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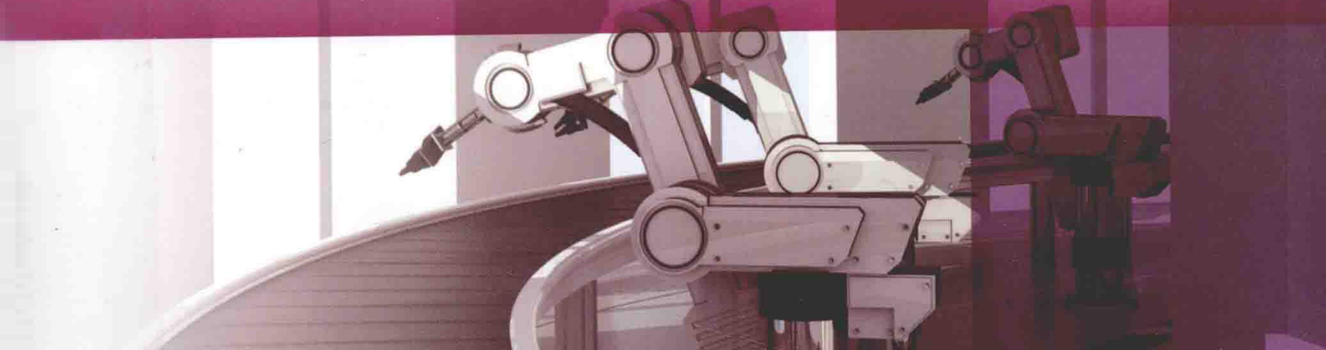
电气工程、自动化专业规划教材

自动化专业英语教程

戴文进 魏 萍 编著



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自动化专业英语教程

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内 容 简 介

本书共分电工电子、电动机及其拖动、控制理论与控制工程、计算机及其运用、智能技术 5 大部分，每一部分分别包含英语原文（全部出自原版书籍与文献）、专业英语词汇、课文注释、参考译文 4 个部分。本书取材新颖，内容丰富，注释详尽，译文准确。

本书可作为自动化专业英语的适用教材，也可作为其他相近专业的参考书，还可供有关技术人员选用。

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前　言

自动化专业英语是自动化专业的一门重要的专业基础课程，该门课程的学习，对于学生将所学的基础英语如何运用于自动化专业领域，具有很重要的作用。

作者在这门课程长期的教学实践中，积累了一定的教学经验和教学素材，现编著成《自动化专业英语教程》一书，由电子工业出版社出版。本书共分电工电子、电动机及其拖动、控制理论与控制工程、计算机及其运用、智能技术5大部分，每一部分又分别包含英语原文（全部出自原版书籍与文献）、专业英语词汇、课文注释、参考译文4个部分。

本书取材新颖、内容丰富、注释详尽、译文准确，是自动化专业英语的适用教材，也可作为其他相近专业的参考书，还可供有关技术人员选用。

本书由南昌大学戴文进教授和魏萍副教授编写，其中魏萍老师撰写了第一部分，即Part 1，戴文进老师撰写了其余4个部分，即Part 2到Part 5。我们虽然长期工作在教学第一线，且对专业英语课程的教学内容和方法有一定体会，但毕竟水平有限，故书中谬误之处在所难免，敬请读者不吝指正。

编著者

2016年6月

目　　录

Part 1

Electrics & Electronics

Unit 1 Generation of Three-Phase Voltages

1.1 Text

Generation, transmission, and heavy-power utilization of ac electric energy almost invariably involve a type of system or circuit called a poly-phase system or poly-phase circuit. *In such a system, each voltage source consists of a group of voltages having related magnitudes and phase angles.* 【1】 *Thus, a q-phase system employs voltage sources which typically consist of q voltages substantially equal in magnitude and successively displaced by a phase angle of $360^{o}/q$.* 【2】 A three-phase system employs voltage sources which typically consist of three voltages substantially equal in magnitude and displaced by phase angles of 120^{o}.Because it possesses definite economic and operating advantages, the three-phase system is by far the most common, and consequently emphasis is placed on three-phase circuits in this appendix.

The three individual voltages of a three-phase source may each be connected to its own independent circuit. We would then have three separate single-phase systems. Alternatively, as will be shown in Section A.1, symmetrical electric connections can be made between the three voltages and the associated circuitry to form a three-phase system. It is the latter alternative that we are concerned with in this appendix. Note that the word phase now has two distinct meanings. It may refer to a portion of a poly-phase system or circuit, or, as in the familiar steady-state circuit theory, it may be used in reference to the angular displacement between voltage or current phasors. *There is very little possibility of confusing the two.* 【3】

Consider the elementary two-pole, three-phase generator of Fig.1.1.1. On the armature are three coils aa',bb',and cc' whose axes are displaced $120°$ in space from each other. This winding can be represented schematically as shown in Fig.1.1.2. When the field is excited and rotated, voltages will be generated in the three phases in accordance with Faraday's law. *If the field structure is designed so that the flux is distributed sinusoidally over the poles, the flux linking any phase will vary sinusoidally with time, and sinusoidal voltages will be induced in the three phases.* 【4】As shown in

APPENDIX A Three-Phase Circuits

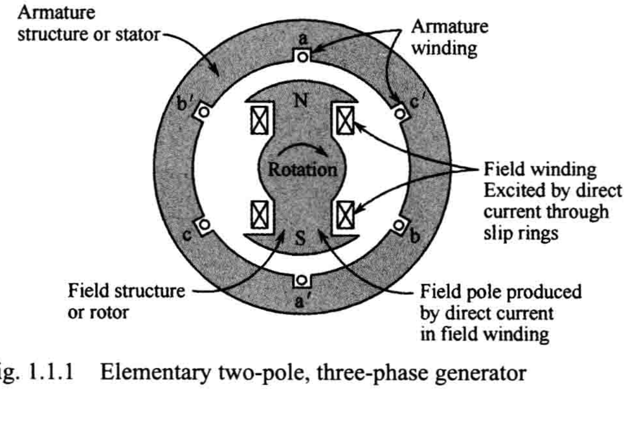

Fig. 1.1.1 Elementary two-pole, three-phase generator

Fig.1.1.3, these three voltages will be displaced 120° electrical degrees in time as a result of the phases being displaced 120° in space. The corresponding phasor diagram is shown in Fig.1.1.4. In general, the time origin and the reference axis in diagrams such as Fig.1.1.3 and Fig.1.1.4 are chosen on the basis of analytical convenience.

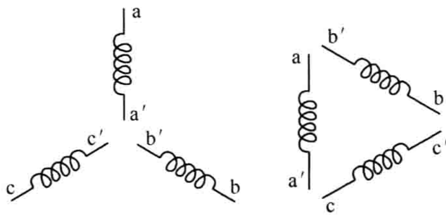

Fig. 1.1.2 Schematic representation of the windings of Fig. 1.1.1

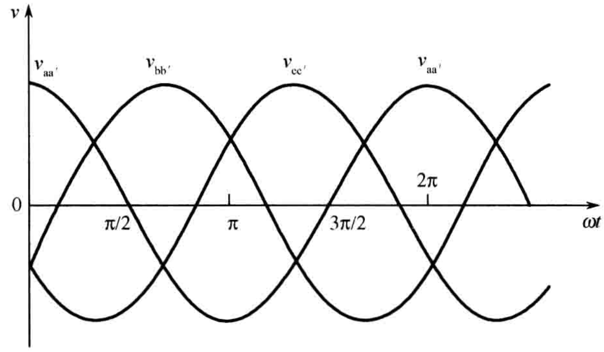

Fig.1.1.3 Voltages generated in the windings of Fig.1.1.1 and Fig.1.1.2

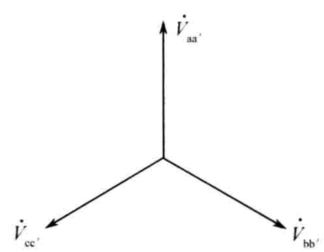

Fig.1.1.4 Phasor diagram of generated voltages

There are two possibilities for the utilization of voltages generated in this manner. The six terminals a, a', b, b', c, and c' of the three-phase winding may be connected to three independent single-phase systems, or the three phases of the winding may be interconnected and used to supply a three-phase system. The latter procedure is adopted almost universally. The three phases of the winding may be interconnected in two possible ways, as shown in Fig.1.1.5. Terminals a', b', and c' may be joined to form the neutral n, yielding a Y connection, or terminals a and b', b and c', and c and a' may be joined individually, yielding a Δ connection. In the Y connection, a neutral conductor, shown dashed in Fig.1.1.5a, may or may not be brought out. If a neutral conductor exists, the system is a four-wire, three-phase system; if not, it is a three-wire, three-phase system. In the Δ connection (Fig.1.1.5b), no neutral exists and only a three-wire, three-phase system can be formed.

The three-phase voltages of Fig.1.1.3 and Fig.1.1.4 are equal and displaced in phase by 120 degrees, a general characteristic of a balanced three-phase system. Furthermore, in a balanced three-

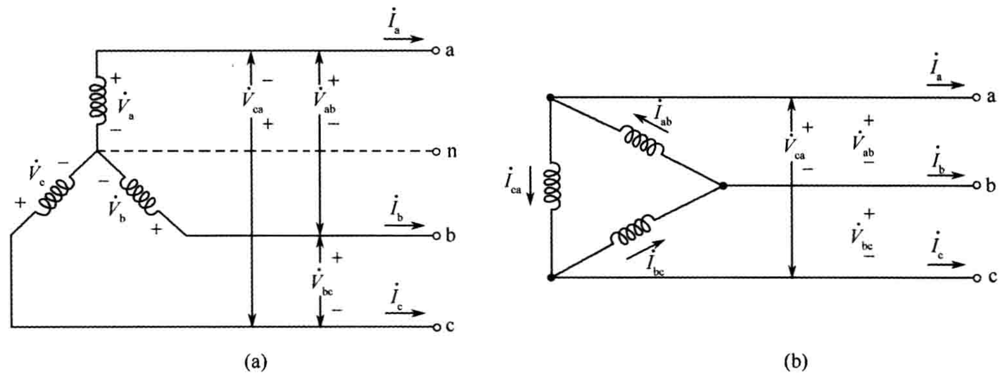

Fig. 1.1.5 Three-phase connections: (a) Y connection and (b) Δ connection

phase system the impedance in any one phase is equal to that in either of the other two phases, so that the resulting phase currents are also equal and displaced in phase from each other by 120 degrees. Likewise, equal power and equal reactive power flow in each phase. An unbalanced three-phase system, however, may be unbalanced in one or more of many ways; the source voltages may be unbalanced, either in magnitude or in phase, or the phase impedances may not be equal. Note that only balanced systems are treated in this appendix, and none of the methods developed or conclusions reached apply to unbalanced systems. Most practical analyses are conducted under the assumption of a balanced system. Many industrial loads are three-phase loads and therefore inherently balanced, and in supplying single-phase loads from a three-phase source definite efforts are made to keep the three-phase system balanced by assigning approximately equal single-phase loads to each of the three phases.

1.2 Specialized English Words

generation	发电
transmission	输电
heavy-power utilization	大功率电气设备
ac electric energy	交流电能
three-phase system(circuit)	三相系统（电路）
steady-state circuit theory	稳态电路理论
angular displacement	相位移
voltage(current)phasor	电压（电流）相量
armature	电枢
coil	线圈
winding	绕组
Faraday's law	法拉第电磁感应定律
Sinusoidally	正弦
electrical degree	电角度
neutral	中性（点）
a three-wire, three-phase system	三相三线制系统

a four-wire, three-phase system	三相四线制系统
power flow	有功潮流
reactive power flow	无功潮流
unbalanced three-phase system	不对称三相系统
balanced three-phase system	对称三相系统

1.3 Notes

【1】In such a system, each voltage source consists of a group of voltages having related magnitudes and phase angles.句中，“having related magnitudes and phase angles”是一个现在分词短语，其做名词“voltages”的后置定语，所以全句译成：“在这种系统中，供电电压是由其值和相位都有相互关联关系的一组电压组成”。

【2】Thus, a q-phase system employs voltage sources which typically consist of q voltages substantially equal in magnitude and successively displaced by a phase angle of 360°/q.这是一个主从复合句，其主句为：“a q-phase system employs voltage sources”，由定语从句的引导词“which”引导的定语从句：“typically consist of q voltages substantially equal in magnitude and successively displaced by a phase angle of 360°/q”做名词“voltage sources”的后置定语，所以全句译成：“因此，组成 q 相系统的就是其大小基本相等，而相位角则互差 360°/q 的 q 相电压”。

【3】There is very little possibility of confusing the two.这句话其实很简单，主要是要注意“little”这个词的含义，也即要分清“little”与“a little”的区别：“little”表示“没多少”，而“a little”表示“有一些”。所以，该句应译为：“这两者之间几乎不会有什么歧义”。

【4】 If the field structure is designed so that the flux is distributed sinusoidally over the poles, the flux linking any phase will vary sinusoidally with time, and sinusoidal voltages will be induced in the three phases. 这个句子结构比较复杂，从总体上看，它是一个由并列连词“and”将两个子句：“If the field structure is designed so that the flux is distributed sinusoidally over the poles, the flux linking any phase will vary sinusoidally with time”和“sinusoidal voltages will be induced in the three phases”连接起来的并列复合句。只不过前一个子句本身又比较复杂，从总体上看，它是一个由“If”引导的条件状语从句“the field structure is designed so that the flux is distributed sinusoidally over the poles”与主句“the flux linking any phase will vary sinusoidally with time”组成的主从复合句。只不过该条件状语从句“the field structure is designed so that the flux is distributed sinusoidally over the poles” 本身又是一个主从复合句，其主句是：“the field structure is designed”，从句是由“so that”引导的结果状语从句：“the flux is distributed sinusoidally over the poles”。所以，全句应译为：“如果磁场的结构设计使得磁通沿磁极表面正弦分布的话，那么任一相的磁链也就随时间正弦变化了，因而在三相绕组中便产生三相正弦电压”。

值得一提的是：主结构上的并列连词“and”，在语法上起连接两子句的作用，其语法意义是“并列”的，但其在含义上并不是“并列”的，而是“递进”的。

1.4 Translation

三相电压的产生

交流电能的产生、输送及其大功率电气设备，几乎都要涉及多相系统或多相电路。在这种系统中，供电电压是由其值和相位都有相互关联关系的一组电压组成。因此，组成 q 相系统的就是其大小基本相等，而相位角则互差 $360°/q$ 的 q 相电压。组成三相系统的就是其大小基本相等，而相位角则互差 120°的三相电压。因为其拥有确定无疑的经济和运行方面的优越性，因此三相系统是迄今为止最为通用的系统。这样，三相电路自然也便成了本附录中的重点。

三相电源中的三个不同的电压，可分别接至各自不同的电路。这样，便可有三个不同的单相系统。换句话说，正像将在 A.1 节中看到的那样，可在三相电压与对应的三相电气设备之间形成一个三相系统。正是后面的那种变换，便有了读者与本附录的渊源。请注意，“相”这个词现在有了两个不同的含义。其可以指多相系统或电路中的一个部分，也可像在众所周知的稳态电路理论中的那样，用来表示电压或电流相量之间的相位移。这两者之间几乎不会有什么歧义。

如图 1.1.1 所示，有一台简单的两极三相发电机。在其电枢中有三个线圈 aa′,bb′ 和 cc'，其轴线在空间互差 120°的电角度。这个绕组用可图表示之，如图 1.1.2 所示。当有励磁且电机的转子在旋转时，根据法拉第电磁感应定律，在三相绕组中就会产感应生感应电压。如果磁场的结构设计使得磁通沿磁极表面正弦分布的话，那么任一相的磁链也就随时间正弦变化了，因而在三相绕组中便产生三相正弦电压。如图 1.1.3 所示，由于相绕组在空间互差 120°，因而这三相电压在时间上便互差 120°电角度。相应的相量图如图 1.1.4 所示。通常，在像如图 1.1.3 和图 1.1.4 所示的那些图中的时间起点和参考轴的选取，都是基于分析方便上的考虑。

按这种方法发出的电压可采取两种方法取出。可将三相绕组的 6 个端点 a、a'、b、b'、c 和 c'分别连接到三个单相系统，也可将该绕组的三个相相互连接起来对一个三相系统供电。经常采用的几乎都是后一种方式。如图 1.1.5 所示，绕组的三个相可有两种连接方式。可将端点 a'、b'和 c'连接起来形成中性点 n，进而接成 Y 接法；也可将端点 a 和 b'、b 和 c'、c 和 a'分别连接起来从而接成Δ接法。在 Y 接法中，从中性点 n 引出的导线（在图 1.1.5a 中已略去）可有可无。如果有的话，该系统则称之为三相四线制；如果没有，则称之为三相三线制。在Δ接法（如图 1.1.5b 所示）中，由于没有中性点，因而只能接成三相三线制系统。

如图 1.1.3 和图 1.1.4 所示的三相电压其大小相等，相位上互差 120°，这是一个典型的三相对称系统。此外，在三相对称系统中，任意一相的阻抗也均与其他两相中的阻抗相等，因此各相中的相电流也大小相等，相位上互差 120°。同理，各相中的有功潮流和无功潮流均相等。然而，对于不对称系统来说，其不对称可以有一种或多种方式：也许是电源电压不对称，这又可能是电压值的大小不等，也可能是相位上不是互差 120°，或者两者皆有之；也有可能是各相的阻抗不相等。要注意的是：本附录只论及对称系统，且其导出的方法和结论均不适用于不对称系统。在实际中，分析大都在对称系统的假定前提下进行。许多工业负载都是三相负载，因而原本都是对称的，而在用三相电源对单相负载供电时，肯定会竭尽全力地通过在每相中尽量配置相等的单相负载，以维持三相系统的对称。

Unit 2　Three-phase Voltages, Currents and Power

2.1　Text

When the three phases of the winding in Fig.1.1.1 are Y-connected, as in Fig. 1.1.5a, the phasor diagram of voltages is that of Fig.1.2.1 The phase order or phase sequence in Fig 1.2.1 is abc; that is, the voltage of phase a reaches its maximum 120° before that of phase b.

The three-phase voltages $\dot{V}_a$, $\dot{V}_b$ and $\dot{V}_c$ are called line-to-neutral voltages. The three voltages $\dot{V}_{ab}$, $\dot{V}_{bc}$, and $\dot{V}_{ca}$ are called line-to-line voltages. The use of double-subscript notation in Fig.1.2.1 greatly simplifies the task of drawing the complete diagram. The subscripts indicate the points between which the voltage is determined; for example, the voltage $\dot{V}_{ab}$ is calculated as $\dot{V}_{ab} = \dot{V}_a - \dot{V}_b$.

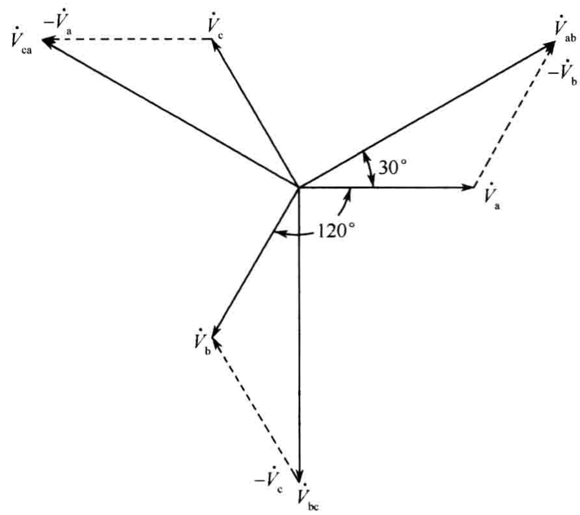

Fig.1.2.1　Voltage phasor diagram for a Y-connected system

By Kirchhoff 's voltage law, the line-to-line voltage $\dot{V}_{ab}$ is

$$\dot{V}_{ab} = \dot{V}_a - \dot{V}_b = \sqrt{3}\dot{V}_a \angle 30° \qquad (1.2.1)$$

as shown in Fig. 1.2. 1 Similarly,

$$\dot{V}_{bc} = \sqrt{3}\dot{V}_b \angle 30° \qquad (1.2.2)$$

and

$$\dot{V}_{ca} = \sqrt{3}\dot{V}_c \angle 30° \qquad (1.2.3)$$

These equations show that the magnitude of the line-to-line voltage is $\sqrt{3}$ tunes the line-to-neutral voltage.

When the three phases are Δ -connected, the corresponding phasor diagram of currents is given in Fig 1.2.2. The Δ currents are $\dot{I}_{ab}$, $\dot{I}_{bc}$, and $\dot{I}_{ca}$. By Kirchhoff 's current law, the line current $\dot{I}_a$ is

$$\dot{I}_{\mathrm{a}} = \dot{I}_{\mathrm{ab}} - \dot{I}_{\mathrm{ca}} = \sqrt{3} I_{\mathrm{ab}} \angle -30^\circ \tag{1.2.4}$$

as can be seen from the phasor diagram of Fig 1.2.2. Similarly,

$$\dot{I}_{\mathrm{b}} = \sqrt{3} I_{\mathrm{bc}} \angle -30^\circ \tag{1.2.5}$$

and

$$\dot{I}_{\mathrm{c}} = \sqrt{3} I_{\mathrm{ca}} \angle -30^\circ \tag{1.2.6}$$

Stated in words, Eqs. 1.2.4 to 1.2.6 show that for a Δ connection, the magnitude of the line current is $\sqrt{3}$ times that of the Δ current. As we see, the relations between Δ currents and line currents of a Δ connection are similar to those between the line-to-neutral and line-to-line voltages of a Y connection.

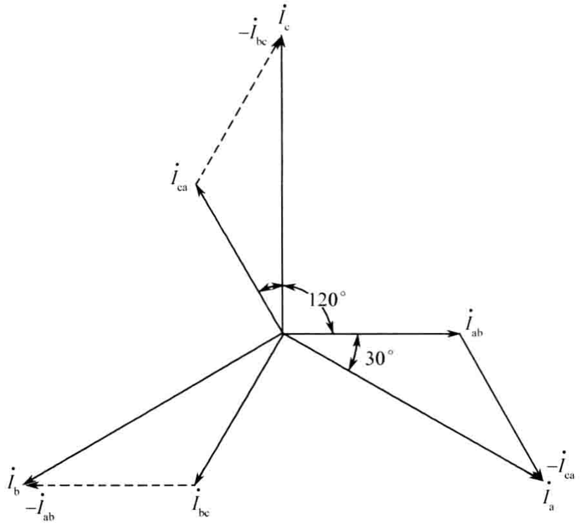

Fig. 1.2.2 Current phasor diagram for Δ connection

With the time origin taken at the maximum positive point of the phase-a voltage wave, the instantaneous voltages of the three phases are

$$v_{\mathrm{a}}(t) = \sqrt{2} V_{\mathrm{rms}} \cos \omega t \tag{1.2.7}$$

$$v_{\mathrm{b}}(t) = \sqrt{2} V_{\mathrm{rms}} \cos(\omega t - 120^\circ) \tag{1.2.8}$$

$$v_{\mathrm{c}}(t) = \sqrt{2} V_{\mathrm{rms}} \cos(\omega t + 120^\circ) \tag{1.2.9}$$

where V_{rms} is the rms value of the phase-to-neutral voltage. When the phase currents are displaced from the corresponding phase voltages by the angle θ, the instantaneous phase currents are

$$i_{\mathrm{a}}(t) = \sqrt{2} I_{\mathrm{rms}} \cos(\omega t + \theta) \tag{1.2.10}$$

$$i_{\mathrm{a}}(t) = \sqrt{2} I_{\mathrm{rms}} \cos(\omega t + \theta - 120^\circ) \tag{1.2.11}$$

$$i_{\mathrm{c}}(t) = \sqrt{2} I_{\mathrm{rms}} \cos(\omega t + \theta + 120^\circ) \tag{1.2.12}$$

where I_{rms} is the rms value of the phase current.

The instantaneous power in each phase then becomes

$$P_{\mathrm{a}}(t) = v_{\mathrm{a}}(t) i_{\mathrm{a}}(t) = V_{\mathrm{rms}} I_{\mathrm{rms}} \left[\cos(2\omega t + \theta) + \cos\theta\right] \tag{1.2.13}$$

$$P_{\mathrm{b}}(t) = v_{\mathrm{b}}(t) i_{\mathrm{b}}(t) = V_{\mathrm{rms}} I_{\mathrm{rms}} \left[\cos(2\omega t + \theta - 240^\circ) + \cos\theta\right] \tag{1.2.14}$$

$$P_{\mathrm{c}}(t) = v_{\mathrm{c}}(t) i_{\mathrm{c}}(t) = V_{\mathrm{rms}} I_{\mathrm{rms}} \left[\cos(2\omega t + \theta + 240^\circ) + \cos\theta\right] \tag{1.2.15}$$

Note that the average power of each phase is equal

$$< P_a(t) >=< P_b(t) >=< P_c(t) >= V_{rms} I_{rms} \cos\theta \tag{1.2.16}$$

The phase angle θ between the voltage and current is referred to as the power-factor angle and $\cos\theta$ is referred to as the power factor. If θ is negative, then the power factor is said to be lagging; if θ is positive, then the power factor is said to be leading.

The total instantaneous power for all three phases is

$$P(t) = P_a(t) + P_b(t) + P_c(t) = 3V_{rms} I_{rms} \cos\theta \tag{1.2.17}$$

Notice that the sum of the cosine terms which involve time in Eqs. 1.2.13 to 1.2.15 (the first terms in the brackets) is zero. 【1】 We have shown that the total of the instantaneous power for the three phases of a balanced three-phase circuit is constant and does not vary with tune. This situation is depicted graphically in Fig.1.2.3. Instantaneous powers for the three phases are plotted, together with the total instantaneous power, which is the sum of the three individual waves. The total instantaneous power for a balanced three-phase system is equal to 3 tunes the average power per phase. This is one of the outstanding advantages of poly-phase systems. It is of particular advantage in the operation of poly-phase motors since it means that the shaft-power output is constant and that torque pulsations, with the consequent tendency toward vibration, do not result.

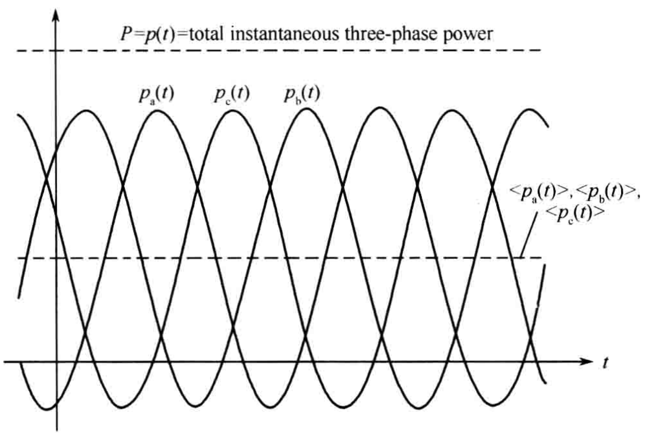

Fig. 1.2.3 Instantaneous power in a three-phase system

On the basis of single-phase considerations, the average power per phase P_{ph} for either a Y- or Δ -connected system connected to a balanced three-phase load of impedance $Z_{ph} = R_{ph} + jX_{ph} \Omega$ /phase is

$$P_{ph} = V_{rms} I_{rms} \cos\theta = I_{ph}^2 R_{ph} \tag{1.2.18}$$

Here R_{ph} is the resistance per phase. The total three-phase power P is

$$P = 3P_{ph} \tag{1.2.19}$$

Similarly, for reactive power per phase Q_{ph} and total three-phase reactive power Q,

$$Q_{ph} = V_{rms} I_{rms} \sin\theta = I_{ph}^2 X_{ph} \tag{1.2.20}$$

and

$$Q = 3Q_{ph} \tag{1.2.21}$$

where X_{ph} is the reactance per phase.

The apparent power per phase, also referred to as the volt-amperes per phase, S_{ph},-and total three-phase apparent power S are

$$S_{ph} = V_{rms} I_{rms} = I_{rms}^2 Z_{ph} \tag{1.2.22}$$

$$S = 3S_{ph} \tag{1.2.23}$$

In Eqs. 1.2.18 and1.2.20, θ is the angle between phase voltage and phase current. As in the single-phase case, it is given by

$$\theta = \arctan\left(\frac{X_{ph}}{R_{ph}}\right) = \arccos\left(\frac{R_{ph}}{Z_{ph}}\right) = \arcsin\left(\frac{X_{ph}}{Z_{ph}}\right) \tag{1.2.24}$$

The power factor of a balanced three-phase system is therefore equal to that of any one phase.

2.2 Specialized English Words

Y-connected	Y 接
phasor diagram	相量图
Δ -connected	Δ 接
phase order（phase sequence）	相序
line-to-neutral voltage	线对中性点电压（即相电压）
line-to-line voltage	线对线电压（即线电压）
double-subscript	双下标
complete diagram	复数平面图
Kirchhoff's voltage law	基尔霍夫电压定律
Kirchhoff's current law	基尔霍夫电流定律
rms value	均方根值（有效值）
average power	平均功率
instantaneous power	瞬时功率
power-factor angle	功率因数角
power factor	功率因数
shaft-power output	转轴上的功率输出
torque pulsations	转矩的脉动
vibration	振动
apparent power	视在功率
volt-amperes	伏安数

2.3 Notes

【1】Notice that the sum of the cosine terms which involve time in Eqs.1.2.13 to 1.2.15 (the first terms in the brackets) is zero.首先应该看出这是一个祈使句，全句无主语，动词“Notice”的宾语是由“that”引导出的宾语从句：“the sum of the cosine terms which involve time in Eqs.1. 2.13 to 1.2.15 (the first terms in the brackets) is zero.”。该从句的句干是：“the sum of the cosine terms……is zero.”只是“the sum”的后置定语“of the cosine terms”又有一个后置定语，不过

该后置定语为一定语："which involve time in Eqs.1.2.13 to 1.2.15 (the first terms in the brackets)"，其意为："从式(1.2.13)到式(1.2.15)中的与时间有关的"，圆括号中的"the first terms in the brackets"是其同位语。所以，全句应译为："注意，从式(1.2.13)到式(1.2.15)中的与时间有关的各余弦项（即各方括号中的第一项）之和为零"。

2.4 Translation

三相电压、电流和功率

当图 1.1.1 中的绕组采用 Y 接法时，如图 1.1.5a 所示，其电压的相量图如图 1.2.1 所示。该相量图的相序为 abc，也就是说，a 相达到最大的时间超前 b 相 120°。

$\dot{V}_a$，$\dot{V}_b$ 和 $\dot{V}_c$ 三相电压称为线对中性点电压。$\dot{V}_{ab}$，$\dot{V}_{bc}$ 和 $\dot{V}_{ca}$ 三相电压称为线对线电压。图 1.2.1 中的双下标的标注法与复平面图的标注法很相似。下标指的是电压两端之间的那两点，比如，电压 $\dot{V}_{ab}$ 就是根据 $\dot{V}_{ab}=\dot{V}_a-\dot{V}_b$ 计算出来的。

根据基尔霍夫电压定律，线对线电压 $\dot{V}_{ab}$ 为：

$$\dot{V}_{ab}=\dot{V}_a-\dot{V}_b=\sqrt{3}\dot{V}_a\angle 30° \tag{1.2.1}$$

同理，如图 1.2.1 所示，有：

$$\dot{V}_{bc}=\sqrt{3}\dot{V}_b\angle 30° \tag{1.2.2}$$

和

$$\dot{V}_{ca}=\sqrt{3}\dot{V}_c\angle 30° \tag{1.2.3}$$

以上各式说明，线对线电压为线对中性点电压的 $\sqrt{3}$ 倍。

当三相 Δ 接时，相应的电流相量图如图 1.2.2 所示。Δ 接时各相电流为 $\dot{I}_{ab}$，$\dot{I}_{bc}$ 和 $\dot{I}_{ca}$。根据基尔霍夫电流定律，线电流 $\dot{I}_a$ 为：

$$\dot{I}_a=\dot{I}_{ab}-\dot{I}_{ca}=\sqrt{3}I_{ab}\angle -30° \tag{1.2.4}$$

正像从图 1.2.2 中可看到的那样，同理有：

$$\dot{I}_b=\sqrt{3}I_{bc}\angle -30° \tag{1.2.5}$$

和

$$\dot{I}_c=\sqrt{3}I_{ca}\angle -30° \tag{1.2.6}$$

将以上三式归纳起来，可见 Δ 接时各线电流为各相电流的 $\sqrt{3}$ 倍。可以看出，Δ 接时相电流与各线电流之间的关系，与 Y 接时线对中性点电压与线对线电压（即线电压）的关系是类似的。

由于时间的起始点取在当 a 相电压波达到正最大值时，因而三相电压的瞬时值为：

$$v_a(t)=\sqrt{2}V_{rms}\cos\omega t \tag{1.2.7}$$

$$v_b(t)=\sqrt{2}V_{rms}\cos(\omega t-120°) \tag{1.2.8}$$

$$v_c(t)=\sqrt{2}V_{rms}\cos(\omega t+120°) \tag{1.2.9}$$

式中，V_{rms} 为相电压的均方根值。当相电流落后相电压 θ 角时，相电流的瞬时值为：

$$i_a(t)=\sqrt{2}I_{rms}\cos(\omega t+\theta) \tag{1.2.10}$$

$$i_b(t)=\sqrt{2}I_{rms}\cos(\omega t+\theta-120°) \tag{1.2.11}$$

$$i_c(t)=\sqrt{2}I_{rms}\cos(\omega t+\theta+120°) \tag{1.2.12}$$

式中，I_{rms} 为相电流的均方根值。

这样，每相功率的瞬时值便成了：

$$P_a(t) = v_a(t)i_a(t) = V_{rms}I_{rms}\left[\cos(2\omega t + \theta) + \cos\theta\right] \tag{1.2.13}$$

$$P_b(t) = v_b(t)i_b(t) = V_{rms}I_{rms}\left[\cos(2\omega t + \theta - 240°) + \cos\theta\right] \tag{1.2.14}$$

$$P_c(t) = v_c(t)i_c(t) = V_{rms}I_{rms}\left[\cos(2\omega t + \theta + 240°) + \cos\theta\right] \tag{1.2.15}$$

注意，每相的平均功率等于：

$$< P_a(t) > = < P_b(t) > = < P_a(t) > = V_{rms}I_{rms}\cos\theta \tag{1.2.16}$$

电压与电流之间的夹角 θ 为功率因数角，$\cos\theta$ 为功率因数。如若 θ 角为负，那么功率因数就是滞后的；如若 θ 角为正，那么功率因数就是超前的。

三相瞬时功率之和为：

$$P(t) = P_a(t) + P_b(t) + P_c(t) = 3V_{rms}I_{rms}\cos\theta \tag{1.2.17}$$

注意，从式(1.2.13)到式(1.2.15)中的与时间有关的各余弦项（即各方括号中的第一项）之和为零。如前所述，对称三相电路的三相瞬时功率之和为一常数，其不随时间变化而变化。这一结论在图 1.2.3 中明确地表示出来了。三相的瞬时功率与其之和（也就是三个瞬时功率的波形叠加)在图中一并画出。对称三相电路的三相瞬时功率之和为每相的平均功率的 3 倍。这就是多相系统的一个突出的优点。这一点对于多相电动机的运行来说是尤其难能可贵的，这是因为（多相瞬时功率之和为一常数）这一事实意味着电动机转轴上的功率输出为一常数， 因而便不会产生转矩的脉动，而它正是可能引起振动的原因。

以单相为基础来分析，不论它是 Y 接还是 Δ 接，对于一个每相均接有三相对称阻抗 $Z_{ph} = R_{ph} + jX_{ph}\ \Omega$ 的系统来说，其平均功率 P_{ph} 为：

$$P_{ph} = V_{rms}I_{rms}\cos\theta = I_{ph}^2 R_{ph} \tag{1.2.18}$$

式中，R_{ph} 为每相的电阻。

三相功率之和 P 为：

$$P = 3P_{ph} \tag{1.2.19}$$

同理，每相的无功功率 Q_{ph} 和三相的无功功率 Q 为：

$$Q_{ph} = V_{rms}I_{rms}\sin\theta = I_{ph}^2 X_{ph} \tag{1.2.20}$$

及

$$Q = 3Q_{ph} \tag{1.2.21}$$

式中，X_{ph} 为每相的电抗。

每相的视在功率，也就是每相的伏安数 S_{ph} 和三相总的伏安数 S 为：

$$S_{ph} = V_{rms}I_{rms} = I_{rms}^2 Z_{ph} \tag{1.2.22}$$

$$S = 3S_{ph} \tag{1.2.23}$$

在式(1.2.18)和式(1.2.20)中，θ 角为相电压与相电流之间的夹角。与单相中的情形一样，其由下式给出：

$$\theta = \arctan\left(\frac{X_{ph}}{R_{ph}}\right) = \arccos\left(\frac{R_{ph}}{Z_{ph}}\right) = \arcsin\left(\frac{X_{ph}}{Z_{ph}}\right) \tag{1.2.24}$$

因而，三相对称系统的功率因数就等于每相的功率因数。