8	0.261	0.388	0.160	37.3	L0.68
4.7	220.0	182.7	93.7	0.195	0.390	0.342	37.5	L0.99
6.7	220.3	182.9	93.5	0.256	0.391	0.505	37.7	C0.77
Changes in	Don'tchange	Don'tchange	Don'tchange	change	Don'tchange	change	Don'tchange	change

Why can appear the phenomenon? Because of different fluorescent lamp circuit in parallel capacitance value, The power supply voltage, daylight lamp resistance, ballast resistor, ballast impedance, angular frequency are the same. So ballast current, voltage constant, fluorescent tube voltage constant, the active power unchanged; Along with the rising of the shunt capacitance values, by capacitance current $I_C = \omega CU$ also increases (as shown in figure 6, by $I_{C1} \to I_{C2} \to I_{C3}$), and capacitive current $\dot{I}_C$ voltage $\dot{U}$ 90° in advance. $\dot{I} = \dot{I}_L + \dot{I}_C$,because $\dot{I}_L$ is changeless, by the total current I phasor diagram 6 shows the line from the change trend of increase with the decrease of the first(by $I_1 \to I_2 \to I_3$); The power supply voltage $\dot{U}$ and line current $\dot{I}$ phase Angle φ From the change trend of increase with the decrease of the first(by $\varphi_1 \to \varphi_2 \to \varphi_3$); The power factor $\cos\varphi$ First increases then decreases. Fluorescent lamp can be seen from the phasor diagram can also be other 2.0μ F, 4.7 μF capacitance circuit in parallel, the line current $\dot{I}_1$、$\dot{I}_2$ lags behind the voltage $\dot{U}$, so the circuit is inductive; And 6.7 μF capacitance in parallel circuit the total current $\dot{I}_3$ ahead of voltage $\dot{U}$, so the circuit with capacitive.

Conclusion

By means of inductive communication circuit of theoretical research and experimental results analysis the following conclusions:

(1) the inductive circuit is the total voltage and current relationship between the number of RMS voltage, current and impedance model conforms to the ohm's law, advance phase relationship as the voltage current φ Angle （$0<\varphi\leq 90^{\circ}$）, frequency relationship for the voltage, current and frequency;

(2) the inductive circuit load to calculate the power with the active power energy exchange between inductance and power energy with reactive power calculation, the size of the power supply capacity by the method of apparent power, power supply capacity into the proportion of active power by power factor calculation;

(3) the inductive circuit in parallel capacitance value appropriately can improve the power factor, the parallel capacitance values are not properly can reduce the power factor.

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