Experiment 2：Line Frequency Alternating Current Source Applications

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1. Aim

(1) Study how to plan to test the parameters of an iron-cored coil .
(2) Know how to measure three-phase source and three-phase circuits.
(3) Learn to use Wattmeter, Ammeter and digital multimeter properly.
(4) Study measuring the power pf single-phase and three-phase circuits.
(5) Verify the way to improve power efficiency.
(6) Understand the relationship between phase sequence, voltages, rotating directions and speed of AC asynchronous motors.

2. Principle and method

2.1 Plan to test the parameters of an iron-cored coil.

(1) Test the resistance R_L and inductance L of the iron-cored coil under line-frequency source by instruments supplied.

(2) By connecting 4 different values of capacitors with the inductor, study the effects on circuit parameters, and find out the capacitance which is needed to be paralleled with the inductor to achieve maximum power factor *cosΦ*.

2.2 Three-phase circuit

(1) Measure the parameters of Y-type loads.

(2) Measure the parameters of △-type loads.

2.3 Analysis and discussion for testing parameters of an iron-cored coil.

(1) For iron-cored coil, the medium is magnetic material.

(2) The resistance R_L and inductance L will be changing under different AC voltage.

(3) R_L and L are none-linear with U_i .

(4) Measuring and calculating parameters.

$$P = U*I*\cos\Phi$$

$$Z = U / I$$

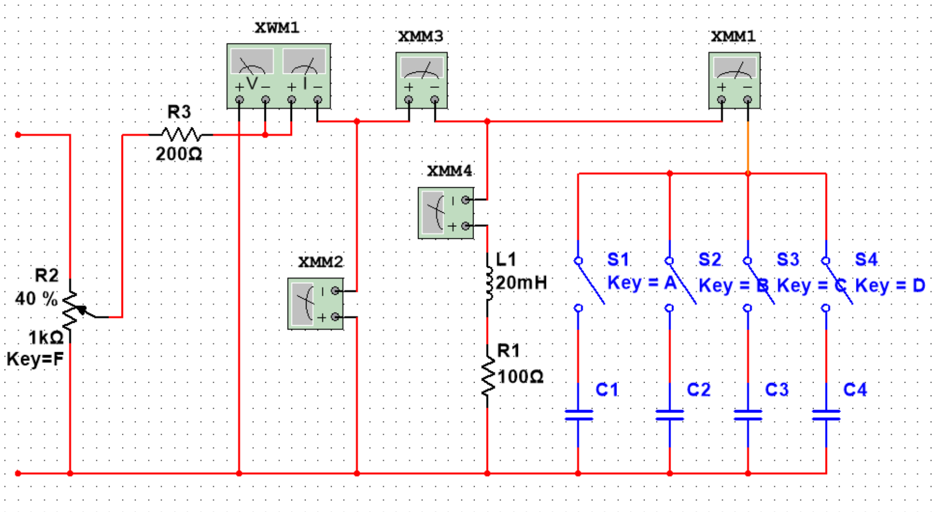
$$P = I^2R_L$$

$$L = \sqrt{Z^2 - R_L^2}/2\pi f$$

(5)Three-phase asynchronous motor

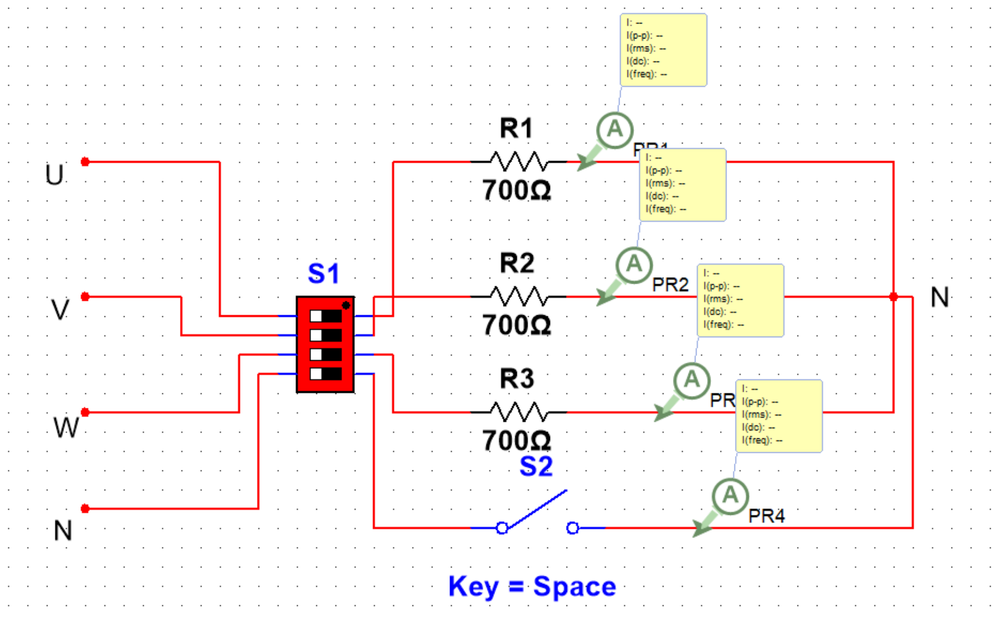
3. Experiment circuits

3.1 Reference circuit of iron-cored coil parameter measurement

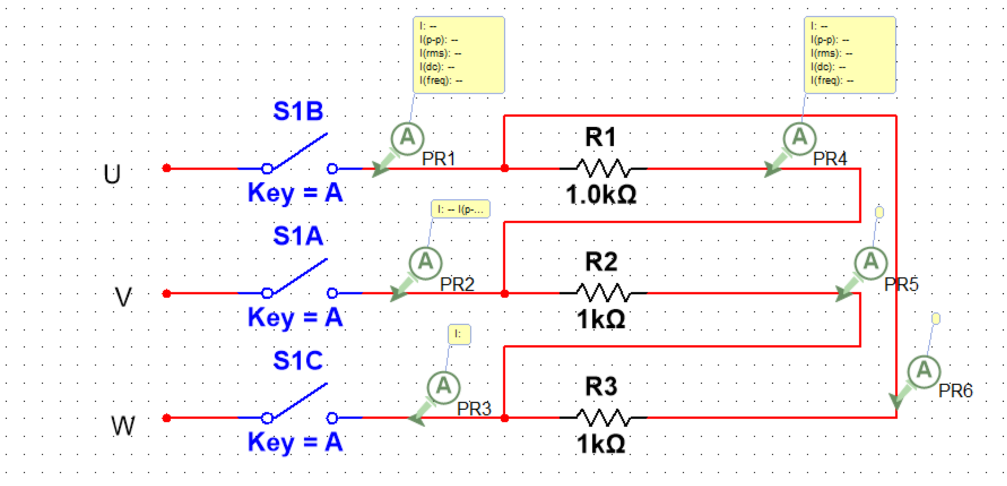


3.2 Three-phase power and three-phase loads circuits

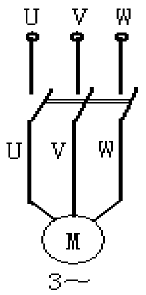
Y-type loads:



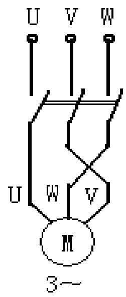
Δ-type loads:



3.3 Three-phase induction motor circuits



(a) Phase sequence UVWU



(b) Phase sequence UWVU

4. Instruments

(1) Current plug and sockets, and voltage test pens
(2) Ammeter
(3) Digital multimeter
(4) Wattmeter

Can be used to measure average power of AC circuits.

$$\text{Range}_{\text{Power}}\,(\text{fsd}) = \text{Range}_{I} \times \text{Range}_{U}$$

Methods to measuring three-phase circuit power：

One wattmeter → Symmetrical loads, $P_T=3*P_1$；

Two watt meters → every junction current is zero, $P_T=P_1+P_2$；

Three watt meters → fit to all circuits, $P_T=P_1+P_2+P_3$；

Method to measuring single-phase circuit power：branch power.

(5) Three-Phase Power
(6) Experiment Board
(7) 3 groups of windings and connections of 3-phase asynchronous motors

5. Tasks

(1) Iron-cored coil parameters measurement

1.1 Based on design plan, measure the parameters in data table. Calculate the values of R_L and L under given current, and calculate cosφ of inductor.

1.2 Study the effects on circuit parameters after the inductor is parallel with capacitors. Find the capacitance to achieve maximum cosφ.

1.3 Observe whether there is any effect when I_L changes, to further understand the meaning of component working parameter.

(2) Y-type loads circuit

Construct Y-type loads circuit, and measure the parameters according to table 2-1 on page 13 of Lab Manual.

(3) △-type loads circuit

Construct △-type loads circuit, and measure the parameters according to table 2-2 on page 13.

(4) Observe the rotation of 3-phase asynchronous motor under different connections.

6. Data collation and analysis

6.1 Data table of iron-cored coil parameter measurement

The range of wattmeter: 120v(15000Ω for inner resistance) and 0.5A(0.15Ω for inner resistance). I measure power P1 and P2 by external connection and internal connection.

Calculate Cosφ：

$S = U_L * I_L$ (1) $\quad P_L = U_L * I_L * \text{Cos}\varphi$ (2)

$P_L = P_T - I_L^2 * R1$ (3) $\quad U_L = U_T - I_L * R_1$ (4)

R1=100Ω

According to the above formula, for inductance L, $= \frac{P_T - I_L^2 * R_1}{(U_T - I_L * R_1) * I_T}$

For circuit, Cosφ=$\frac{P_T}{U_T * I_T}$

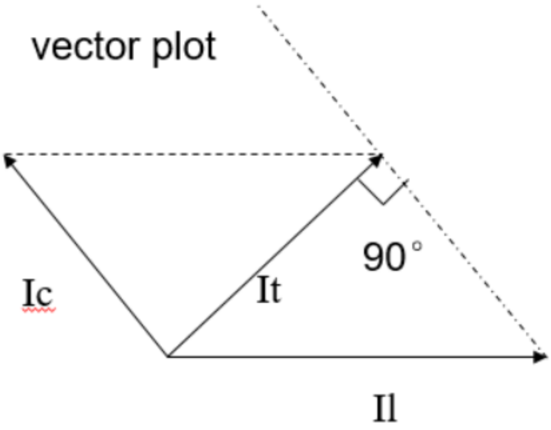
To reduce error, I choose $P_T = (P_1 + P_2)/2$

I calculate Cosφ(L)=0.1282

Capacitor C(uF)	Input voltage U(V)	Total Current I_T（A)	Inductor Current I_L(A)	Capacitor Current I_C(A)	Power P(W)		CosΦ (Totel)
					P2	P1	-----
0	79.0	0.400	0.4	0	18.0	18.0	0.5696
4.7	79.0	0.310	0.4	0.116	17.7	18.0	0.7289
6.9	79.2	0.275	0.4	0.170	17.9	18.0	0.8242
10	79.7	0.245	0.4	0.254	18.05	18.5	0.9359
12.2	79.0	0.227	0.4	0.3095	17.7	18.0	0.9954
15.7	79.0	0.235	0.4	0.399	17.7	18.0	0.9615

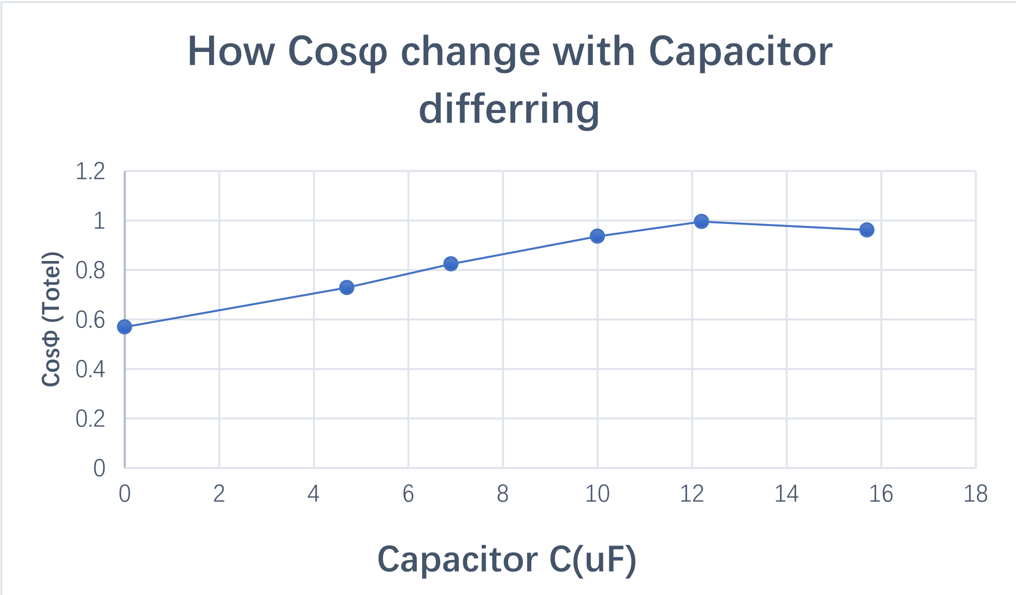
Form6.1 iron-cored coil parameter measurement

From line chart above, my solution is: When a 12.2 μF capacitor was paralleled, the Power factor of whole circuit reaches maximum.



When capacitors are paralleled, Ic starts growing. In the vector plot, Il is stable. So, with the increase of Ic, It firstly increases than decreases. It reaches minimum when It is vertical with Ic. At this moment, Ic、It and Il meet the relation:

$I_T^2 = I_L^2 - I_C^2$.



As I had mentioned,

Cosφ=$\frac{P_T}{U_T * I_T}$.

Because P_T *and* U_T are stable, when It turns to be minimum, Cosφ turns to be maximum. From my data and analysis, the theoretical and experimental results are in good agreement.

6.2 A summary of the experiment 1

When designing circuit, I didn't think of Current limiting resistor. In this experiment, I realized that:

First, I should think of ways to keep circuit safe.

Second, use components that we already have.

Third, experimental design should be simple and feasible.

6.3 Data table of Three-phase power and three-phase loads circuits

6.3.1 Y-loads

I choose the Ammeter with a range of 0.5A(1.4Ω).

Measurement items / Measurement conditions				Line Voltage/V			Phase Voltage/V			Line current or phase current/A			Neutral (Current/A Voltage/V)		Brightness changes of every light
				U_{UV}	U_{VW}	U_{WU}	$U'_{UN'}$	$U'_{VN'}$	$U'_{WN'}$	I_U	I_V	I_W	I_N	U'_{NN}	
Y-type loads	Symmetry	Each phase has a light	Neutral	372.3	372.0	372.1	212.0	212.0	211.3	0.400	0.399	0.396	0	2.6	Basic
			Non-Neutral	373.2	373.0	372.4	212.4	211.5	212.2	0.3905	0.391	0.391	0	2.4	Basic
	Asymmetry	Only phase V、W has a light	Neutral	377.9	375.2	379.3	219.2	216.0	215.6	0	0.399	0.399	0.396	3.1	Yellow light off, no other change
			Non-Neutral	377.6	373.6	379.7	328.5	186.8	186.2	0	0.346	0.345	0	109.0	Yellow light off, others darken

Form 6.2 measurement for Y-type loads

I use 380V for Y-type loads mistakenly. Next time when I don't know setting values, I should ask teachers or read my experiment manual.

Solution:

(1) $U_{Line}\ is\ equal\ to\ around\ \sqrt{3} * U_{phase}$.

(2) If symmetry, Neutral line has no effect; if asymmetry, Neutral line can keep load voltage staple.

(3) Theoretically, U'_{NN} should be 0V. But because of wire resistance, it's a little more than ideal value.

6.3.2 △-loads

I choose the Wattmeter with a range of 240V(30000Ω) and 1A(0.03Ω).

There are two methods of measuring power: Two-meter method and Three-meter method. Two-meter method requires to measure line voltage and line current, then total power is the sum of two power. Three-meter method measures power of every load, and add them together to get total power.

conditions	Line voltage/V			Line current/A			Phase current/A		
	U_{UV}	U_{VW}	U_{WU}	I_U	I_V	I_W	I_{UV}	I_{VW}	I_{WU}
Symmetry Δ-loads, a light for each phase	216.8	216.0	216.1	0.700	0.700	0.700	0.404	0.400	0.404

conditions	P_{Total}/W										
	Two-meter method			Three-meter method				Power of each phase			
Symmetry Δ-loads, a light for each phase	132.0	131.6	263.6	88.0	88.0	88.0	264.0	87.6	86.4	87.3	261.3

Form 6.3 measurement for △-type loads

Solution :

(1) Both Two-meter method and Three-meter method can get total power, Two-meter method is more accurate.

(2) Internal resistance and instability of source may cause test error.

6.4 Measurement of three-phase asynchronous motor

Motor terminals / Times	Z	X	Y	Rotation direction from the right
1	W	U	V	Counterclockwise
2	W	V	U	Clockwise
3	V	W	U	Counterclockwise

If I decrease input voltage, rotating speed slows down.

Solution:

(1) Change phase sequence, rotation direction turns opposite.

(2) The bigger input voltage, the more power, leading to higher rotating speed. I think internal resistance and internal structure of motor can also influence rotating speed.

7. Summary and problem discussion

(1) In this experiment, I learn that how to design a circuit to measure Three-phase AC. I also know how to choose suitable range of ammeter and wattmeter. I know the method of measuring power of Y-load and △-load. Power do not just depend on U and I, however, power factor plays a important role.

(2) My speed of finishing experiment is slower than others. I think it’s the reason that I am often unclear of experiment operation. Next time, I should always think first before action.