

华中科技大学
Huazhong University of
Science and Technology

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《电力系统分析》 (I)

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第二章 电力网各元件的等值电路和参数计算

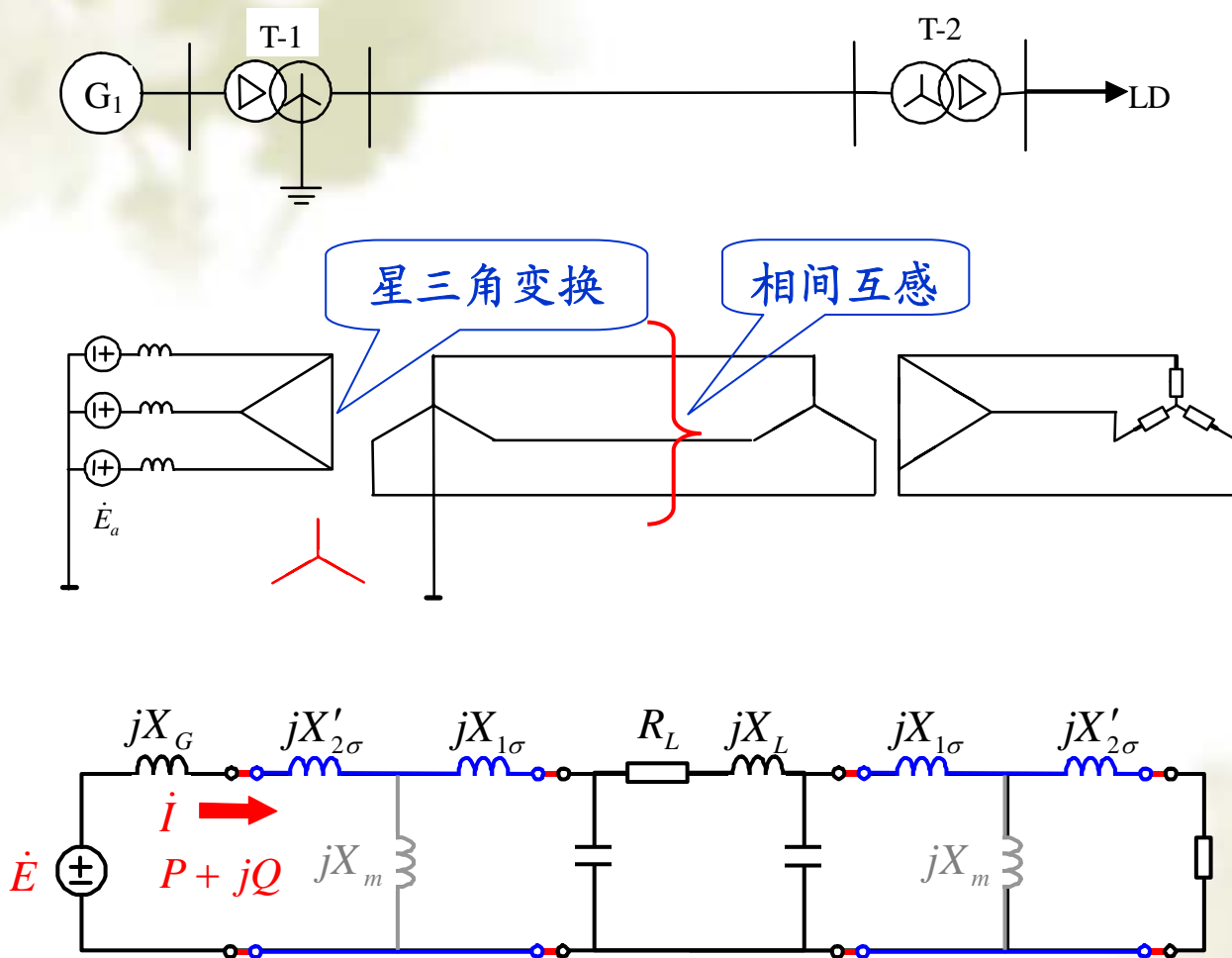
2-1 架空输电线路的参数

2-2 架空输电线路的等值电路

2-3 变压器的等值电路和参数

2-4 标幺制

一相等值电路的概念



□ **三相对称:** 正常稳态或者应用对称分量法

□ **星三角变换:** 三角形电路—星形电路

□ **一相等值参数:** 计及其余两相影响 (比如相间互感)

□ **运行变量:** 线电压, 线电流, 三相功率;

2-1 架空输电线路的参数

- 电阻：载流导线有功损耗
- 电感：载流导线磁场效应
- 电导：带电线路绝缘泄漏及电晕损耗
- 电容：带电线路电场效应

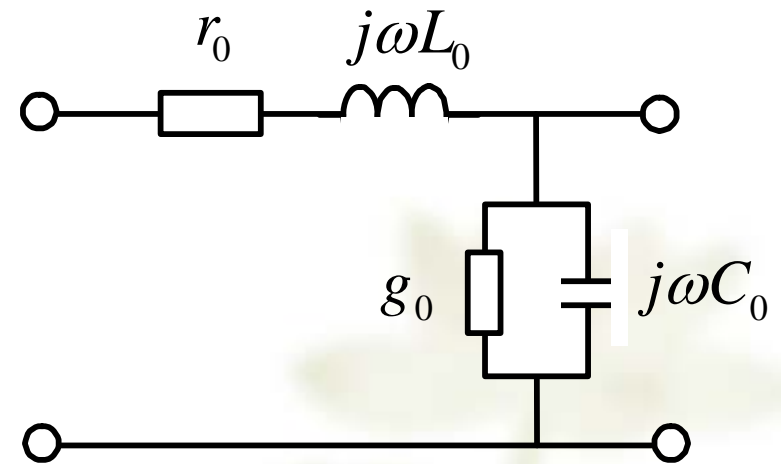


图2-1单位长线路一相等值电路

2-1 架空输电线路的参数

1. 电阻

❖ 直流电阻 $r = \rho / S$

交流电阻 > 直流电阻

❖ 集肤效应和邻近效应

❖ 多股绞线

❖ 标称截面积 > 实际截面积

❖ 与温度有关

2-1 架空输电线路的参数

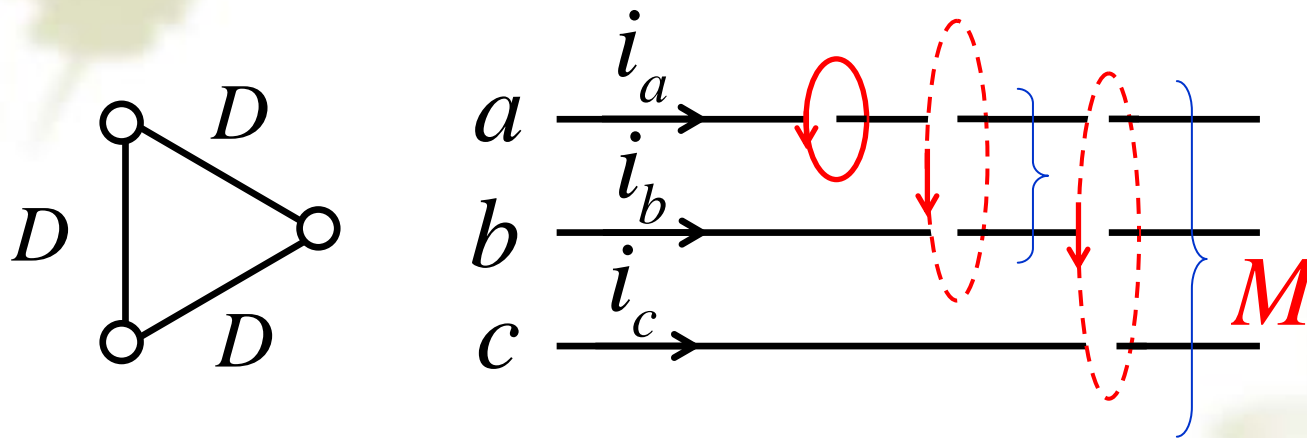
2. 电感--基本算式

(1) 自感
$$L = \psi / i = \frac{\mu_0}{2\pi} \left(\ln \frac{2l}{D_s} - 1 \right)$$

(2) 互感
$$M_{AB} = \psi_{AB} / i_B = \frac{\mu_0}{2\pi} \left(\ln \frac{2l}{D} - 1 \right)$$

2-1 架空输电线路的参数

2. 电感—对称三相输电线路等值电感



$$\psi_a = Li_a + M_{ab}i_b + M_{ac}i_c = Li_a + M(i_b + i_c) = (L - M)i_a$$

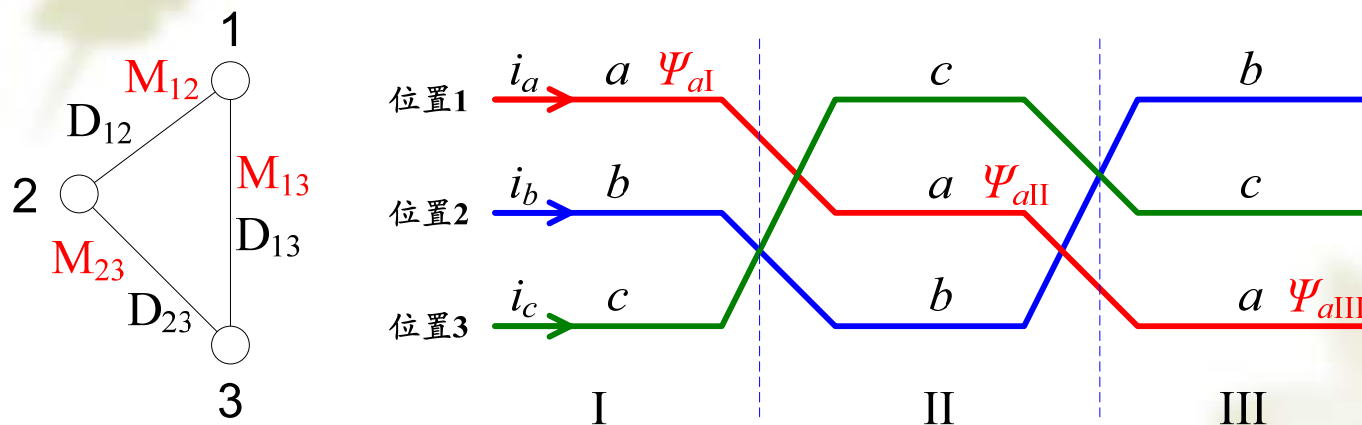
$$L_a = \frac{\psi_a}{i_a} = \frac{\mu_0}{2\pi} \ln \frac{D}{D_s}$$

$$L = \frac{\mu_0}{2\pi} \left(\ln \frac{2l}{D_s} - 1 \right)$$

$$M = \frac{\mu_0}{2\pi} \left(\ln \frac{2l}{D} - 1 \right)$$

2-1 架空输电线路的参数

2. 电感—不对称三相线路：导线换位



$$\begin{aligned}\psi_{aI} &= Li_a + M_{12}i_b + M_{13}i_c \\ \psi_{aII} &= Li_a + M_{23}i_b + M_{12}i_c \\ \psi_{aIII} &= Li_a + M_{13}i_b + M_{23}i_c \\ \psi_a &= (\psi_{aI} + \psi_{aII} + \psi_{aIII})/3\end{aligned}$$

$$L_a = \frac{\psi_a}{i_a} = L - \frac{1}{3}(M_{12} + M_{23} + M_{13}) = \frac{\mu_0}{2\pi} \ln \frac{D_{eq}}{D_s}$$

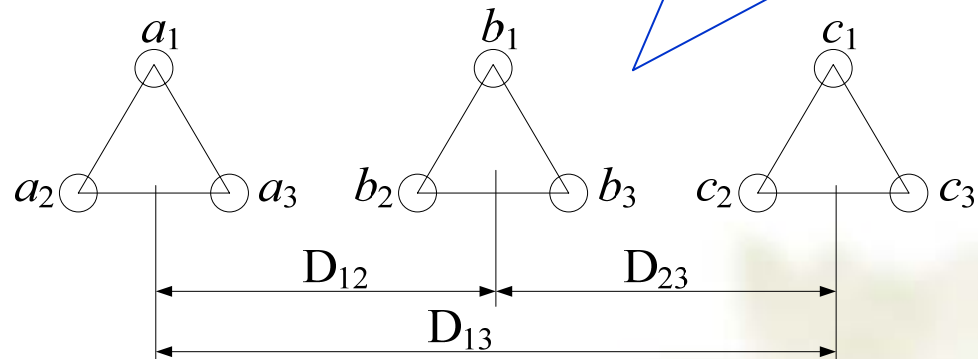
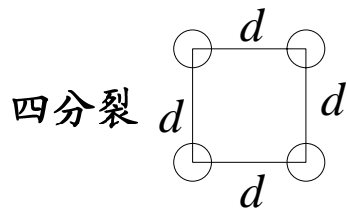
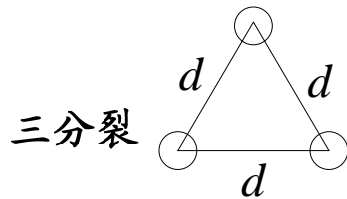
$$D_{eq} = \sqrt[3]{D_{12}D_{23}D_{31}}$$

导线间互几何均距

2-1 架空输电线路的参数

2. 电感—分裂导线

分裂导线对线路参数的影响



$$L_a = \frac{\mu_0}{2\pi} \ln \frac{D_{eq}}{D_s}$$

$$L_a = \frac{\mu_0}{2\pi} \ln \frac{D_{eq}}{D_{sb}}$$

D_{sb} 分裂导线的自几何均距，与分裂根数和间距有关

2-1 架空输电线路的参数

2. 电感—输电线路等值电抗

$$x = 2\pi fL = 0.1445 \lg \frac{D_{\text{eq}}}{D_{\text{sb}}} \quad (\Omega / \text{km})$$

单导线线路：0.4 Ω/km；二分裂导线：0.33 Ω/km，三分裂导线：0.30 Ω/km，四分裂导线：0.28 Ω/km。

钢导线线路：集肤效应、导磁率随电流变化，电阻电感呈现非线性，只能通过试验测定其特性，根据电流值确定其阻抗

2-1 架空输电线路的参数

3. 电导

- ❖ 合理设计绝缘水平降低**泄漏电流**
- ❖ 增大导线截面或者采用分裂导线减少**电晕损耗**
- ❖ $g_0 \approx 0$

2-1 架空输电线路的参数

4. 电容—基本算式

若周围介质的介电系数为常数，则导体所带的电荷 q 与导体的电位 v 将呈线性关系。导体的电容

$$C = \frac{q}{v}$$

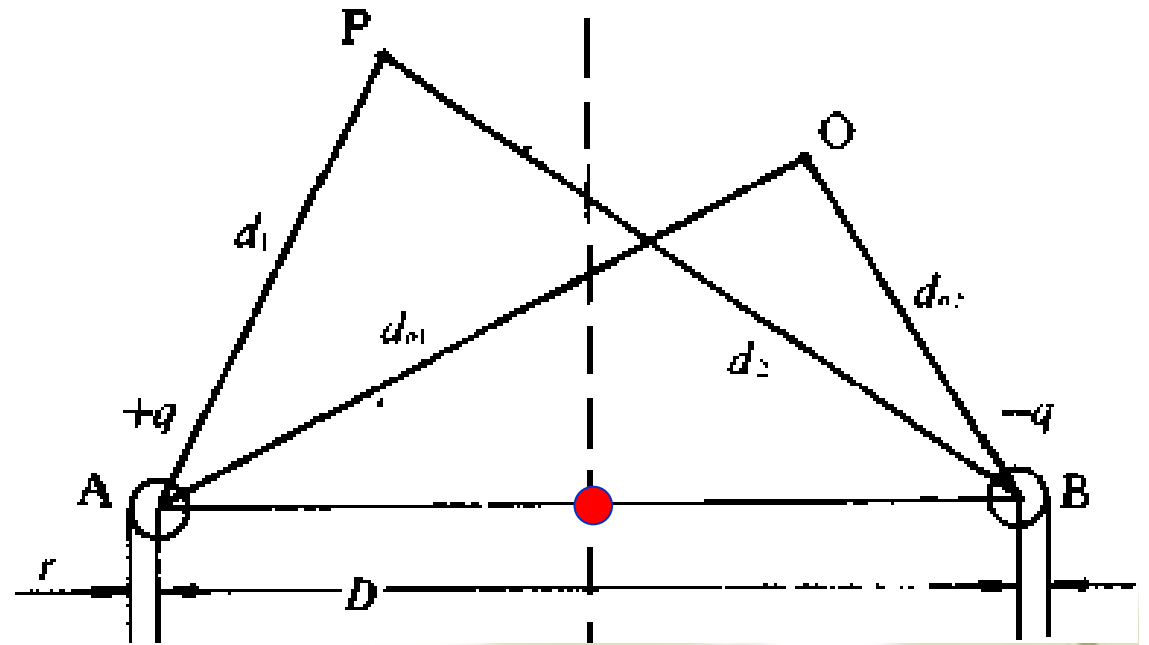
2-1 架空输电线路的参数

4. 电容—基本算式

以导线间中点为零电位

(1) 任意点P电位

$$v_P = \frac{q}{2\pi\epsilon} \ln \frac{d_2}{d_1}$$



(2) 导线A表面电位

$$v_A = \frac{q}{2\pi\epsilon} \ln \frac{D}{r}$$

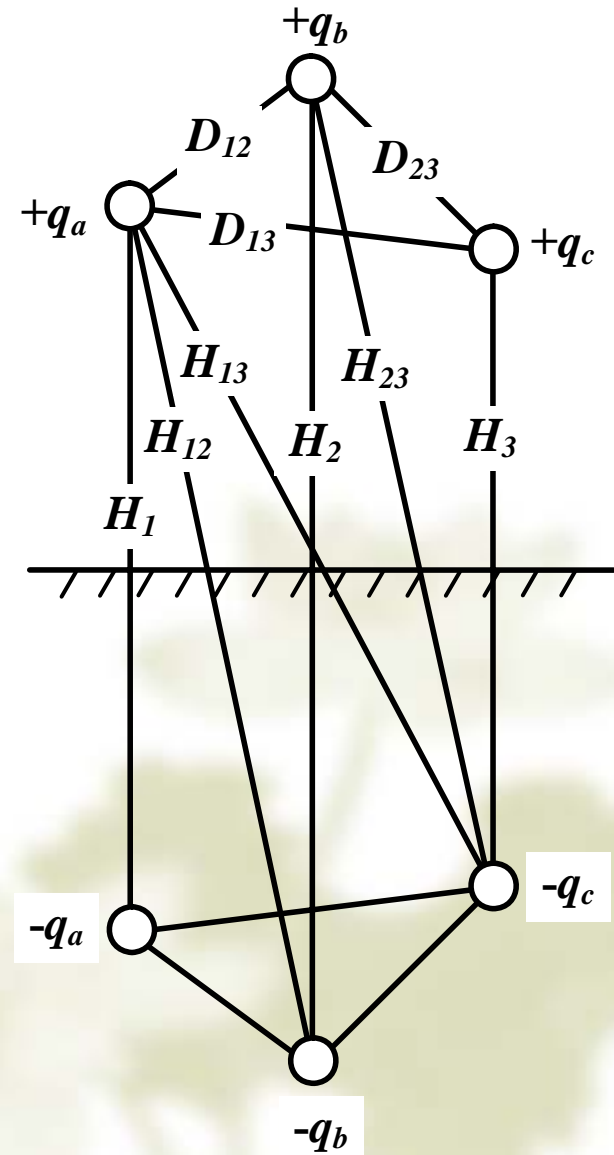
2-1 架空输电线路的参数

4. 电容—三相线路一相等值电容

经过整循环换位的三相线路，一相等值电容：

$$v_{AI} = \frac{1}{2\pi\epsilon} \left[q_a \ln \frac{H_1}{r} + q_b \ln \frac{H_{12}}{D_{12}} + q_c \ln \frac{H_{13}}{D_{13}} \right]$$
$$v_{AII} = \frac{1}{2\pi\epsilon} \left[q_a \ln \frac{H_2}{r} + q_b \ln \frac{H_{23}}{D_{23}} + q_c \ln \frac{H_{12}}{D_{12}} \right]$$
$$v_{AIII} = \frac{1}{2\pi\epsilon} \left[q_a \ln \frac{H_3}{r} + q_b \ln \frac{H_{31}}{D_{13}} + q_c \ln \frac{H_{23}}{D_{23}} \right]$$

$$v_a = \frac{1}{3} (v_{AI} + v_{AII} + v_{AIII}); \quad q_a + q_b + q_c = 0$$



2-1 架空输电线路的参数

4. 电容—三相线路一相等值电容

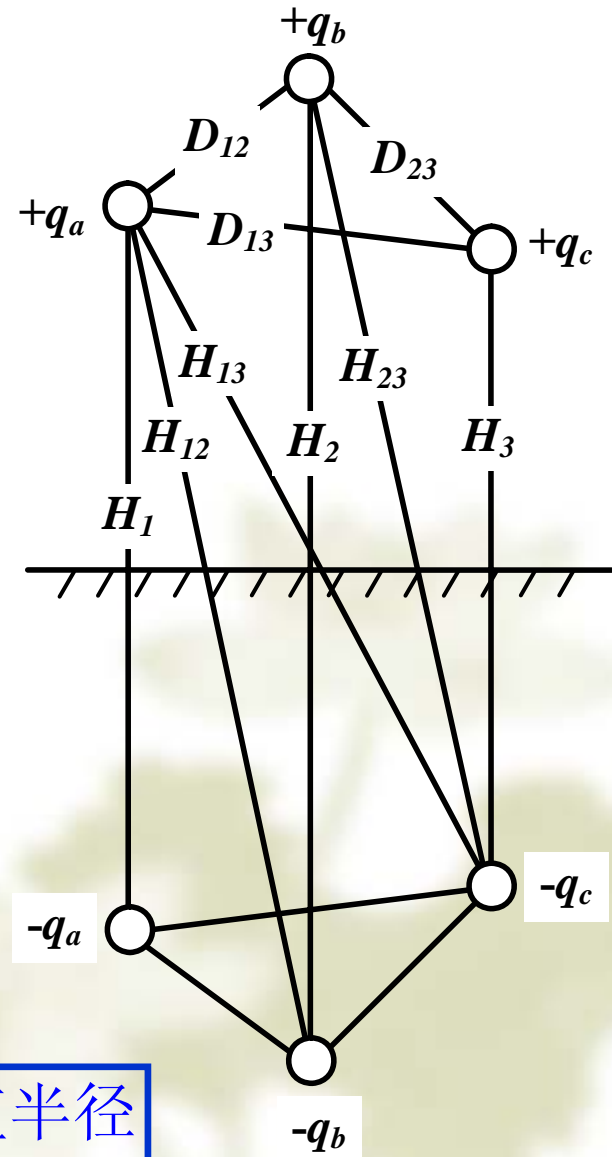
经过整循环换位的三相线路，一相等值电容：

$$v_A = \frac{q_a}{2\pi\epsilon} \left[\ln \frac{\sqrt[3]{D_{12}D_{23}D_{31}}}{r} - \ln \sqrt{\frac{H_{12}H_{23}H_{13}}{H_1H_2H_3}} \right]$$

$$C = \frac{q_a}{v_a} = \frac{2\pi\epsilon}{\ln \frac{D_{eq}}{r_{eq}} - \ln \sqrt[3]{\frac{H_{12}H_{23}H_{31}}{H_1H_2H_3}}}$$

$$C = \frac{0.0241}{\lg D_{eq}/r_{eq}} \times 10^{-6} \quad (\text{F/km})$$

r_{eq} : 导线等值半径



2-1 架空输电线路的参数

4. 电容—三相线路等值电纳

$$b = 2\pi f_N C = \frac{7.58}{\lg D_{\text{eq}}/r_{\text{eq}}} \times 10^{-6} \quad (\text{S/km})$$

各种电压等级线路的电纳值变化不大。

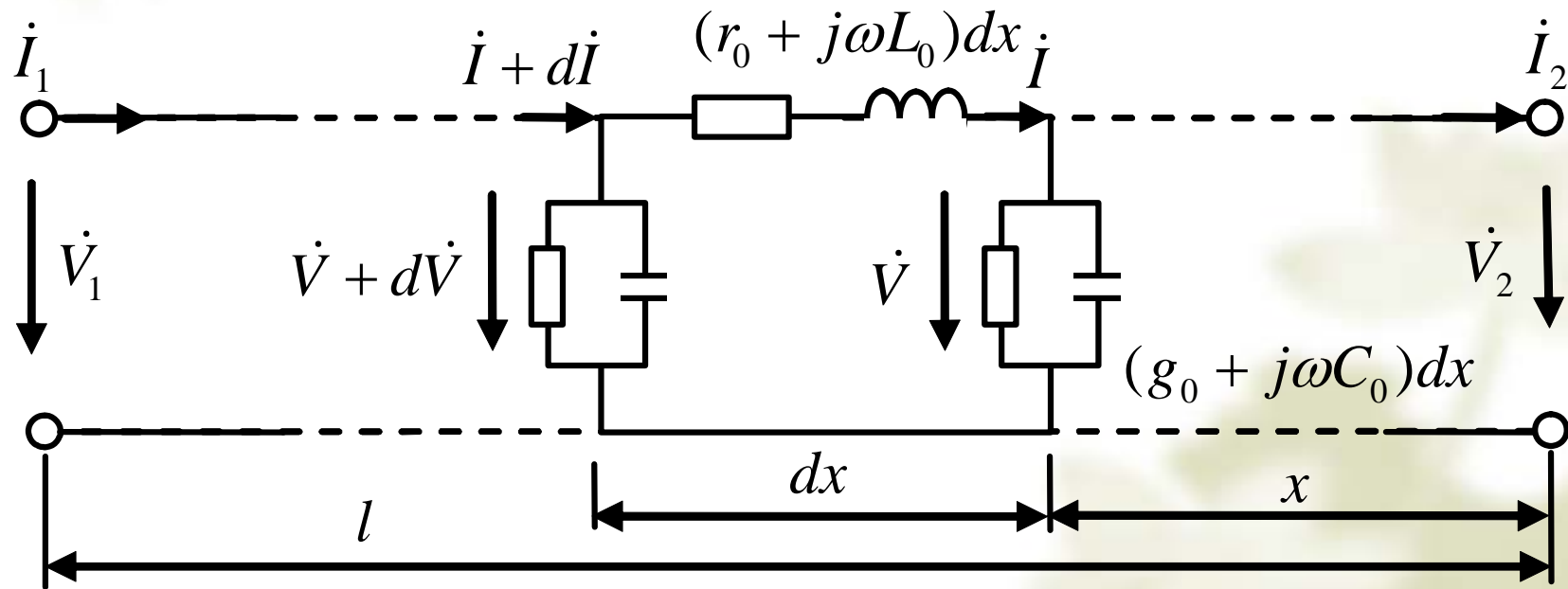
单导线线路：大约为 $2.8 \times 10^{-6} \text{S/km}$ 左右；分裂导线线路，

当每相分裂根数分别为2根,3根和4根时，分别约为

$3.4 \times 10^{-6} \text{S/km}$ ， $3.8 \times 10^{-6} \text{S/km}$ ，和 $4.1 \times 10^{-6} \text{S/km}$ 。

2-2 架空输电线路的等值电路

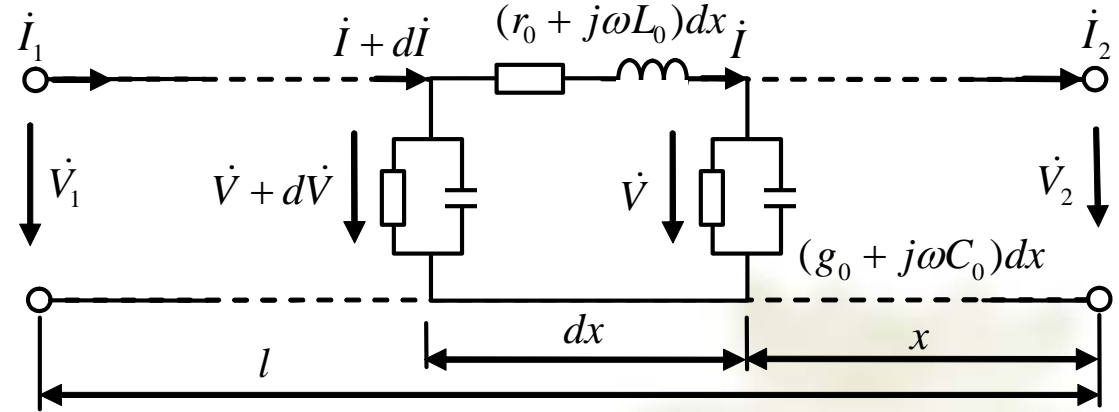
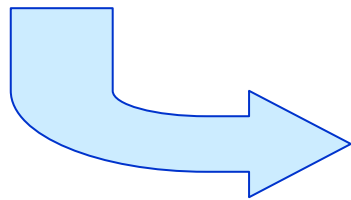
1. 长线等值电路



2-2 架空输电线路的等值电路

2. 输电线路方程式

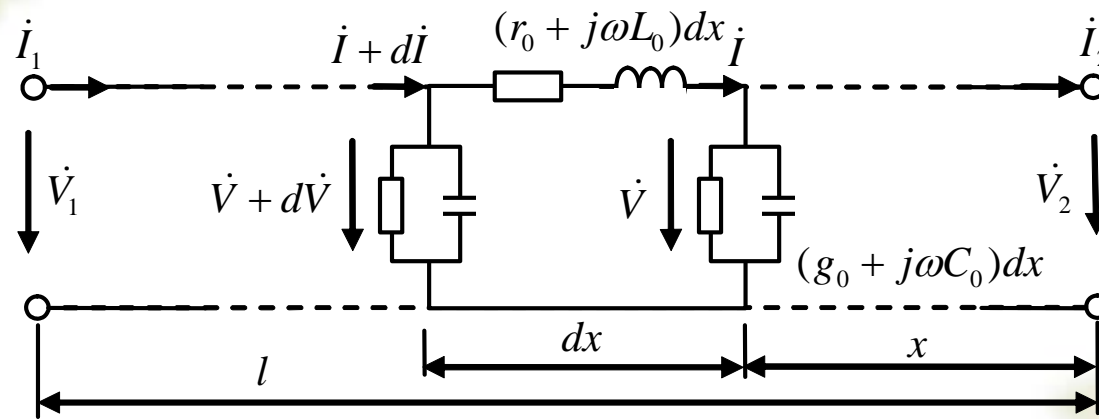
$$\begin{cases} \frac{d\dot{V}}{dx} = (r_0 + j\omega L_0)\dot{I} \\ \frac{d\dot{I}}{dx} = (g_0 + j\omega C_0)\dot{V} \end{cases}$$



$$\begin{cases} \frac{d^2\dot{V}}{dx^2} = (g_0 + j\omega C_0)(r_0 + j\omega L_0)\dot{V} \\ \lambda_{1,2} = \pm \sqrt{(g_0 + j\omega C_0)(r_0 + j\omega L_0)} \end{cases}$$

2-2 架空输电线路的等值电路

3. 特性阻抗和传播常数



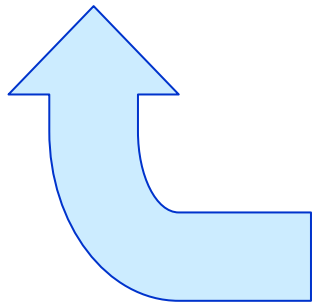
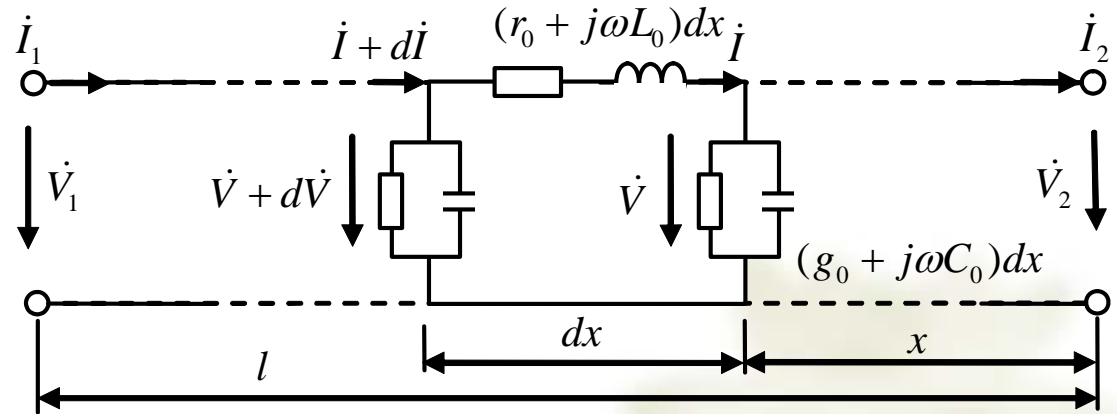
$$Z_C = \sqrt{(r_0 + j\omega L_0)/(g_0 + j\omega C_0)} = R_C + jX_C = |Z_C| e^{j\theta_C}$$

$$\gamma = \sqrt{(g_0 + j\omega C_0)(r_0 + j\omega L_0)} = \beta + j\alpha$$

2-2 架空输电线路的等值电路

4. 输电线路方程式通解

$$\begin{cases} \dot{V} = A_1 e^{\gamma x} + A_2 e^{-\gamma x} \\ \dot{I} = \frac{A_1}{Z_C} e^{\gamma x} - \frac{A_2}{Z_C} e^{-\gamma x} \end{cases}$$



$$\begin{cases} \frac{d^2 \dot{V}}{dx^2} = (g_0 + j\omega C_0)(r_0 + j\omega L_0) \dot{V} \\ \lambda_{1,2} = \pm \gamma \end{cases}$$

2-2 架空输电线路的等值电路

5. 方程式边界条件及系数 A_1 、 A_2

$$\begin{cases} \dot{V} = A_1 e^{\gamma x} + A_2 e^{-\gamma x} \\ \dot{I} = \frac{A_1}{Z_C} e^{\gamma x} - \frac{A_2}{Z_C} e^{-\gamma x} \end{cases} \xrightarrow[x=0]{\dot{V} = \dot{V}_2, \dot{I} = \dot{I}_2} \begin{cases} \dot{V}_2 = A_1 + A_2 \\ \dot{I}_2 = \frac{A_1}{Z_C} - \frac{A_2}{Z_C} \end{cases}$$

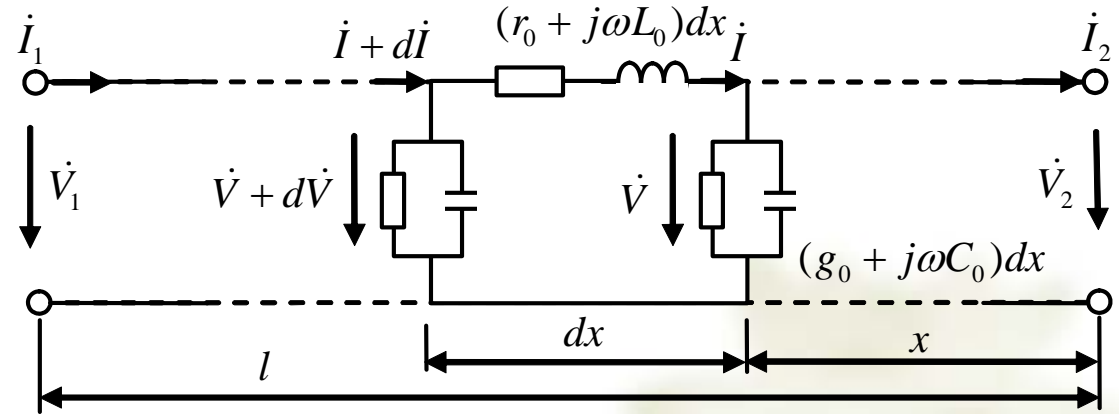
$$A_1 = \frac{1}{2}(\dot{V}_2 + Z_C \dot{I}_2) \quad A_2 = \frac{1}{2}(\dot{V}_2 - Z_C \dot{I}_2)$$

2-2 架空输电线路的等值电路

重写方程式通解

$$A_1 = \frac{1}{2}(\dot{V}_2 + Z_C \dot{I}_2)$$

$$A_2 = \frac{1}{2}(\dot{V}_2 - Z_C \dot{I}_2)$$

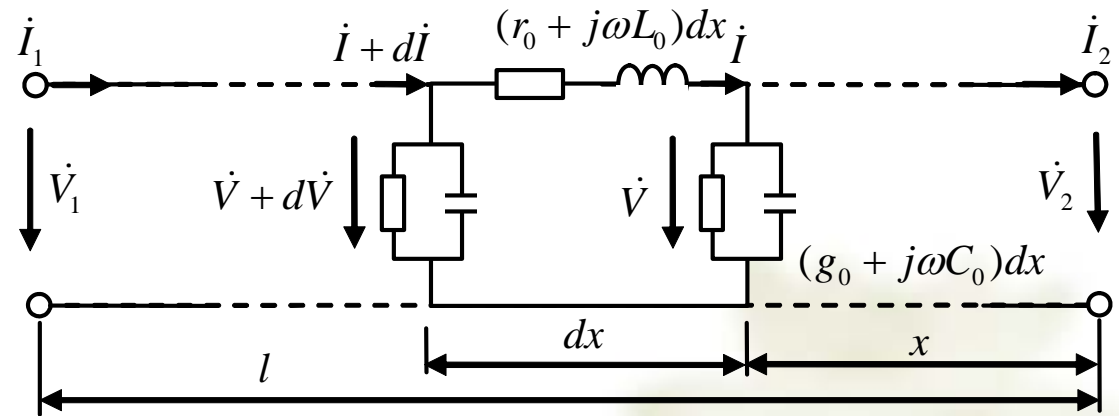


$$\begin{cases} \dot{V} = A_1 e^{\gamma x} + A_2 e^{-\gamma x} \\ \dot{I} = \frac{A_1}{Z_C} e^{\gamma x} - \frac{A_2}{Z_C} e^{-\gamma x} \end{cases} \Rightarrow \begin{cases} \dot{V} = \dot{V}_2 \operatorname{ch} \gamma x + Z_C \dot{I}_2 \operatorname{sh} \gamma x \\ \dot{I} = \frac{\dot{V}_2}{Z_C} \operatorname{sh} \gamma x + \dot{I}_2 \operatorname{ch} \gamma x \end{cases}$$

2-2 架空输电线路的等值电路

6. 输电线路二端口网络方程

$$\begin{bmatrix} \dot{V}_1 \\ \dot{I}_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} \dot{V}_2 \\ \dot{I}_2 \end{bmatrix}$$



$$\begin{cases} \dot{V}_1 = \dot{V}_2 \operatorname{ch} \gamma l + Z_C \dot{I}_2 \operatorname{sh} \gamma l \\ \dot{I}_1 = \frac{\dot{V}_2}{Z_C} \operatorname{sh} \gamma l + \dot{I}_2 \operatorname{ch} \gamma l \end{cases} \leftarrow \begin{cases} \dot{V} = \dot{V}_2 \operatorname{ch} \gamma x + Z_C \dot{I}_2 \operatorname{sh} \gamma x \\ \dot{I} = \frac{\dot{V}_2}{Z_C} \operatorname{sh} \gamma x + \dot{I}_2 \operatorname{ch} \gamma x \end{cases}$$

2-2 架空输电线路的等值电路

7. 输电线路集中参数等值电路

$$\begin{cases} \dot{V}_1 = \dot{V}_2 \operatorname{ch}\gamma l + Z_C \dot{I}_2 \operatorname{sh}\gamma l \\ \dot{I}_1 = \frac{\dot{V}_2}{Z_C} \operatorname{sh}\gamma l + \dot{I}_2 \operatorname{ch}\gamma l \end{cases}$$

$$Z' = Z_C \operatorname{sh}\gamma l$$

$$Y' = 2(\operatorname{ch}\gamma l - 1) / (Z_C \operatorname{sh}\gamma l)$$

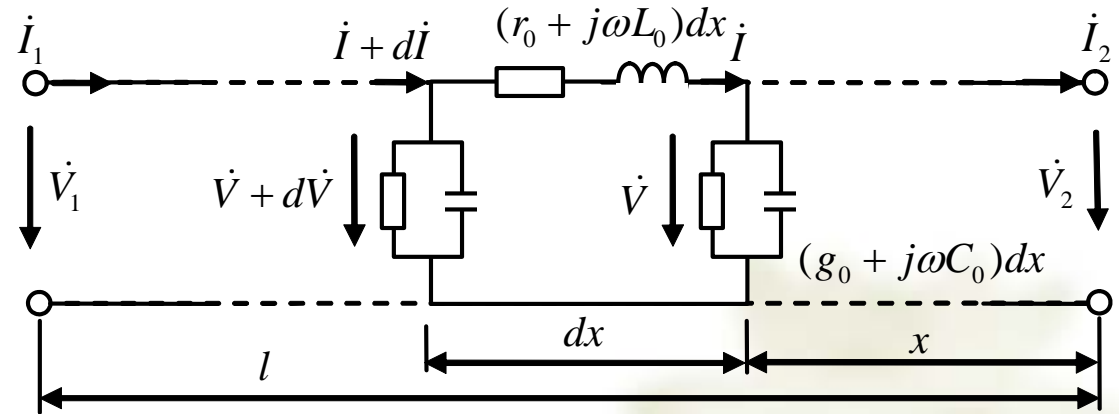
$$\begin{cases} \dot{I}_2 = (\dot{V}_1 - \dot{V}_2 \operatorname{ch}\gamma l) / Z_C \operatorname{sh}\gamma l \\ \dot{I}_1 = \frac{\dot{V}_2}{Z_C} \operatorname{sh}\gamma l + (\dot{V}_1 - \dot{V}_2 \operatorname{ch}\gamma l) \operatorname{ch}\gamma l / Z_C \operatorname{sh}\gamma l \end{cases}$$

$$\begin{cases} \dot{I}_1 = \frac{Y'}{2} \dot{V}_1 + \frac{1}{Z'} (\dot{V}_1 - \dot{V}_2) \\ \dot{I}_2 = \frac{1}{Z'} (\dot{V}_1 - \dot{V}_2) - \frac{Y'}{2} \dot{V}_2 \end{cases}$$

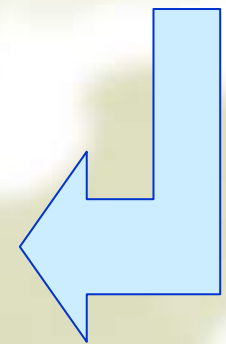
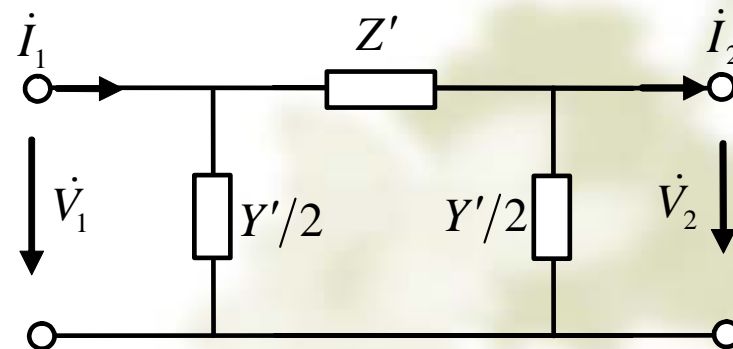
2-2 架空输电线路的等值电路

7. 输电线路Π型等值电路

$$\begin{cases} \dot{I}_1 = \frac{Y'}{2} \dot{V}_1 + \frac{1}{Z'} (\dot{V}_1 - \dot{V}_2) \\ \dot{I}_2 = \frac{1}{Z'} (\dot{V}_1 - \dot{V}_2) - \frac{Y'}{2} \dot{V}_2 \end{cases}$$



$$\begin{aligned} Z' &= Z_C \operatorname{sh} \gamma l \\ Y' &= 2(\operatorname{ch} \gamma l - 1) / (Z_C \operatorname{sh} \gamma l) \end{aligned}$$



2-2 架空输电线路的等值电路

8. 输电线路Π型等值电路的参数

$$\begin{cases} Z' = K_Z Z \\ Y' = K_Y Y \end{cases} \longleftrightarrow \begin{cases} Z = (r_0 + j\omega L_0)l \\ Y = (g_0 + j\omega C_0)l \end{cases} \longleftrightarrow \begin{cases} Z' \approx k_r r_0 l + jk_x x_0 l \\ Y' \approx jk_b \omega C_0 l \end{cases}$$

精确参数

近似参数，
单个Π型等值电路
200~300km线路

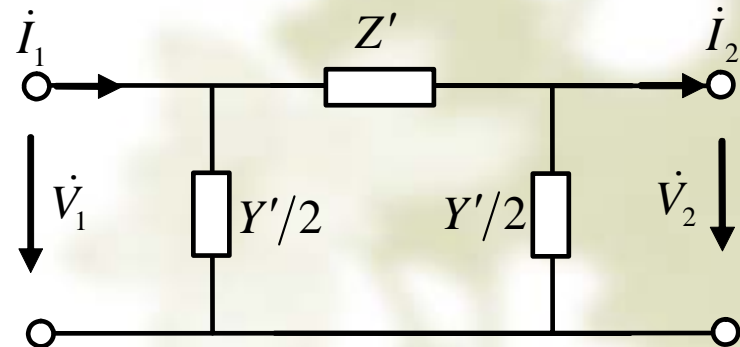
修正参数，
单个Π型等值电路
500~600km线路

$$Z' = Z_c \operatorname{sh}\gamma l$$

$$Y' = 2(\operatorname{ch}\gamma l - 1) / (Z_c \operatorname{sh}\gamma l)$$

$$K_Z = \operatorname{sh}\sqrt{ZY} / \sqrt{ZY}$$

$$K_Y = 2(\operatorname{ch}\gamma l - 1) / (\sqrt{ZY} \operatorname{sh}\gamma l)$$



2-3 变压器等值电路及参数

1. 双绕组变压器等值电路及参数

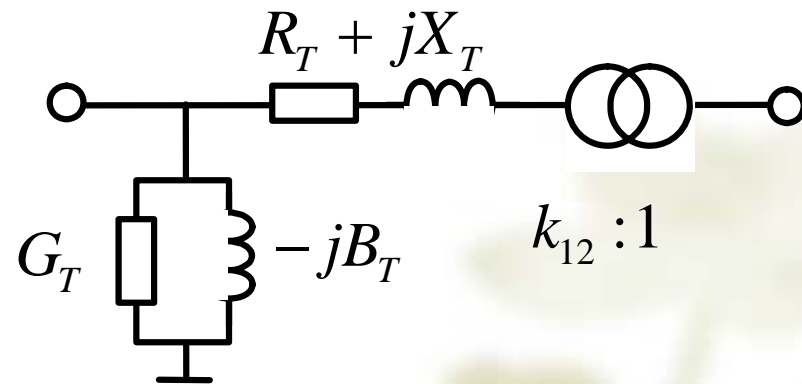
$$R_T \text{ ---- } \Delta P_S$$

$$X_T \text{ ---- } V_S\%$$

$$G_T \text{ ---- } \Delta P_0$$

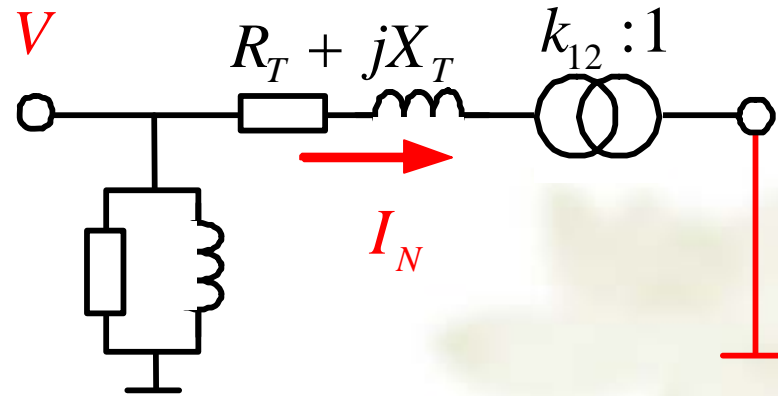
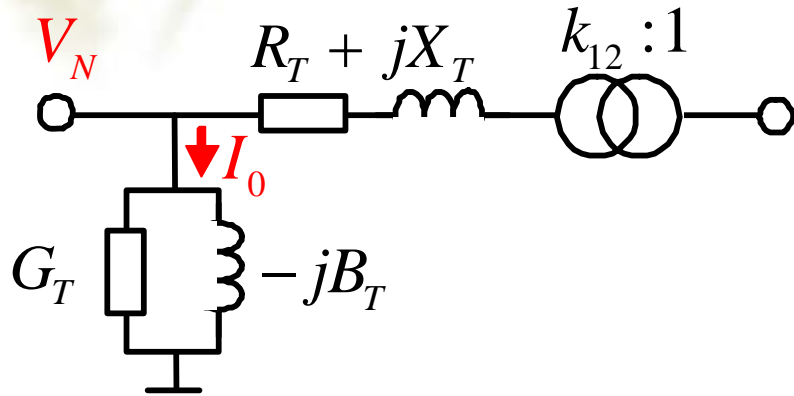
$$B_T \text{ ---- } I_0\%$$

$$k_{12} \text{ ---- } V_{1tN}/V_{2N}$$



2-3 变压器等值电路及参数

1. 双绕组变压器等值电路及参数

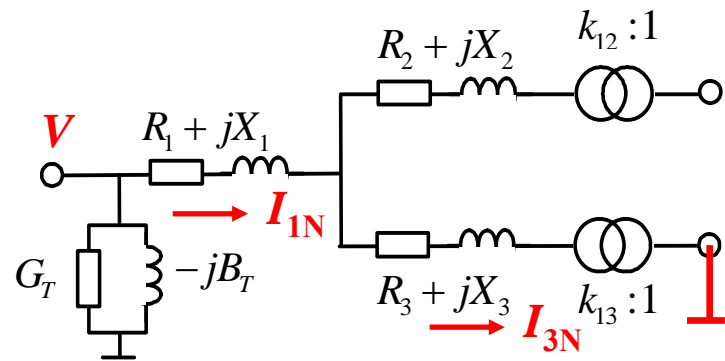
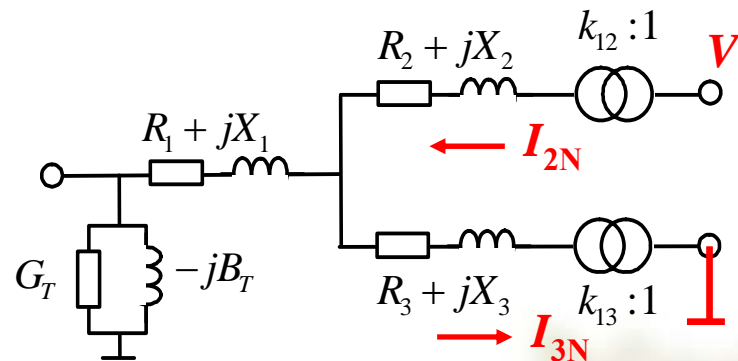
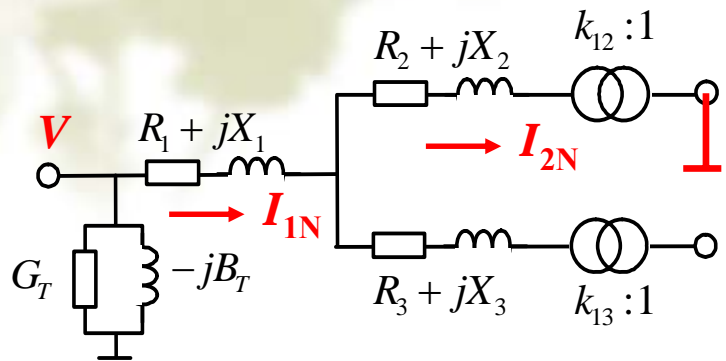


$$\begin{cases} \Delta P_0 = V_N^2 G_T \\ \frac{I_0 \%}{100} = \frac{V_N B_T}{\sqrt{3} I_N} = \frac{V_N^2}{S_N} B_T \end{cases}$$

$$\begin{cases} \Delta P_S = 3 I_N^2 R_T = \frac{S_N^2}{V_N^2} R_T \\ \frac{V_S \%}{100} = \frac{V}{V_N} \approx \frac{\sqrt{3} I_N X_T}{V_N} = \frac{S_N}{V_N^2} X_T \end{cases}$$

2-3 变压器等值电路及参数

2. 三绕组变压器等值电路及参数——短路试验



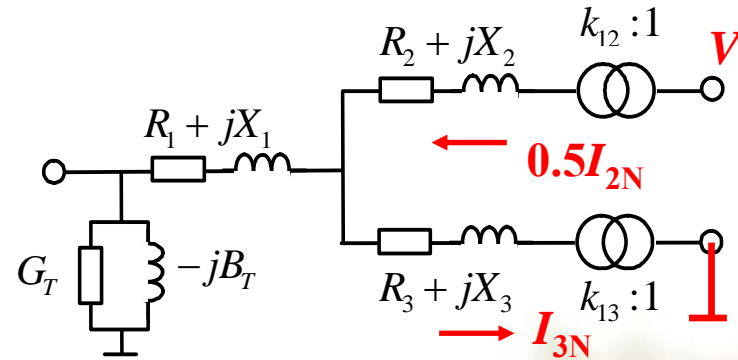
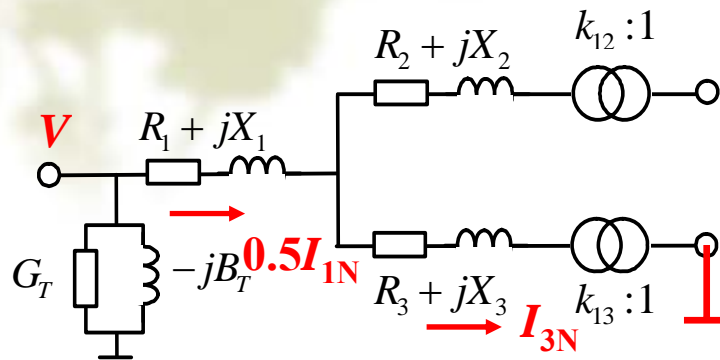
三绕组容量比100/100/100

$$R_i = \frac{\Delta P_{si} V_N^2}{S_N^2} \times 10^3 \quad (i = 1, 2, 3)$$

$$\begin{cases} \Delta P_{S(1-2)} = 3I_{1N}^2 R_1 + 3I_{2N}^2 R_2 = \Delta P_{s1} + \Delta P_{s2} \\ \Delta P_{S(3-1)} = 3I_{1N}^2 R_1 + 3I_{3N}^2 R_3 = \Delta P_{s1} + \Delta P_{s3} \\ \Delta P_{S(2-3)} = 3I_{2N}^2 R_2 + 3I_{3N}^2 R_3 = \Delta P_{s2} + \Delta P_{s3} \end{cases}$$

2-3 变压器等值电路及参数

2. 三绕组变压器等值电路及参数——短路试验



三绕组容量比100/100/50

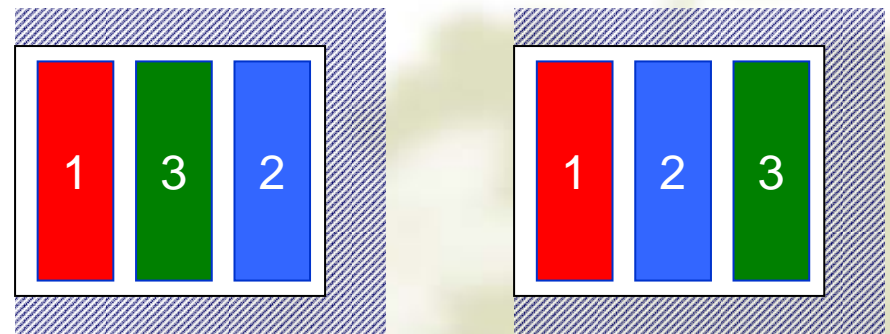
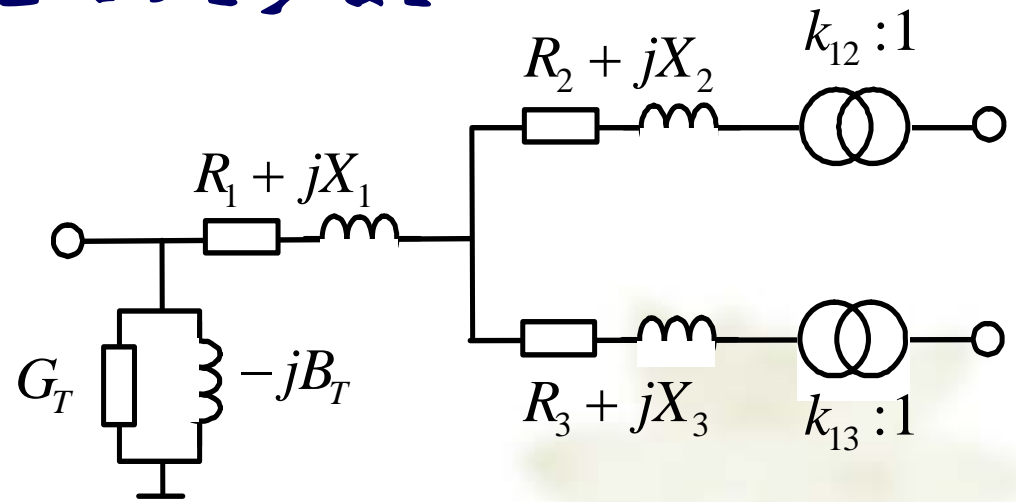
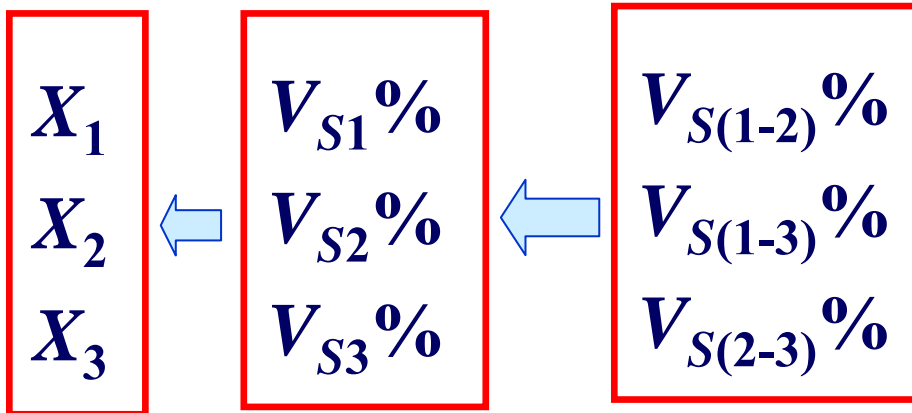
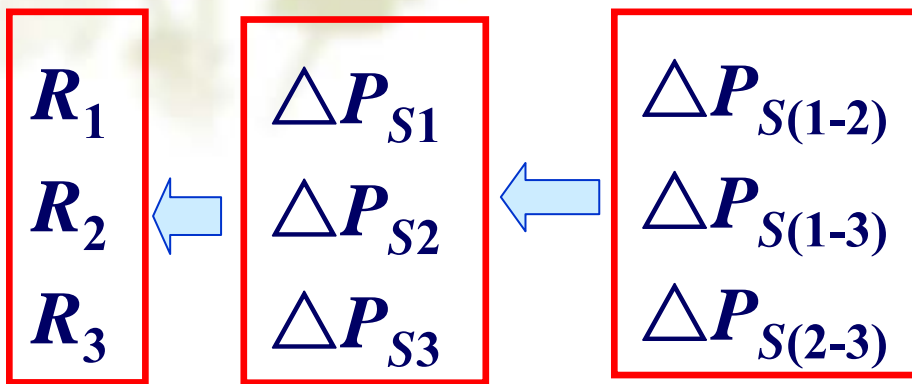
$$R_i = \frac{\Delta P_{si} V_N^2}{S_N^2} \times 10^3 \quad (i = 1, 2, 3)$$

$$\begin{cases} \Delta P_{S(1-2)} = \Delta P_{S1} + \Delta P_{S2} = \Delta P'_{S(1-2)} \\ \Delta P_{S(1-3)} = \Delta P_{S1} + \Delta P_{S3} = 4\Delta P'_{S(1-3)} \\ \Delta P_{S(2-3)} = \Delta P_{S2} + \Delta P_{S3} = 4\Delta P'_{S(2-3)} \end{cases}$$

$$\begin{cases} \Delta P'_{S(1-2)} = 3I_{1N}^2 R_1 + 3I_{2N}^2 R_2 \\ \Delta P'_{S(1-3)} = 3(0.5I_{1N})^2 R_1 + 3I_{3N}^2 R_3 \\ \Delta P'_{S(2-3)} = 3(0.5I_{2N})^2 R_2 + 3I_{3N}^2 R_3 \end{cases}$$

2-3 变压器等值电路及参数

2. 三绕组变压器等值电路及参数



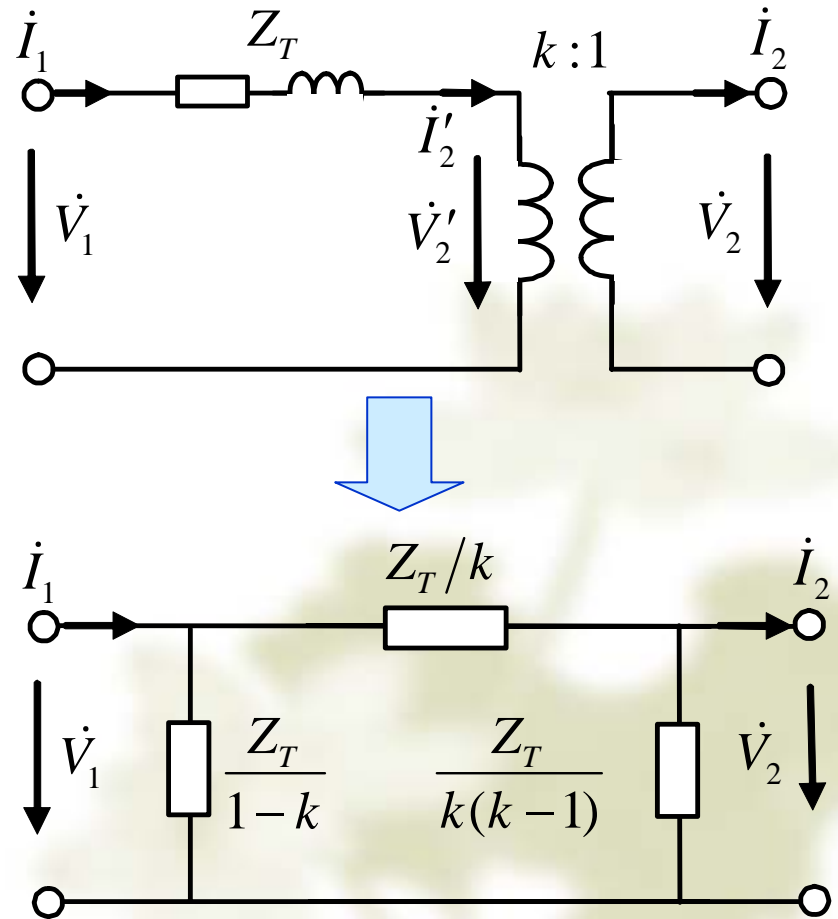
三绕组变压器绕组排列

2-3 变压器等值电路及参数

3. 变压器Π型等值电路

$$\begin{cases} \dot{I}_1 = \frac{\dot{V}_1}{Z_T} - \frac{\dot{V}_2'}{Z_T} = \frac{\dot{V}_1}{Z_T} - \frac{k\dot{V}_2}{Z_T} \\ \dot{I}_2 = k\dot{I}_2' = k\dot{I}_1 = \frac{k\dot{V}_1}{Z_T} - \frac{k^2\dot{V}_2}{Z_T} \end{cases}$$

$$\begin{cases} \dot{I}_1 = \frac{1-k}{Z_T} \dot{V}_1 + \frac{k}{Z_T} (\dot{V}_1 - \dot{V}_2) \\ \dot{I}_2 = \frac{k}{Z_T} (\dot{V}_1 - \dot{V}_2) - \frac{k(k-1)}{Z_T} \dot{V}_2 \end{cases}$$



2-3 变压器等值电路及参数

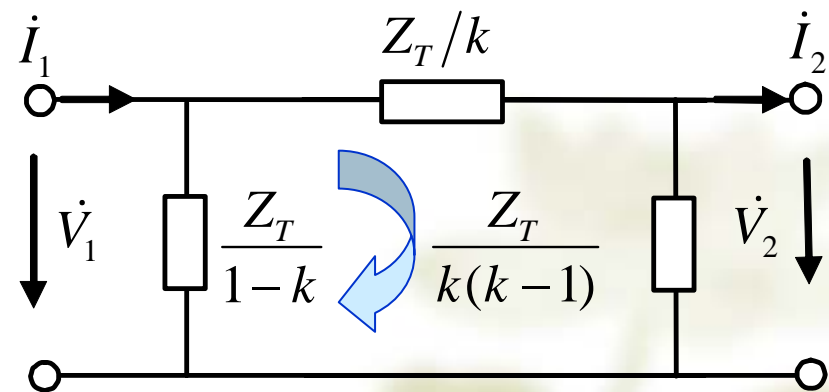
3. 变压器II型等值电路

原副方电压电流：实际值

谐振三角形：阻抗和为零

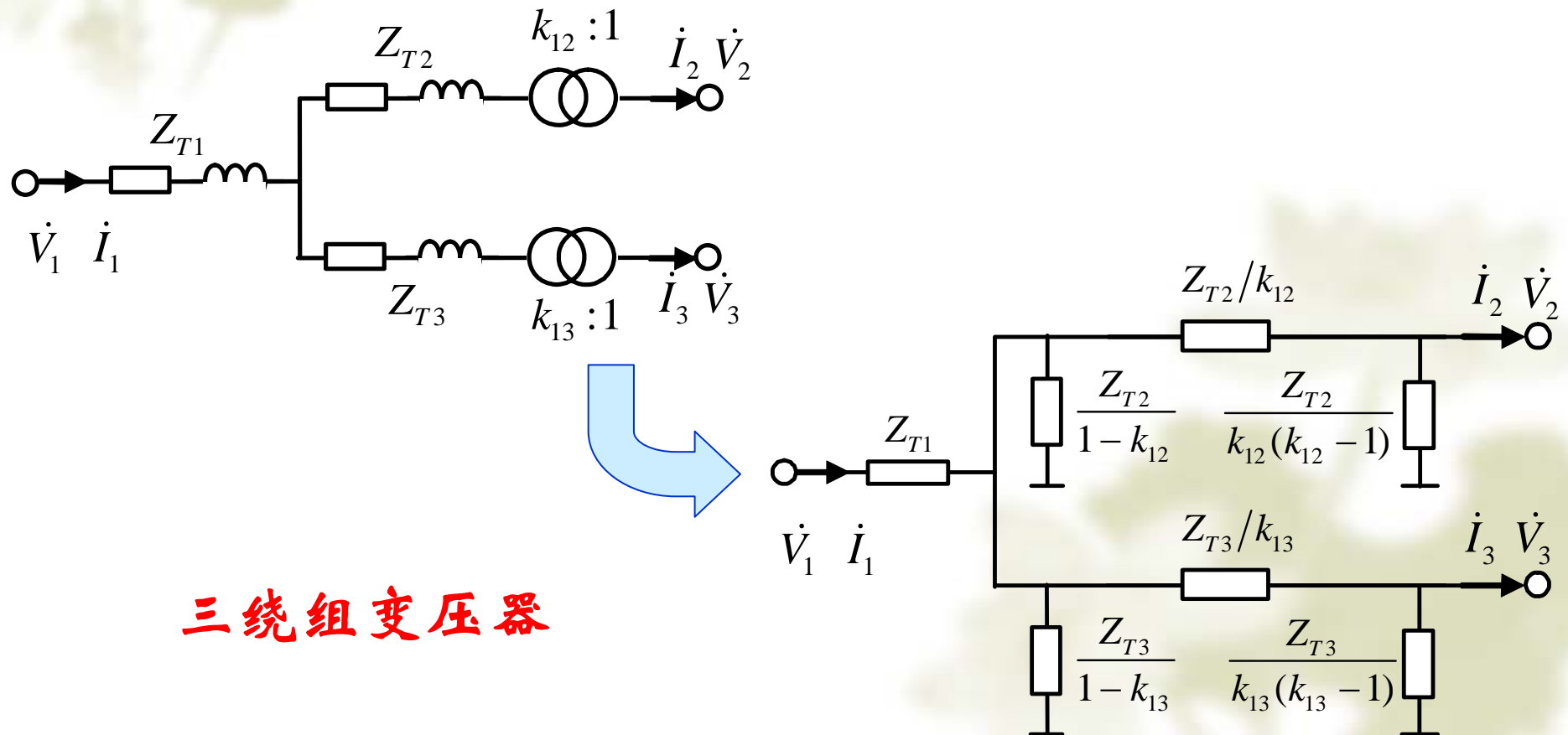
谐振环流：实现电流变换

串联阻抗压降：实现变压



2-3 变压器等值电路及参数

3. 变压器II型等值电路



三绕组变压器

2-4 标么制

1. 标么制的概念

标么值 = $\frac{\text{实际有名值（任意单位）}}{\text{基准值（与有名值同单位）}}$

$$V_* = \frac{V}{V_B}, \quad I_* = \frac{I}{I_B}, \quad S_* = \frac{S}{S_B} = \frac{P + jQ}{S_B}, \quad Z_* = \frac{Z}{Z_B} = \frac{R + jX}{Z_B}$$

2-4 标么制

2. 基准值的选取——单相电路

有名值	$V_P = ZI$	$S_P = V_P I$
基准值	$V_{PB} = Z_B I_B$	$S_{PB} = V_{PB} I_B$
标么值	$V_{P*} = Z_* I_*$	$S_* = V_{P*} I_*$

基准值	$I_B = S_{PB} / V_{PB}$	$Z_B = V_{PB}^2 / S_{PB}$
-----	-------------------------	---------------------------

2-4 标幺制

2. 基准值的选取—三相电路

有名值	$V = \sqrt{3}ZI$	$S = \sqrt{3}VI$
-----	------------------	------------------

基准值	$V_B = \sqrt{3}Z_B I_B$	$S_B = \sqrt{3}V_B I_B$
-----	-------------------------	-------------------------

标幺值	$V_* = Z_* I_*$	$S_* = V_* I_*$
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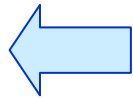
基准值	$I_B = S_B / \sqrt{3}V_B$	$Z_B = V_B^2 / S_B$
-----	---------------------------	---------------------

2-4 标么制

3. 不同基准值的标么值间的换算

$$X_{(B)*} = X_{(有名值)} \times \frac{S_B}{V_B^2} = X_{(N)*} \times \frac{V_N^2}{S_N} \times \frac{S_B}{V_B^2}$$

统一基准下
的标么电抗

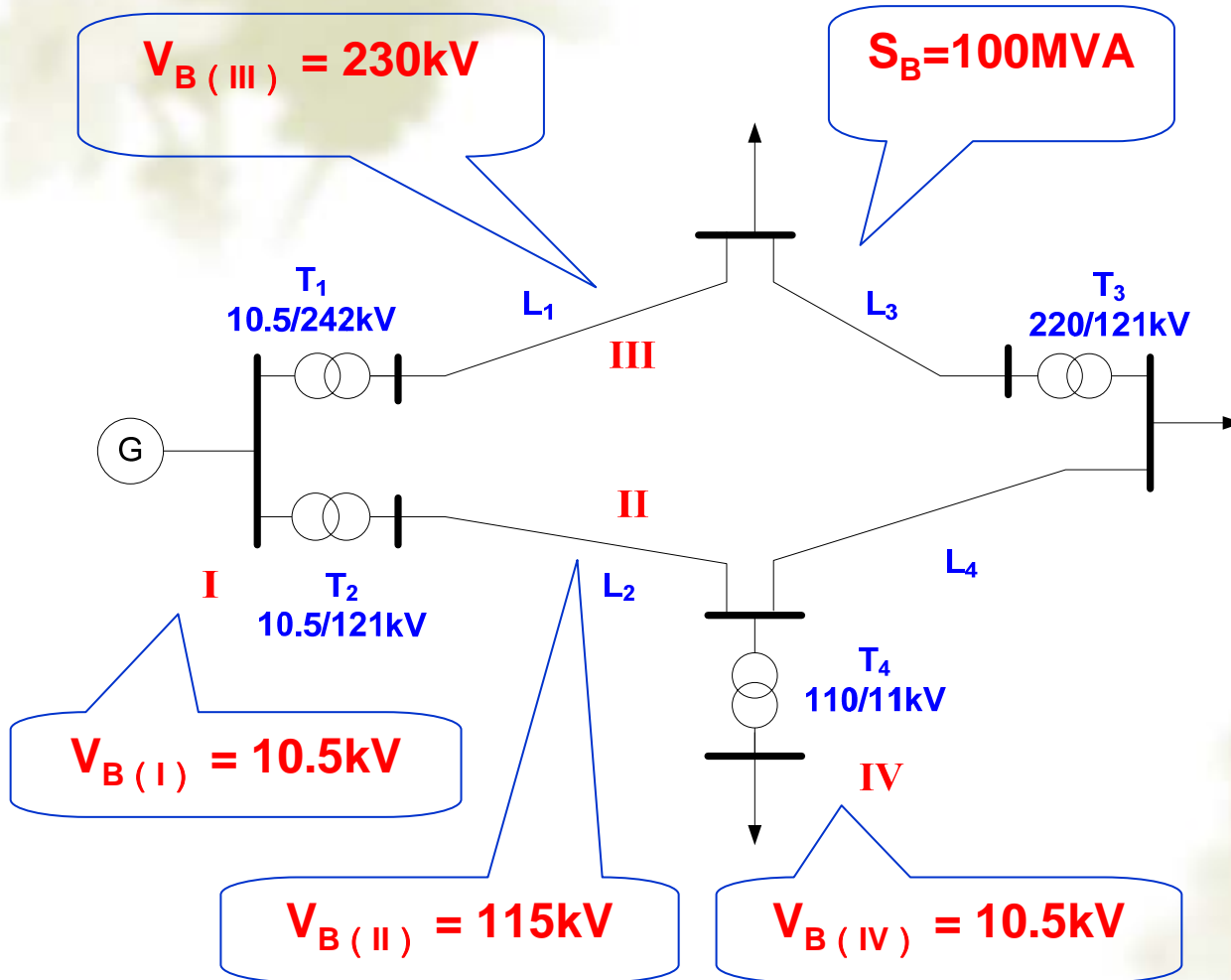


有名值
电抗



额定标
么电抗

2-4 标幺制——基准值选取方法



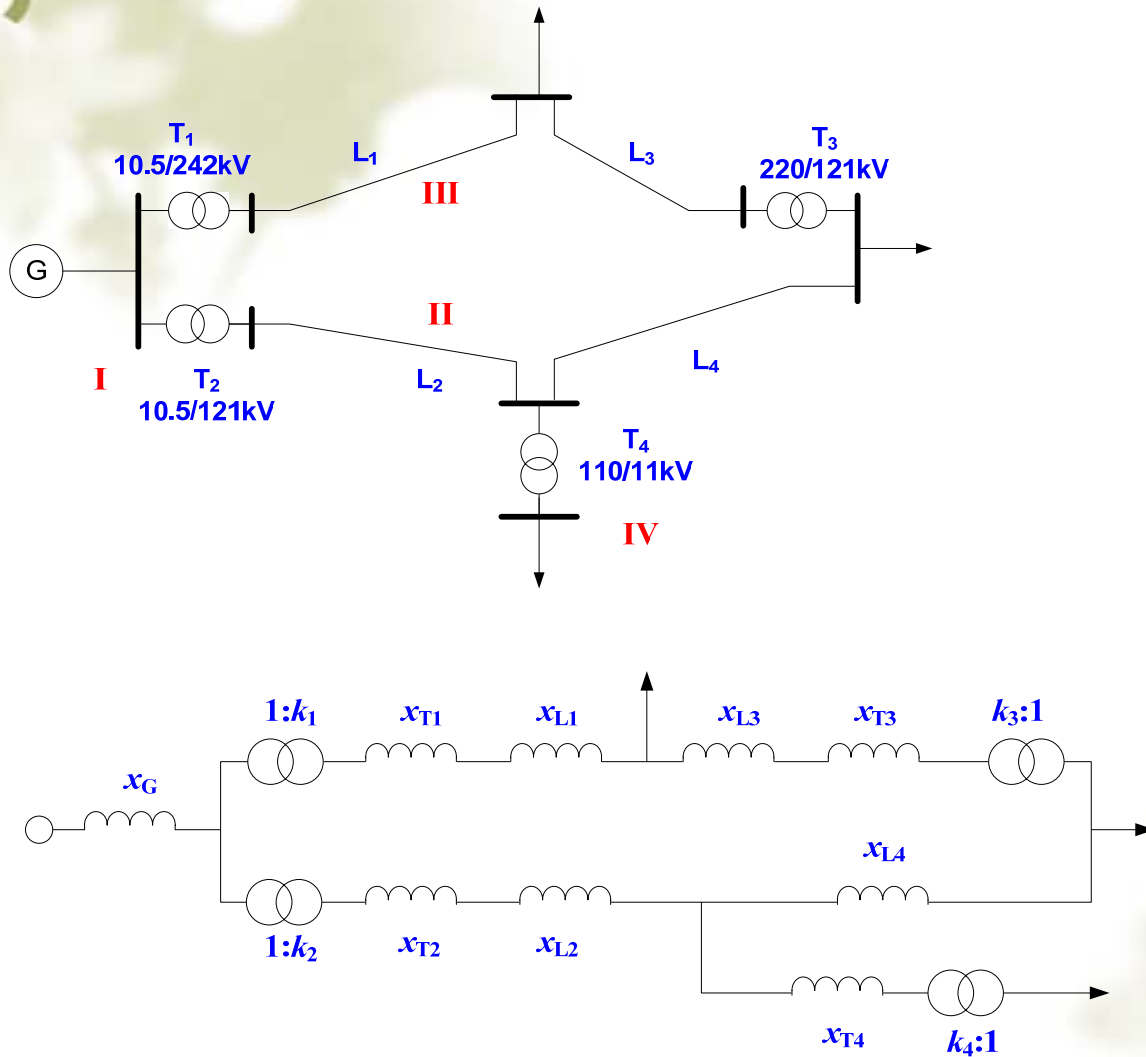
□ 全网统一功率基准;

□ 不同电压等级电网取平均额定电压作为其电压基准;

□ 各级电网平均额定电压: 6.3kV, 10.5kV, 37kV, 115kV, 230kV, 345kV, 525kV

□ 电流、阻抗基准由功率基准和电压基准按三相电路的物理关系确定

2-4 标么制——标么值参数计算



□ 线路电抗标么值计算

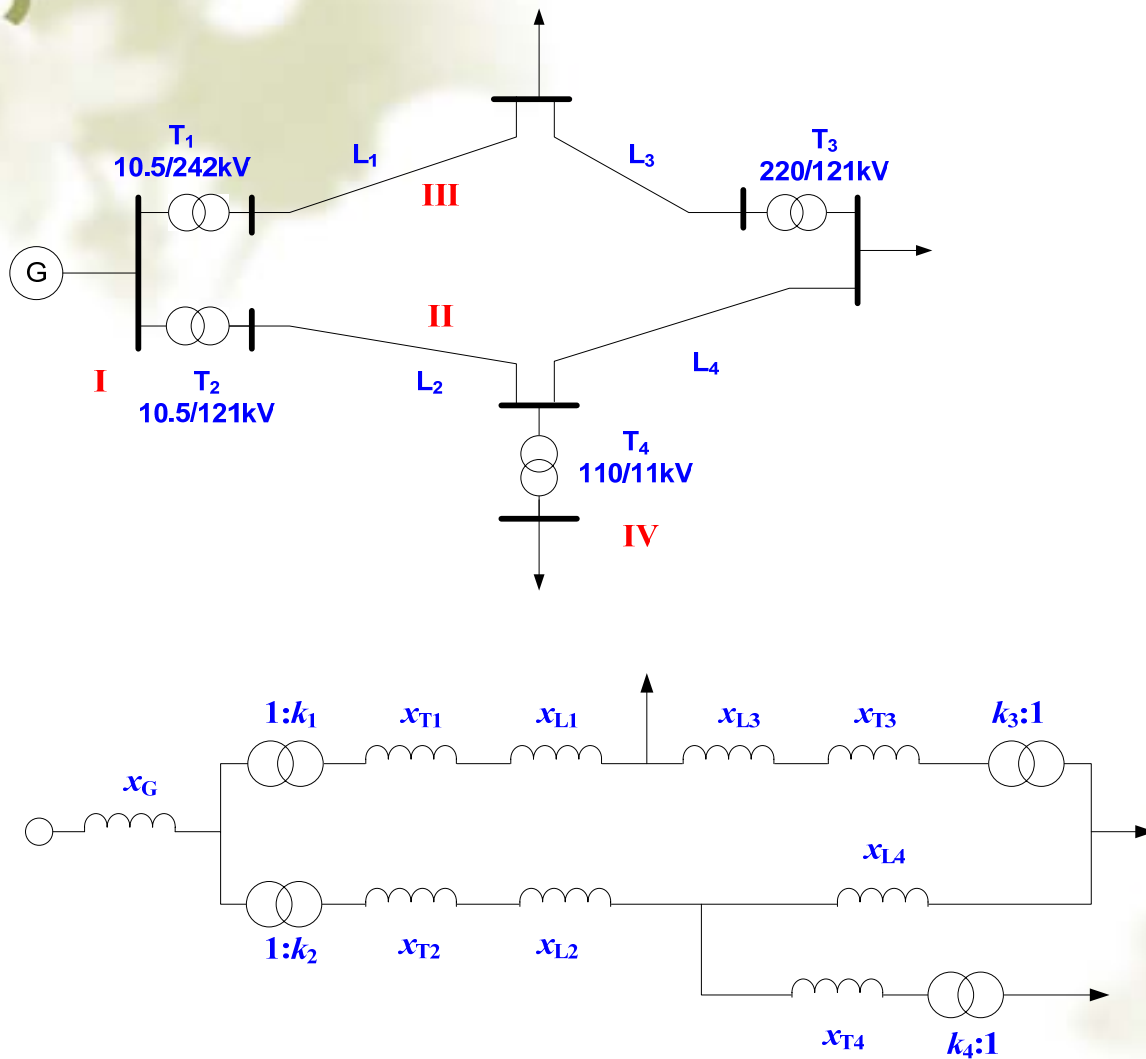
$$x_{L1*} = x_{L1} \times \frac{S_B}{V_{B(III)}^2}$$

$$x_{L2*} = x_{L2} \times \frac{S_B}{V_{B(II)}^2}$$

$$x_{L3*} = x_{L3} \times \frac{S_B}{V_{B(III)}^2}$$

$$x_{L4*} = x_{L4} \times \frac{S_B}{V_{B(IV)}^2}$$

2-4 标么制——标么值参数计算



□ 发电机额定标么电抗

$$x_{G(N)} = x_G \times \frac{S_N}{V_{G(N)}^2}$$

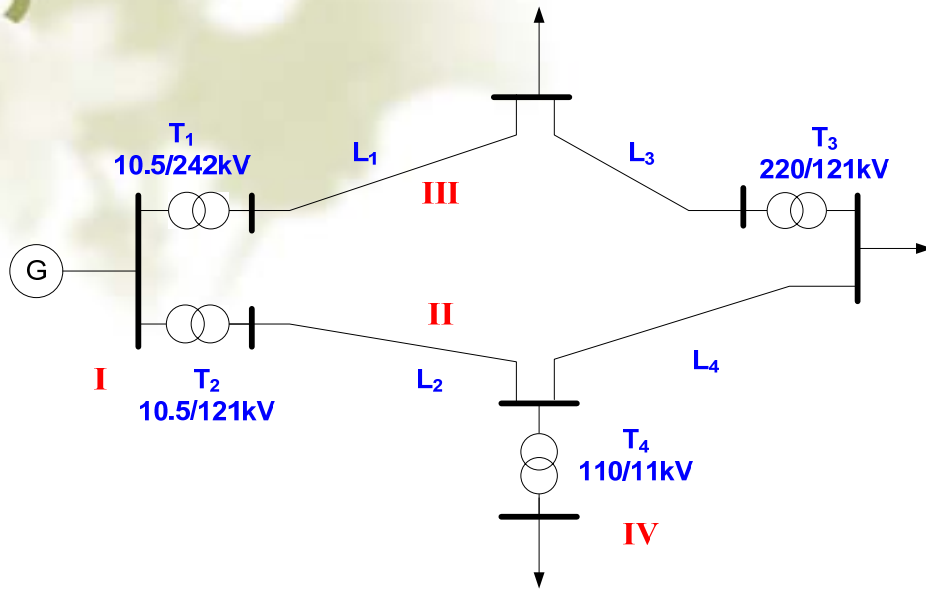
□ 发电机标么电抗

$$x_{G^*} = x_G \times \frac{S_B}{V_{B(I)}^2}$$

□ 标么电抗与额定标么电抗间的转换

$$x_{G^*} = x_{G(N)} \times \frac{V_{G(N)}^2}{S_N} \times \frac{S_B}{V_{B(I)}^2}$$

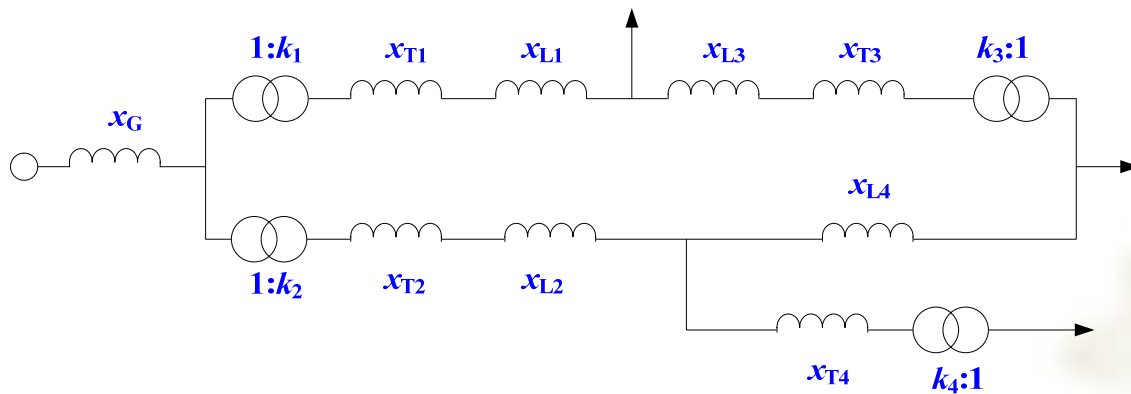
2-4 标么制——标么值参数计算



□ 变压器额定标么电抗

$$x_{T1} = x_{T1(N)^*} \times \frac{V_{T1(NIII)}^2}{S_{T1(N)}}$$

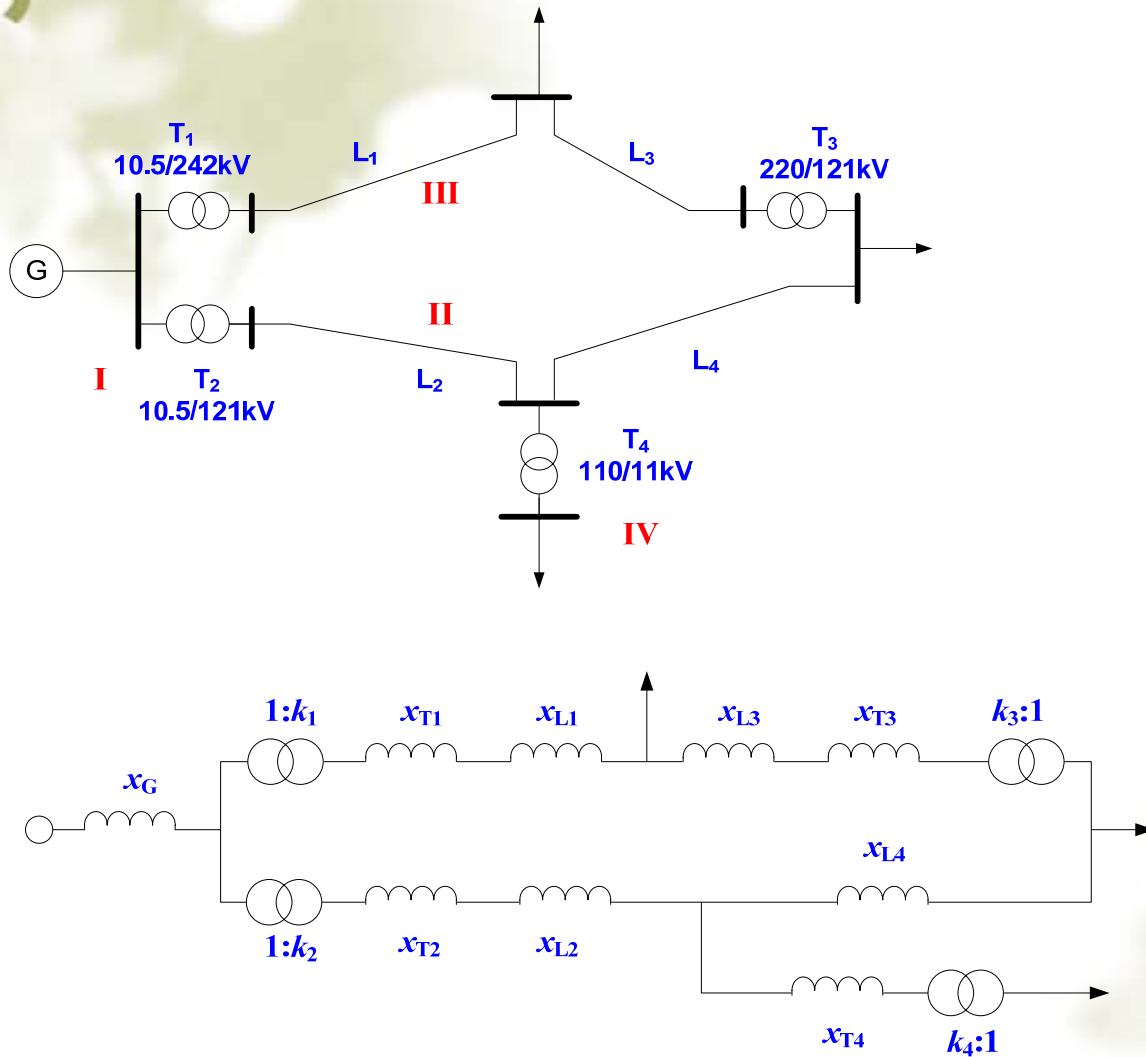
$$x_{T1(N)^*} = \frac{V_s \%}{100}$$



□ 变压器标么电抗转换

$$x_{T1} = x_{T1} \times \frac{S_B}{V_{B(III)}^2}$$

2-4 标么制——标么值参数计算



□ 变压器变比

$$k_{T1} = \frac{V_{T1(N2)}}{V_{T1(N1)}}$$

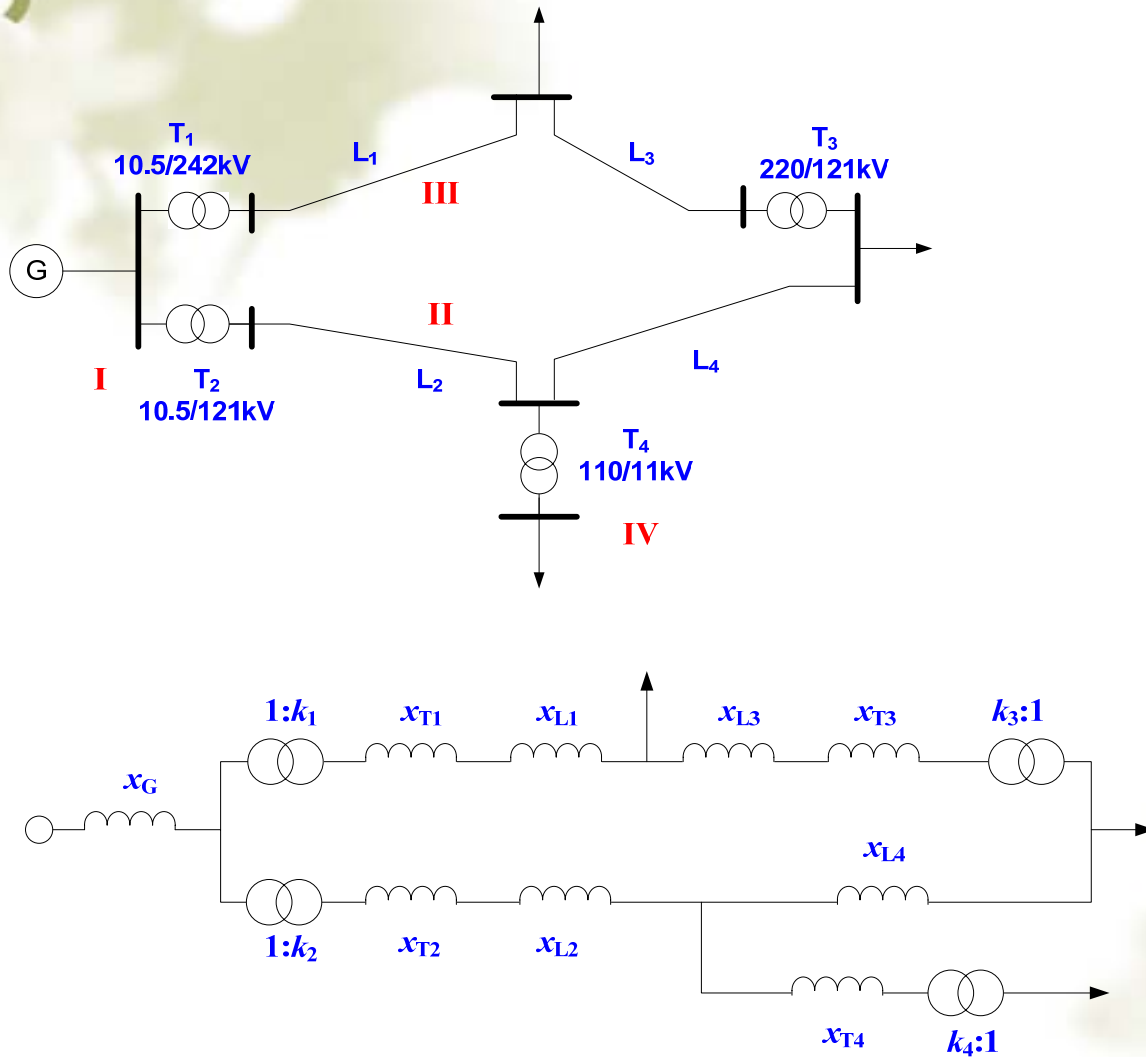
□ 变压器变比标么值

$$k_{T1*} = \frac{V_{T1(N2)} / V_{B(III)}}{V_{T1(N1)} / V_{B(I)}}$$

$$k_{T1*} = \frac{V_{T1(N2)} / V_{T1(N1)}}{V_{B(III)} / V_{B(I)}}$$

$$k_{T1*} = \frac{k_1}{k_{B(I-III)}}$$

2-4 标么制——标么制的特点



□易于比较元件特性和参数

◆同类型元件额定标么参数大致相近

◆同类型电机标么化空载特性基本一样

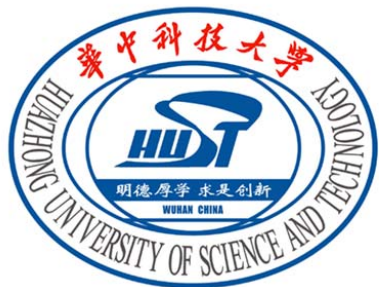
◆变压器短路电压额定标么值0.10左右

□简化计算

◆三相与单相电路标么值计算关系一样

◆线电压与相电压标么值相等

□没有量纲：物理概念不明确

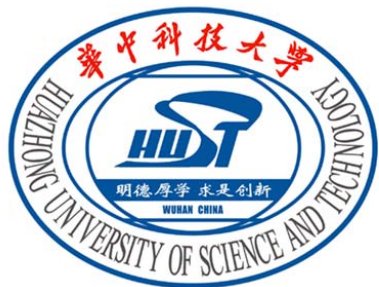


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本章小结

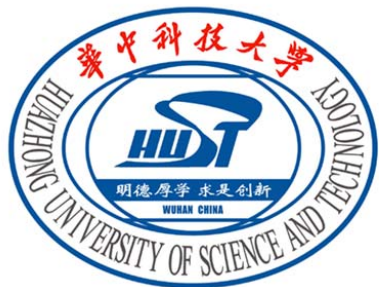
- 电力系统分析中一相等值电路的概念
- 输电线路集中参数的PI型等值电路及参数
- 变压器等值电路及参数计算、PI型等值电路
- 基准值选取原则以及标幺值参数的计算方法



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习题

Ex 2-3, 2-8, 2-11



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To Be Continued