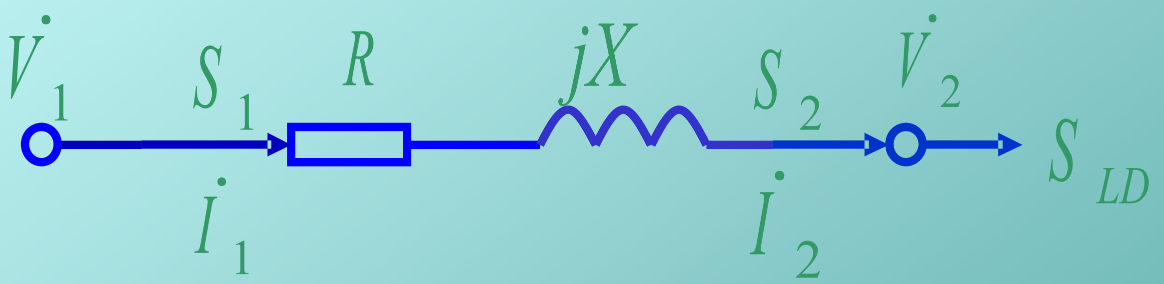
第三章 简单电力网络的计算和分析

- 网络元件的电压降落和功率损耗
- 开式网络的电压和功率分布
- 闭式网络的电压和功率分布
- 多级电压环网的功率分布
- 电力网的电能损耗

3-1 网络元件的电压降落和功率损耗

1. 网络元件的电压降落

元件首末端两点电压的向量差。



$$\dot{V}_1-\dot{V}_2=(R+jX)\dot{I}_2=(R+jX)\dot{I}_1$$

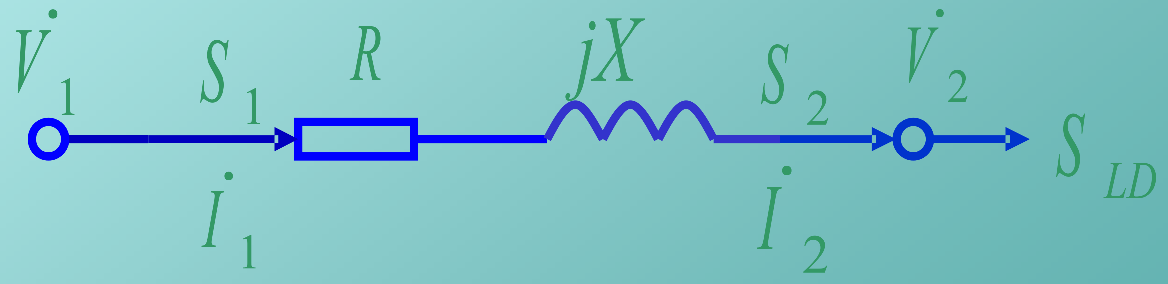
$$S_2 = \dot{V}_2 \dot{I}_2^* = P_2 + jQ_2$$

$$\dot{V}_1 = \dot{V}_2 + \left(\frac{S_2}{\dot{V}_2}\right)^* (R + jX)$$

$$\dot{V}_1 = V_2 + \left(\frac{P_2 - jQ_2}{V_2}\right)(R + jX)$$

以V_2为参考轴

$$= \left(V_2 + \frac{P_2 R + Q_2 X}{V_2}\right) + j\frac{P_2 X - Q_2 R}{V_2}$$



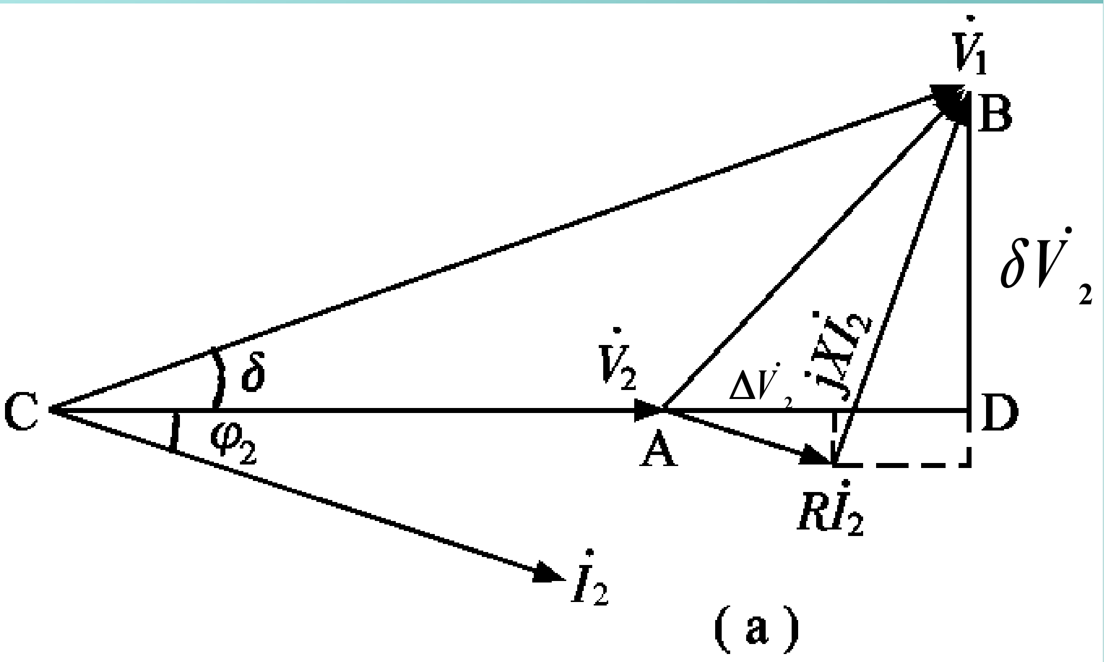
$$\dot{V}_1 = V_2 + \frac{P_2R + Q_2X}{V_2} + j\frac{P_2X - Q_2R}{V_2}$$

$$\dot{V}_1 = \dot{V}_2 + \Delta\dot{V}_2 + \delta\dot{V}_2 = V_2\angle\delta$$

$$V_1 = \sqrt{(V_2 + \Delta V_2)^2 + (\delta V_2)^2}$$

$$\delta = tg^{-1}\frac{\delta V_2}{V_2 + \Delta V_2}$$

$$\left.\begin{aligned} \Delta V_2 &= \frac{P_2R + Q_2X}{V_2} \\ \delta V_2 &= \frac{P_2X - Q_2R}{V_2} \end{aligned}\right\}$$



$$\dot{V}_1 - \dot{V}_2 = (R + jX)\dot{I}_2 = (R + jX)\dot{I}_1$$

因此，由末端电压和功率可求得首端电压

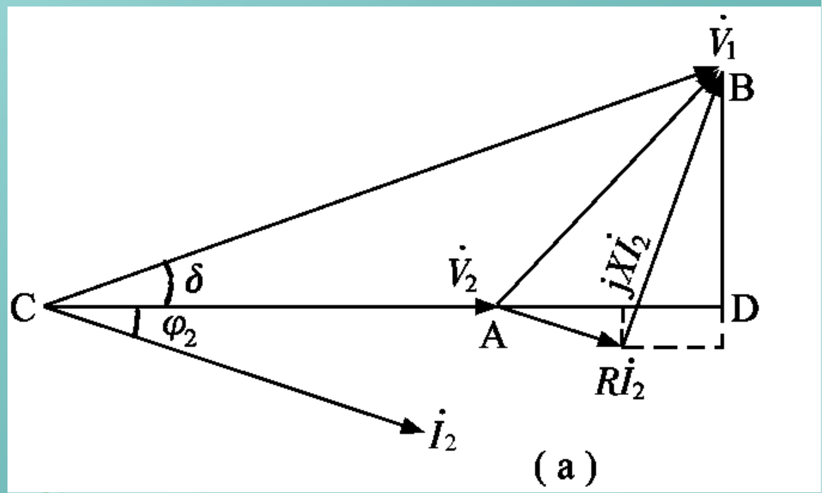
$$\dot{V}_1 = \dot{V}_2 + \Delta\dot{V}_2 + \delta\dot{V}_2$$

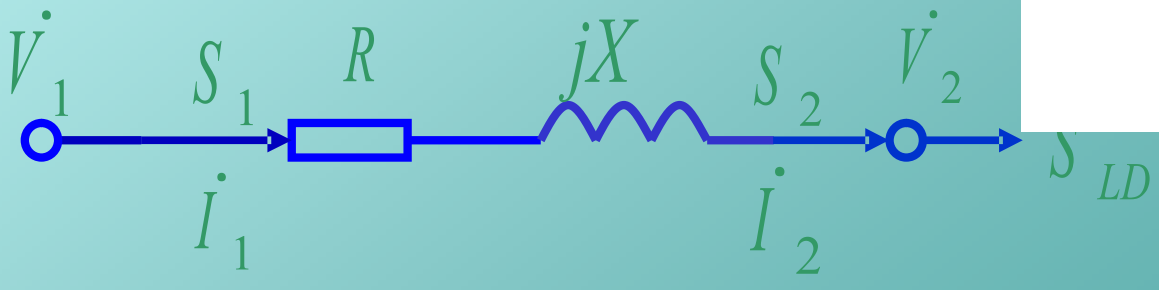
$$= V_2 + \frac{P_2R + Q_2X}{V_2} + j\frac{P_2X - Q_2R}{V_2}$$

$$= V_1\angle\delta_{12}$$

$$V_1 = \sqrt{(V_2 + \Delta V_2)^2 + (\delta V_2)^2}$$

$$\delta = tg^{-1}\frac{\delta V_2}{V_2 + \Delta V_2}$$



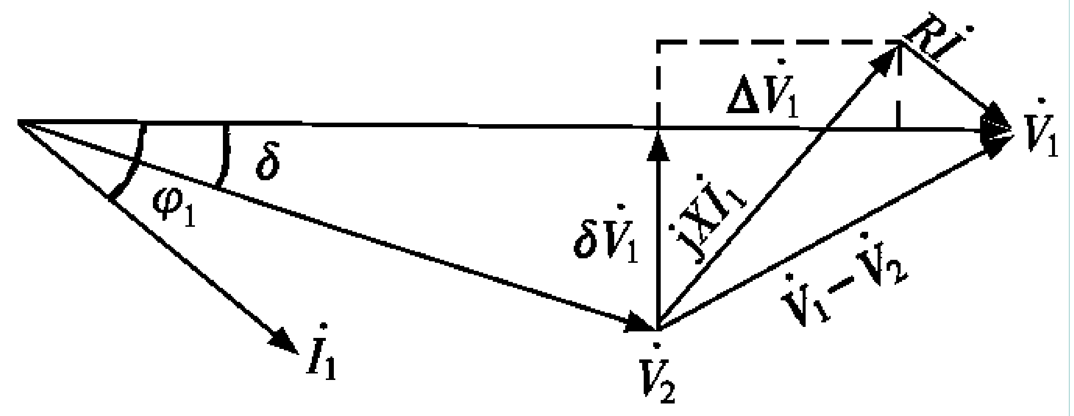


同样,也可由首端电压和功率求得末端电压

$$V_2 = \sqrt{(V_1 - \Delta V_1)^2 + (\delta V_1)^2}$$

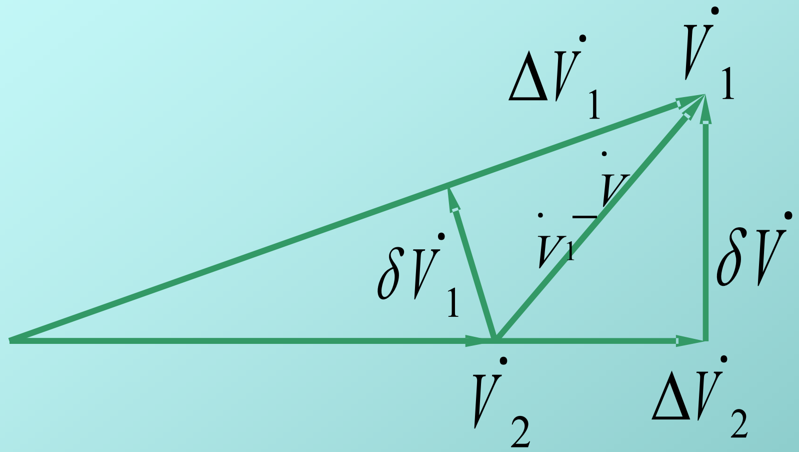
$$\delta = tg^{-1}\frac{\delta V_1}{V_1 - \Delta V_1}$$

$$\left.\begin{aligned} \Delta V_1 &= \frac{P_1 R + Q_1 X}{V_1} \\ \delta V_1 &= \frac{P_1 X - Q_1 R}{V_1} \end{aligned}\right\}$$



(b)

两种分解



$$\left.\begin{aligned}\Delta V_2 &= \frac{P_2 R + Q_2 X}{V_2}\\ \delta V_2 &= \frac{P_2 X - Q_2 R}{V_2}\end{aligned}\right\}$$

$$\left.\begin{aligned}\Delta V_1 &= \frac{P_1 R + Q_1 X}{V_1}\\ \delta V_1 &= \frac{P_1 X - Q_1 R}{V_1}\end{aligned}\right\}$$

$$\left.\begin{aligned}\Delta V &= \frac{PR + QX}{V}\\ \delta V &= \frac{PX - QR}{V}\end{aligned}\right\}$$

特别注意:

计算电压降落时,必须用同一端的电压与功率.

电压降落公式的简化

高压输电线路的特性 X>>R，可令R≈0，则：

$$\left.\begin{aligned}\Delta V &= \frac{PR+QX}{V}\\ \delta V &= \frac{PX-QR}{V}\end{aligned}\right\} \Longrightarrow \left.\begin{aligned}\Delta V &= \frac{QX}{V}\\ \delta V &= \frac{PX}{V}\end{aligned}\right\}$$

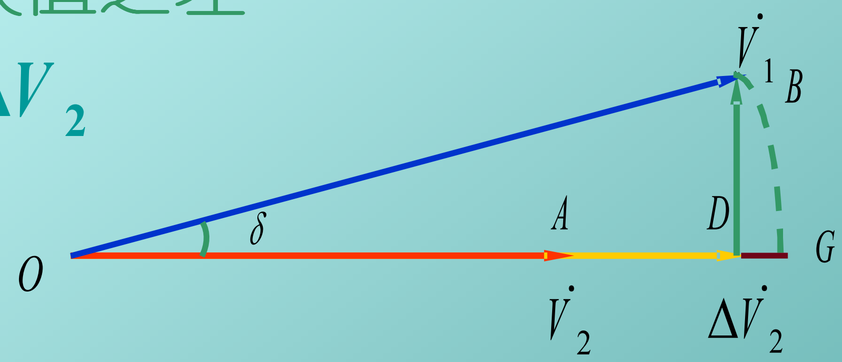
电压损耗和电压偏移

- 电压损耗:两点间电压模值之差

$$\Delta V = V_1 - V_2 = AG \approx \Delta V_2$$

- 或表示为百分值:

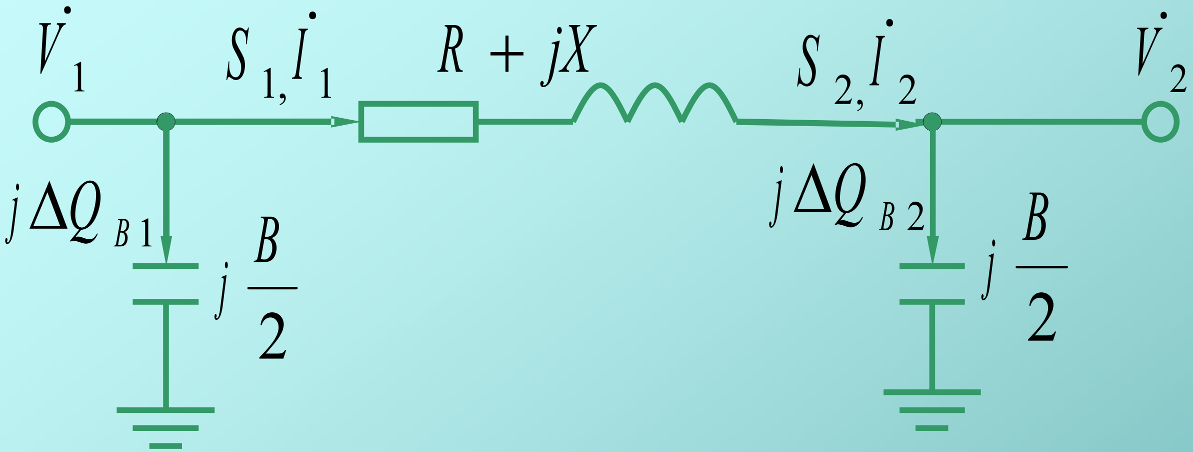
$$\Delta V\% = \frac{V_1 - V_2}{V_N} \times 100\%$$



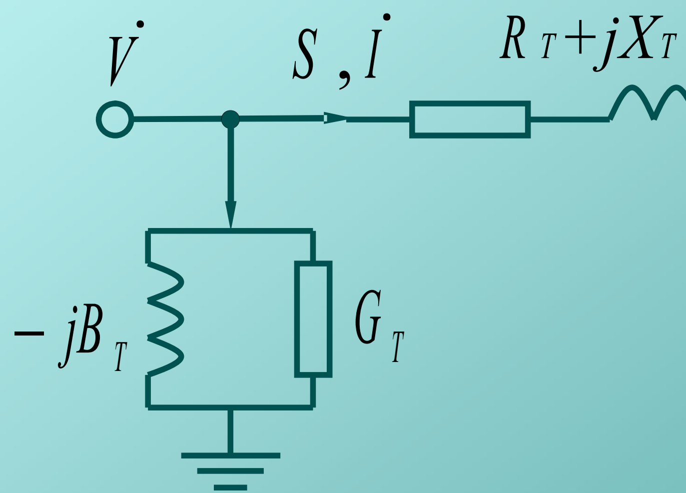
- 电压偏移:线路始末端电压与线路额定电压之差

$$电压偏移(\%) = \frac{V_1 - V_N}{V_N} \times 100\%$$

2. 网络元件的功率损耗



线路



变压器

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（1） 电流流过串联阻抗产生的功率损耗

$$\Delta S = I_2^2(R + jX) = (\frac{S_2}{V_2})^2(R + jX)$$

$$= \frac{P_2^2 + Q_2^2}{V_2^2}(R + jX) = \frac{P_1^2 + Q_1^2}{V_1^2}(R + jX)$$

$$= \frac{P_2^2 + Q_2^2}{V_2^2}R + j\frac{P_2^2 + Q_2^2}{V_2^2}X$$

$$= \Delta P + j\Delta Q$$

（2） 电压加在并联导纳产生的功率损耗

$$\Delta Q_{B_1} = -\frac{1}{2} B V_1^2 \qquad \Delta Q_{B_2} = -\frac{1}{2} B V_2^2$$ 线路

$$\Delta S_0 = (G_T + jB_T) V^2$$ 变压器

直接用变压器空载试验数据计算

$$\Delta S_0 = \Delta P_0 + j\Delta Q_0 = \Delta P_0 + j\frac{I_0\%}{100} S_N$$

（3） 输电效率$=\dfrac{P_2}{P_1}\times 100\%$

3-2 开式网络的电压和功率分布

- 开式网络及其等值电路
- 电压和功率分布的计算

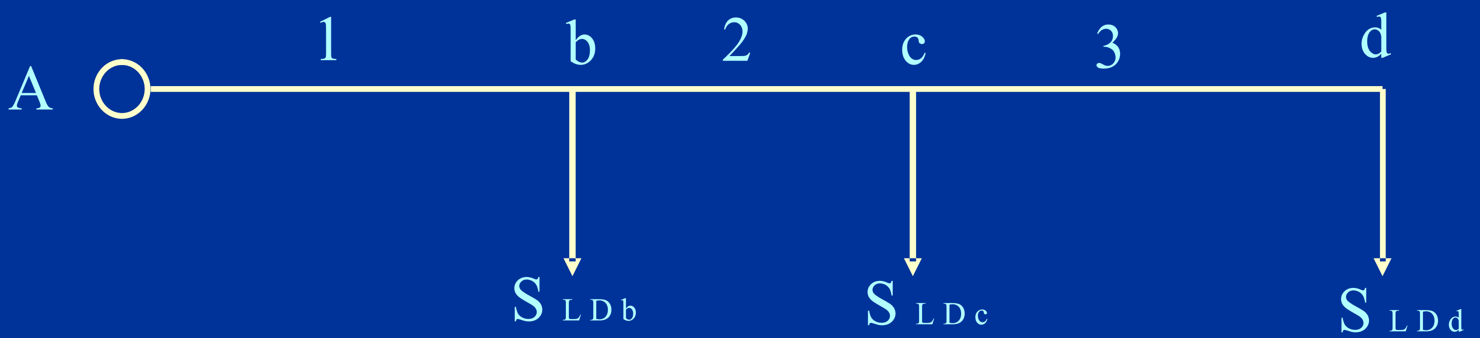
1、同级电压的开式电力网

（1）用V_N求得各点的运算负荷

（2）从末段线路开始，用V_N依次计算各段线路的功率损耗

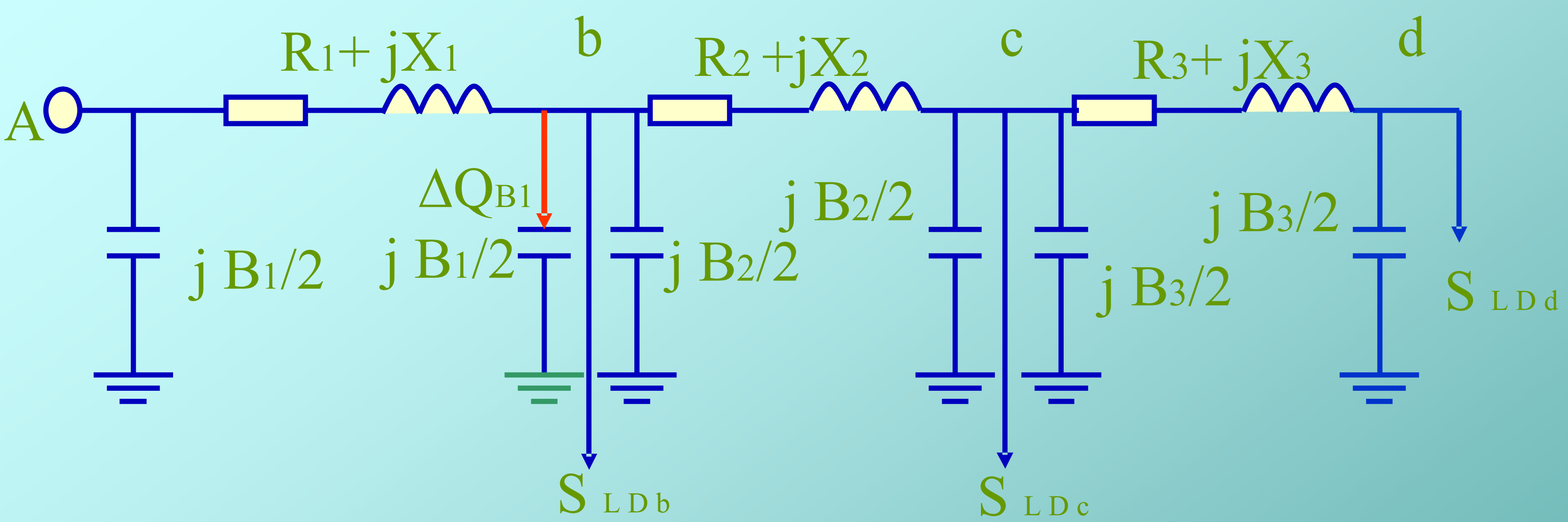
（3）用V_A和已求得的功率分布，从A点开始逐段计算电压降落，求得V_b、V_c和V_d

（4）求得V_b和 V_c V_d重复（1）～（3）



降压变的处理

（1）用V_N求得各点的运算负荷

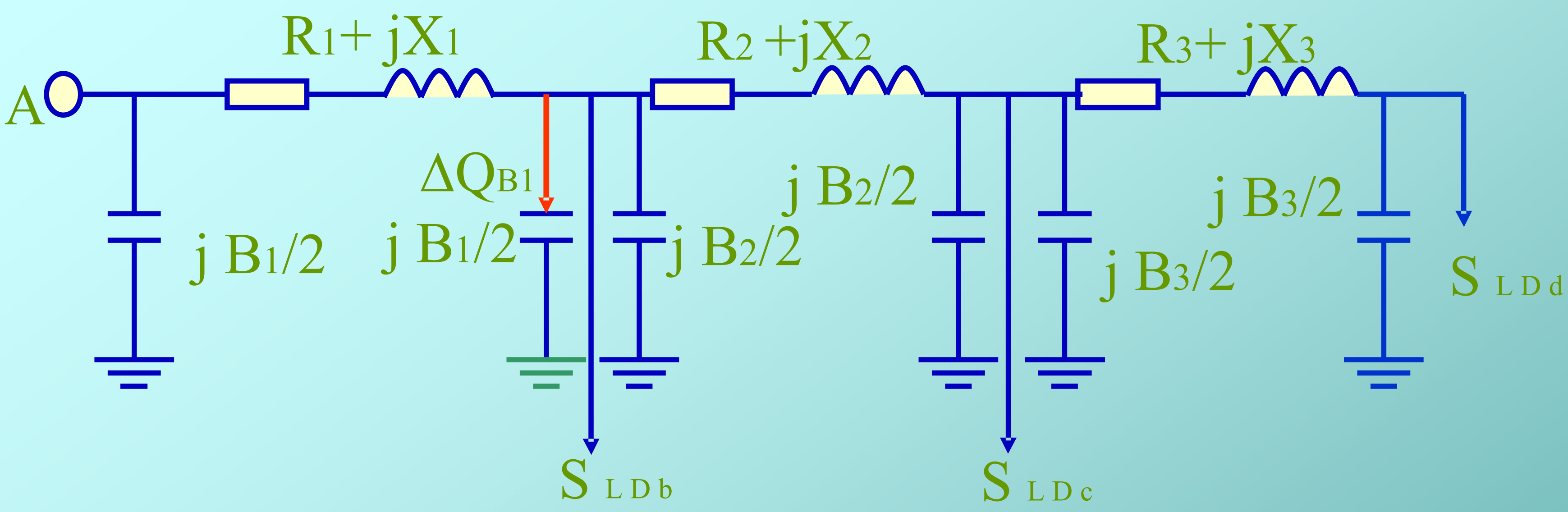


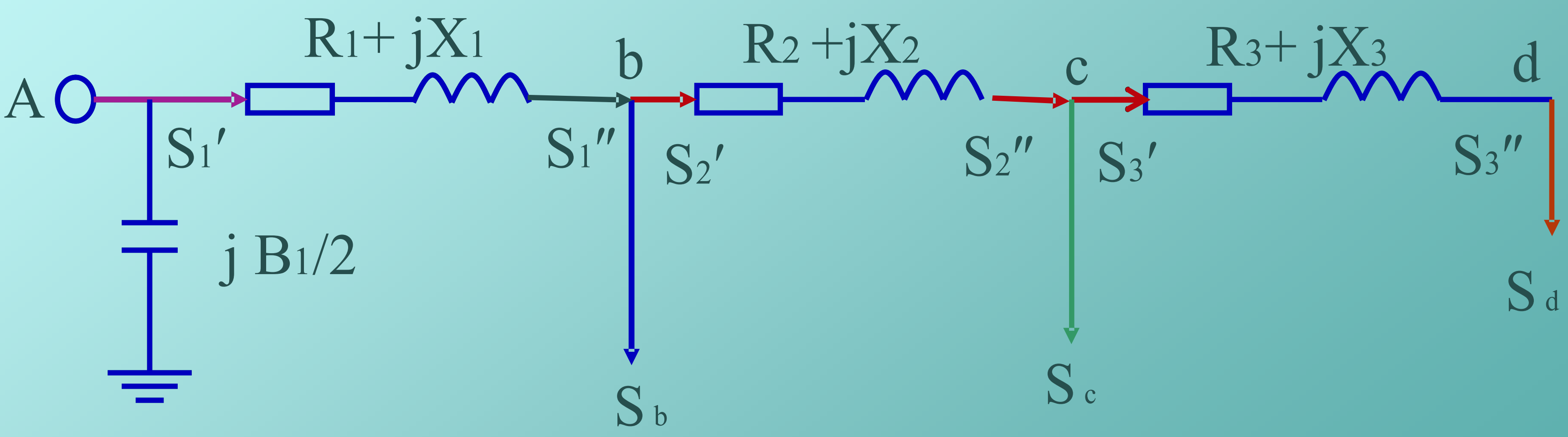
$$\Delta Q_{Bi} = -\frac{1}{2} B_i V_N^2$$

$$S_b = S_{LDb} + j\Delta Q_{B1} + j\Delta Q_{B2}$$

$$S_c = S_{LDc} + j\Delta Q_{B2} + j\Delta Q_{B3}$$

$$S_d = S_{LDd} + j\Delta Q_{B3}$$


A
R1+ jX1
R2 +jX2
R3+ jX3
ΔQB1
j B1/2
j B1/2
j B2/2
j B2/2
j B3/2
j B3/2
S LDb
S LDc
S LDd

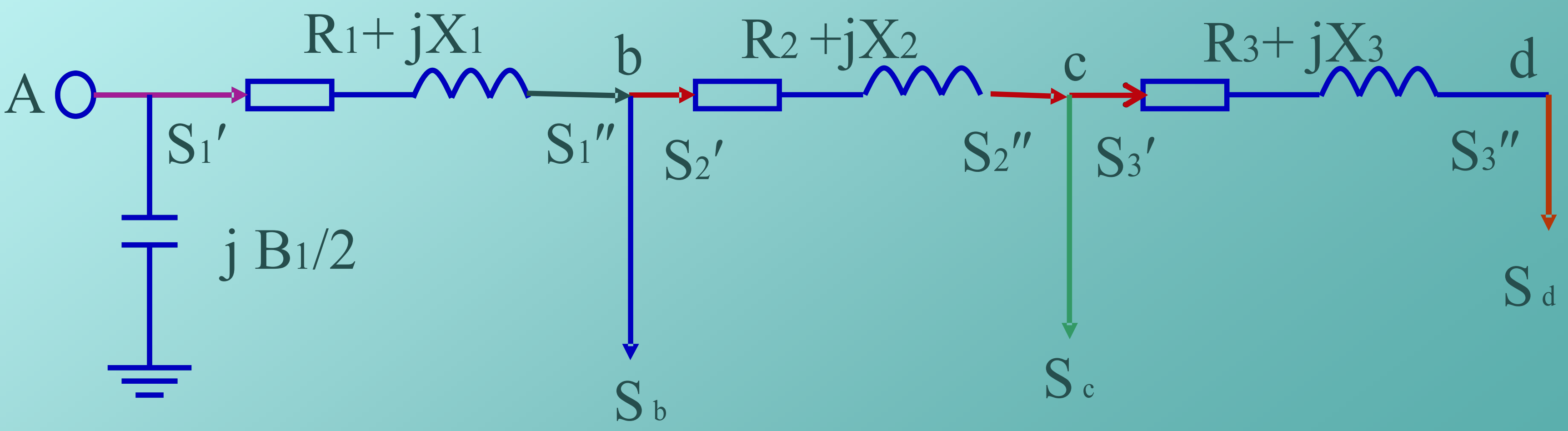

A
R1+ jX1
b
R2 +jX2
c
R3+ jX3
d
S1′
S1″
S2′
S2″
S3′
S3″
j B1/2
S b
S c
S d

从末段线路开始，用V_N依次计算各段线路的功率损耗

$$S_3'' = S_d,\ \Delta S_{L3} = \left(\frac{S_3''}{V_N}\right)^2 (R_3 + jX_3),\ S_3' = S_3'' + \Delta S_{L3}$$

$$S_2'' = S_c + S_3',\ \Delta S_{L2} = \left(\frac{S_2''}{V_N}\right)^2 (R_2 + jX_2),\ S_2' = S_2'' + \Delta S_{L2}$$

$$S_1'' = S_b + S_2',\ \Delta S_{L1} = \left(\frac{S_1''}{V_N}\right)^2 (R_1 + jX_1),\ S_1' = S_1'' + \Delta S_{L1}$$



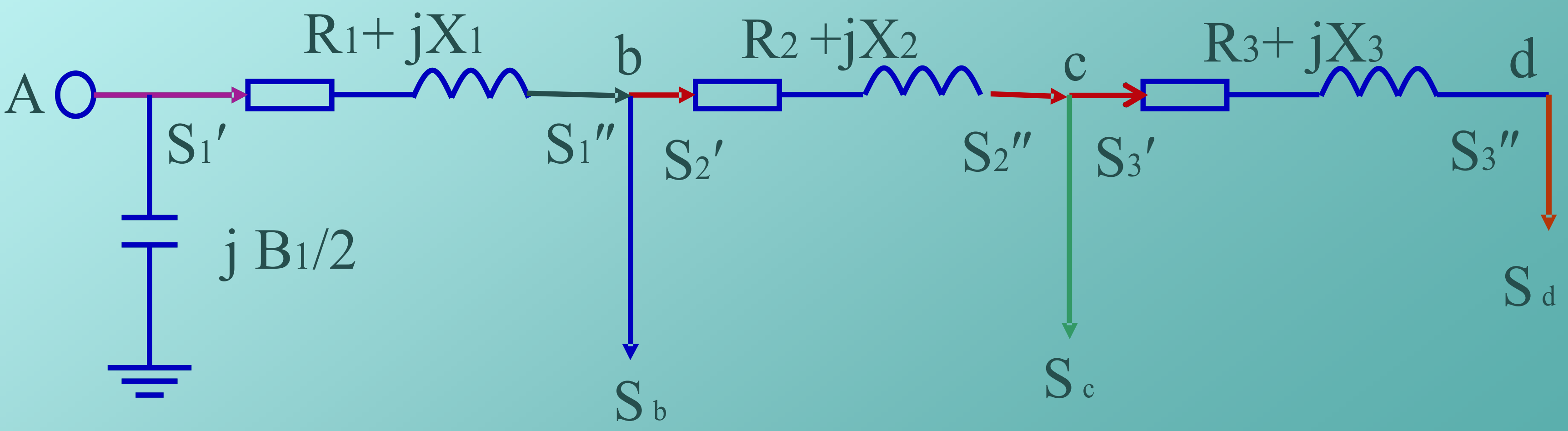
用V_A和已求得的功率分布，从A点开始逐段计算电压降落，求得V_b、 V_c和V_d

$$\Delta V_{Ab}=\frac{P_1'R_1+Q_1'X_1}{V_A},\quad \delta V_{Ab}=\frac{P_1'X_1-Q_1'R_1}{V_A}$$

$$V_b=\sqrt{(V_A-\Delta V_{Ab})^2+(\delta V_{Ab})^2}$$

$$\Delta V_{bc}=\frac{P_2'R_2+Q_2'X_2}{V_b},\quad \delta V_{bc}=\frac{P_2'X_2-Q_2'R_2}{V_b}$$

$$V_c=\sqrt{(V_c-\Delta V_{bc})^2+(\delta V_{bc})^2}$$

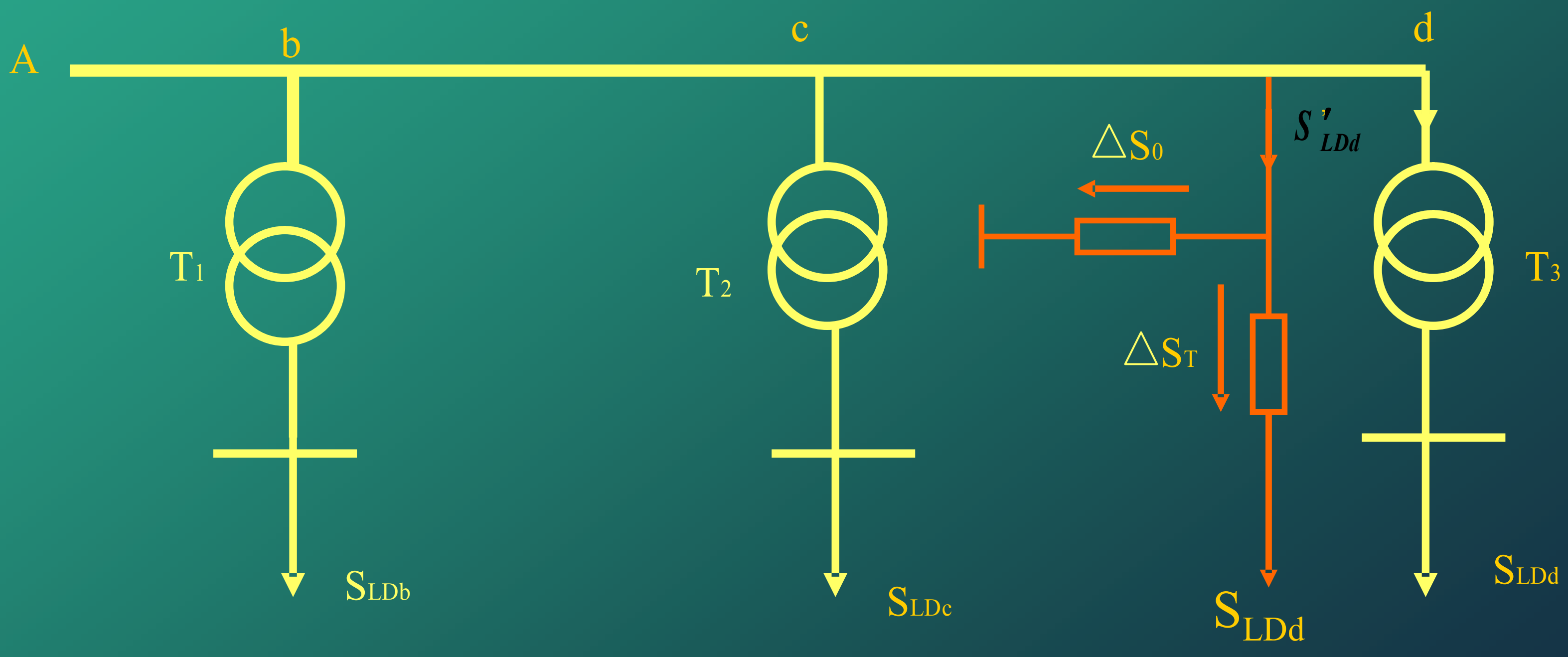


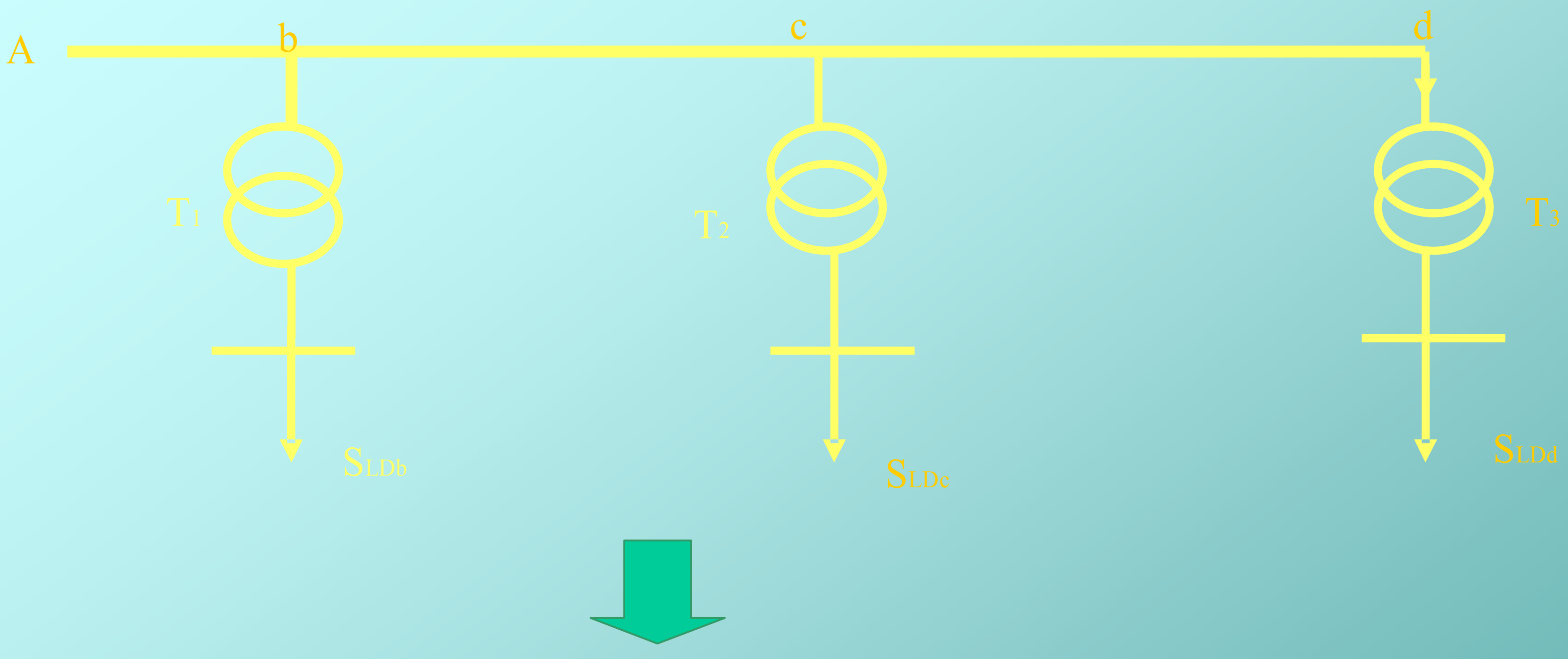
含负荷变压器的计算

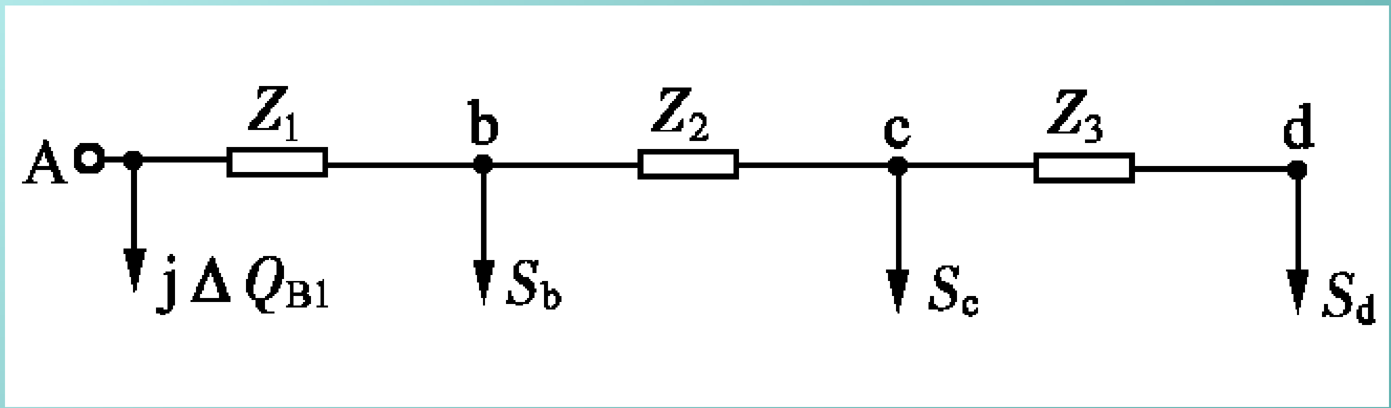
首先计算出对应高压侧的负荷功率，再求相应的运算功率

$$S'_{LD} = S_{LD} + \Delta S_T + \Delta S_0$$

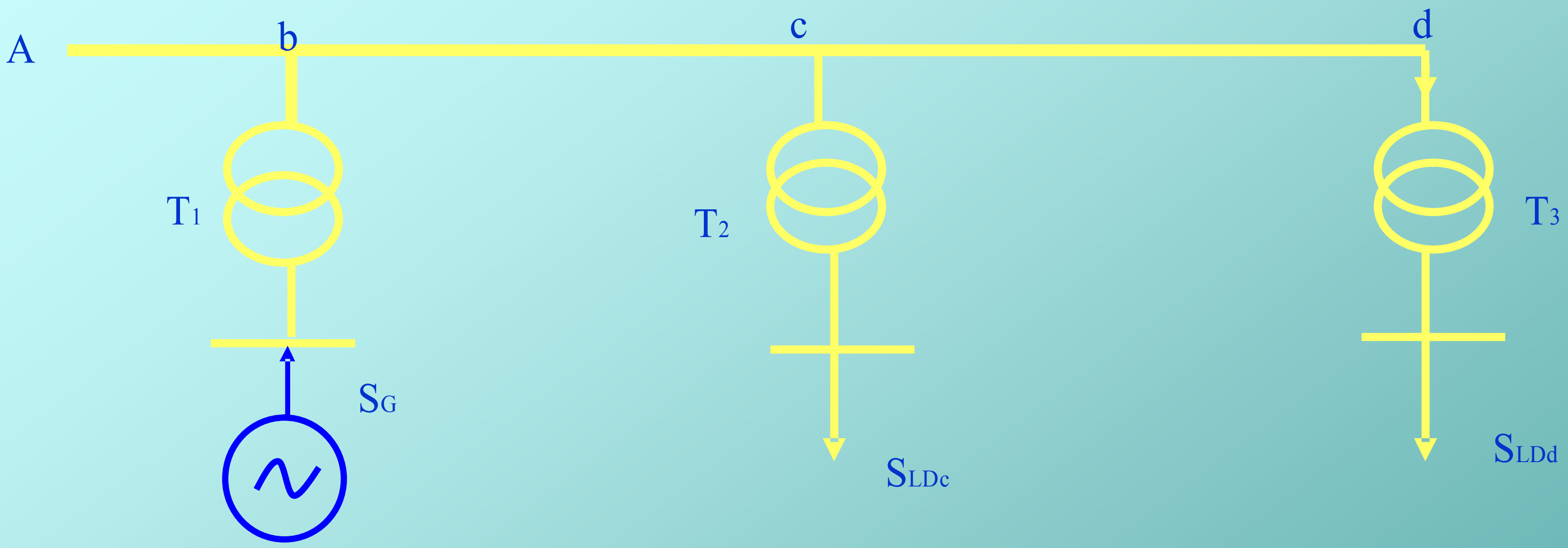
$$\Delta S_T = \left(\frac{S_{LD}}{V_N}\right)^2 (R_T + jX_T)，\Delta S_0 = \Delta P_0 + j\frac{I_0\%}{100}S_N$$




A
b
c
d
T1
T2
T3
SLDb
SLDc
SLDd

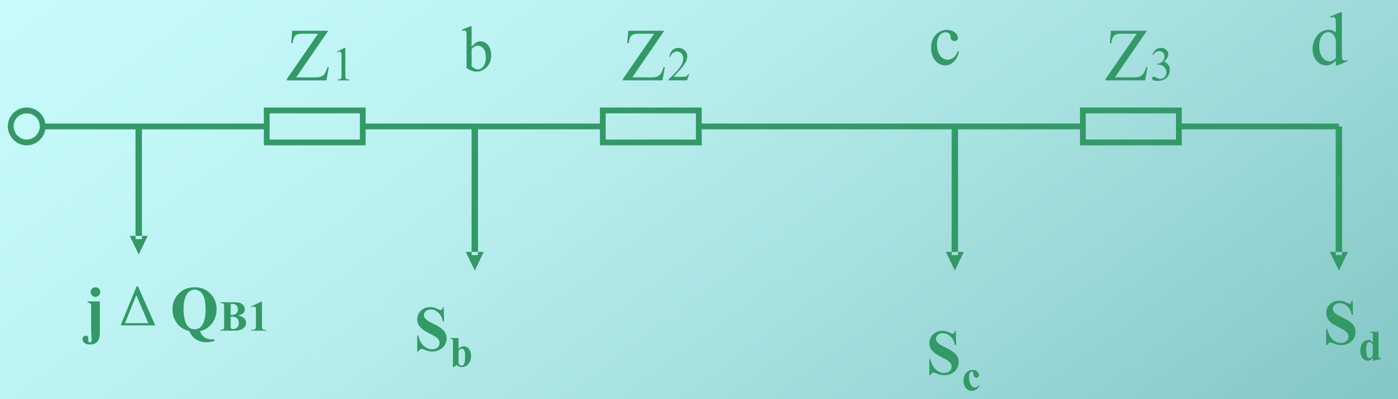

A
Z1
b
Z2
c
Z3
d
jΔQB1
Sb
Sc
Sd

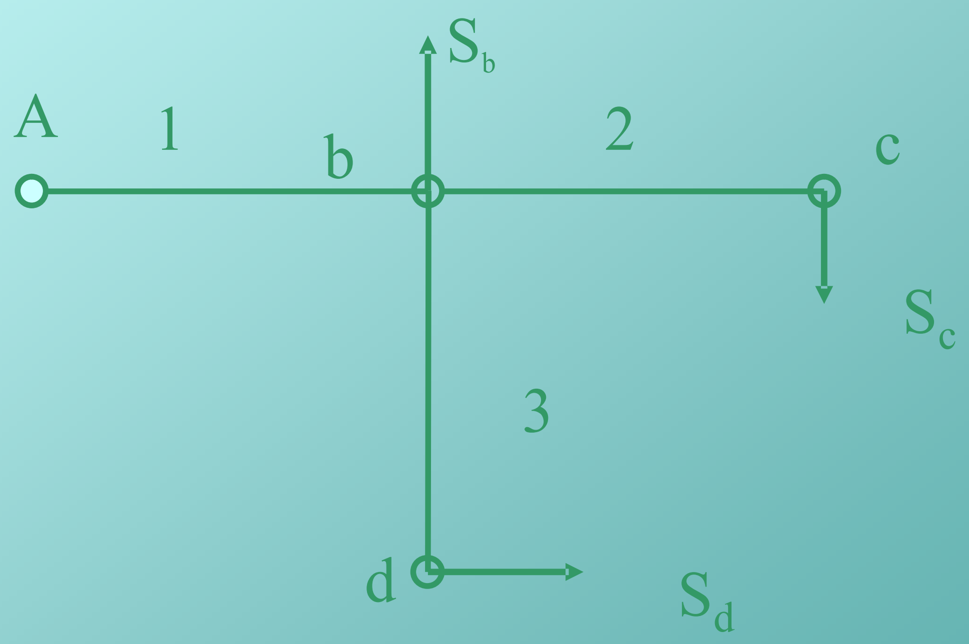
如果节点b接发电机



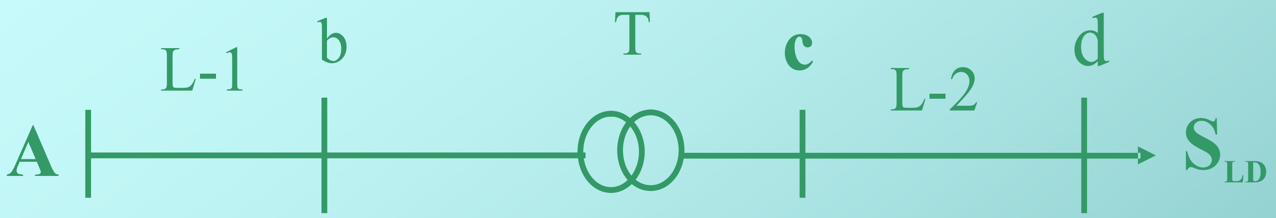
$$S_b = -S_G + \Delta S_{Tb} + \Delta S_{0b} + j\Delta Q_{B1} + j\Delta Q_{B2}$$

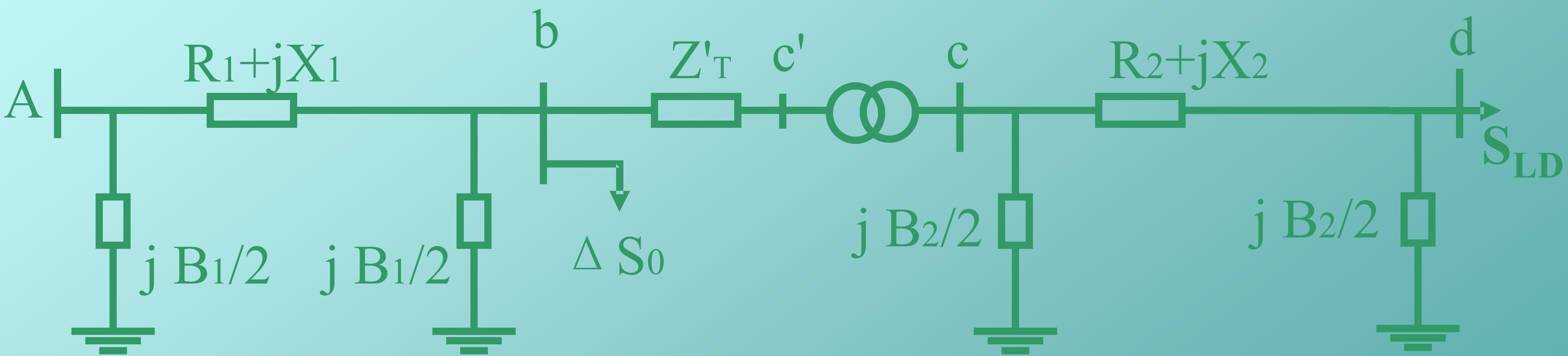
最大电压损耗和电压最低点的电压





2、两级电压的开式电力网

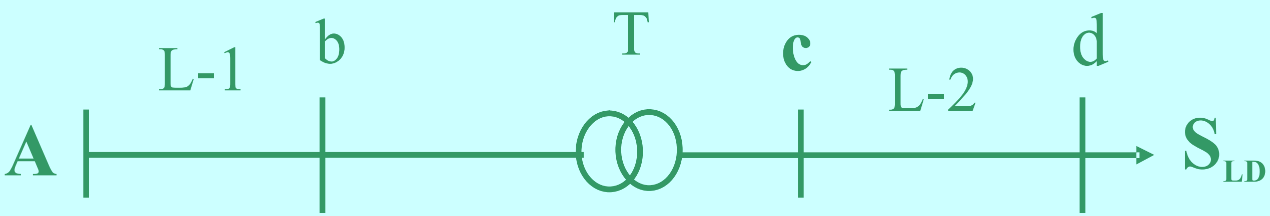


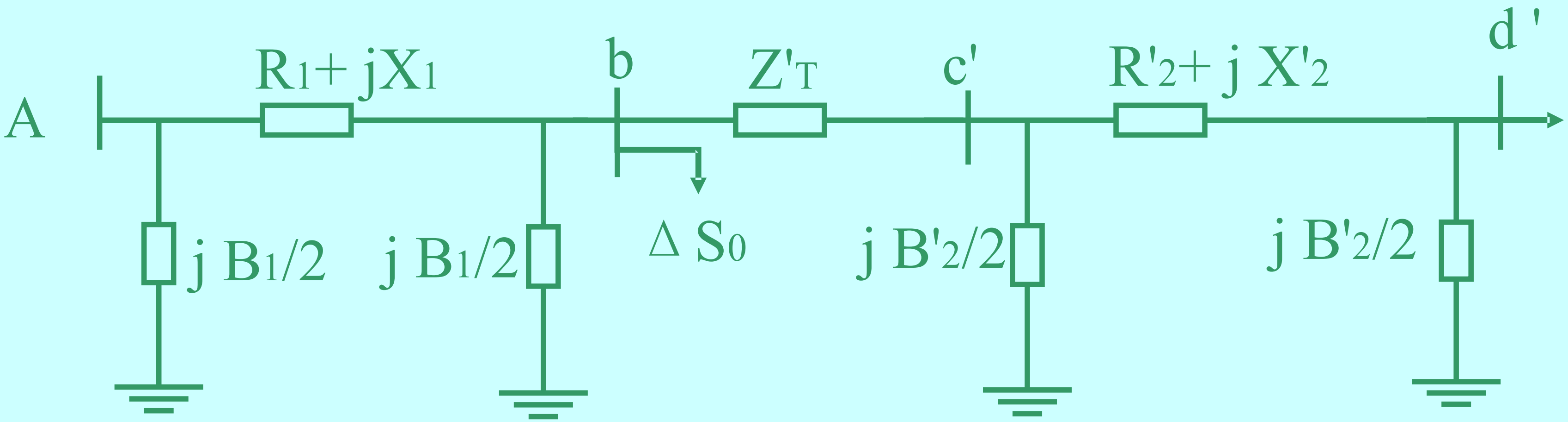


方法一：包含理想变压器，计算时，经过理想变压器功率保持不变，两侧电压之比等于实际变比k。

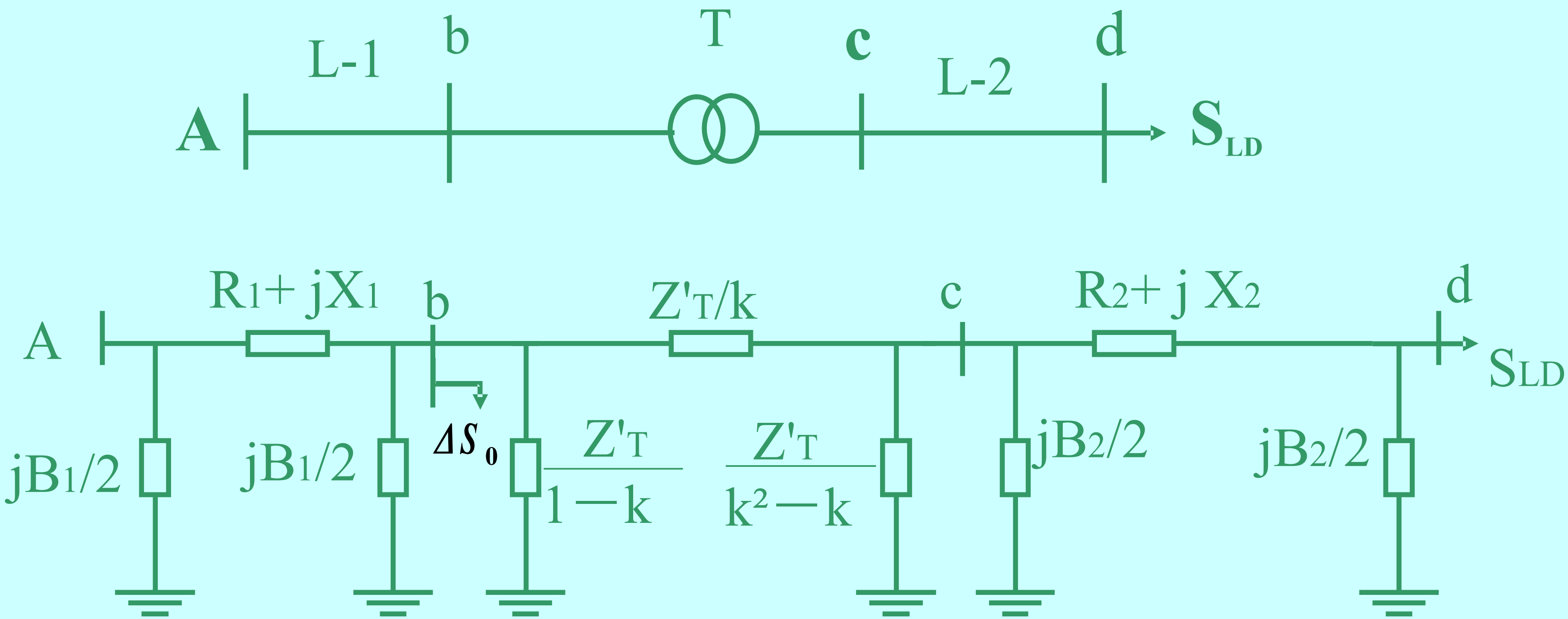
方法二：将线路L_2的参数归算到L_1电压级

$$R_2' = k^2 R_2 \qquad X_2' = k^2 X_2 \qquad B_2' = B_2 / k^2$$





方法三：用 π 型等值电路处理



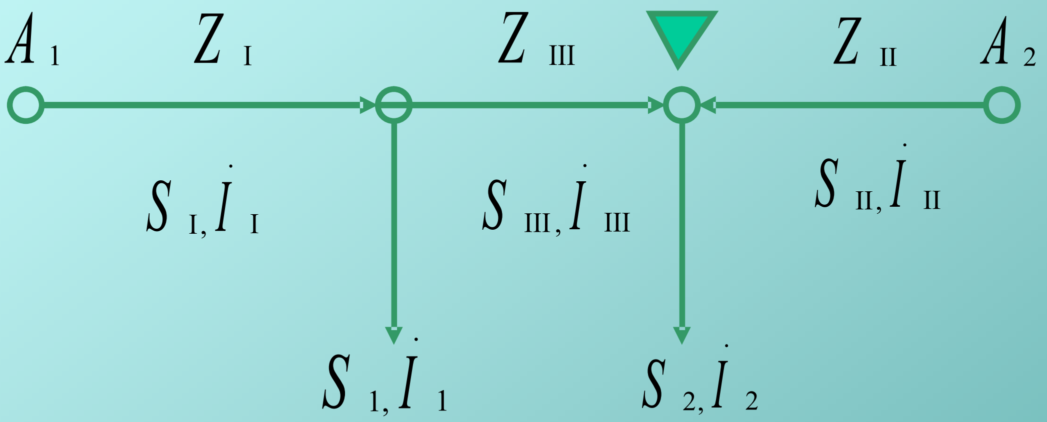
[例3－1]

[例3 －2]

3-3 闭式网络的电压和功率分布

1、两端供电网络的功率分布

（1）不计功率损耗的功率初分布



$$\dot{V}_{A1} - \dot{V}_{A2} = Z_{\mathrm{I}}\dot{I}_{\mathrm{I}} + Z_{\mathrm{III}}\dot{I}_{\mathrm{III}} - Z_{\mathrm{II}}\dot{I}_{\mathrm{II}}$$

$$\dot{I}_{\mathrm{I}} - \dot{I}_{\mathrm{III}} = \dot{I}_{1}$$

$$\dot{I}_{\mathrm{II}} + \dot{I}_{\mathrm{III}} = \dot{I}_{2}$$

由前面的方程组可解出

$$\dot{I}_{I}=\frac{(Z_{II}+Z_{III})\dot{I}_{1}+Z_{II}\dot{I}_{2}}{Z_{I}+Z_{II}+Z_{III}}+\frac{\dot{V}_{A1}-\dot{V}_{A2}}{Z_{I}+Z_{II}+Z_{III}}$$

$$\dot{I}_{II}=\frac{Z_{I}\dot{I}_{1}+(Z_{I}+Z_{III})\dot{I}_{2}}{Z_{I}+Z_{II}+Z_{III}}+\frac{\dot{V}_{A2}-\dot{V}_{A1}}{Z_{I}+Z_{II}+Z_{III}}$$

忽略功率损耗，两端取共轭并同乘V_N，可得：

循环功率

$$S_{I}=\frac{(\overset{*}{Z}_{II}+\overset{*}{Z}_{III})S_{1}+\overset{*}{Z}_{II}S_{2}}{\overset{*}{Z}_{I}+\overset{*}{Z}_{II}+\overset{*}{Z}_{III}}+\frac{(\overset{*}{V}_{A1}-\overset{*}{V}_{A2})V_{N}}{\overset{*}{Z}_{I}+\overset{*}{Z}_{II}+\overset{*}{Z}_{III}}=S_{ILD}+S_{IC}$$

$$S_{II}=\frac{\overset{*}{Z}_{I}S_{1}+(\overset{*}{Z}_{I}+\overset{*}{Z}_{III})S_{2}}{\overset{*}{Z}_{I}+\overset{*}{Z}_{II}+\overset{*}{Z}_{III}}+\frac{(\overset{*}{V}_{A2}-\overset{*}{V}_{A1})V_{N}}{\overset{*}{Z}_{I}+\overset{*}{Z}_{II}+\overset{*}{Z}_{III}}=S_{IILD}+S_{IIC}$$

$$S_{III}=S_{I}-S_{1}$$

由负荷决定的功率

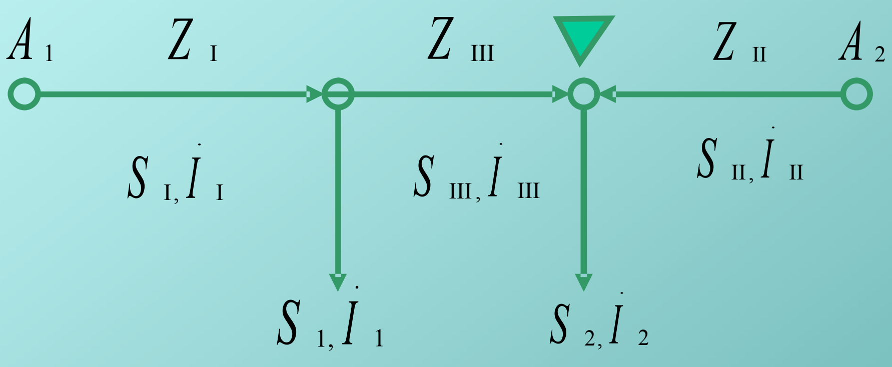
忽略功率损耗的功率分布计算式

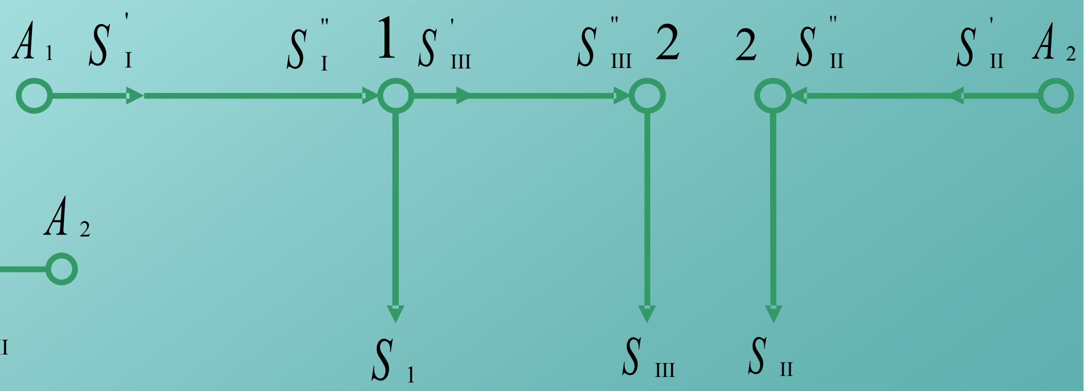
(2) 计及功率损耗的功率分布

- 功率分点：功率由两个方向流入的节点。

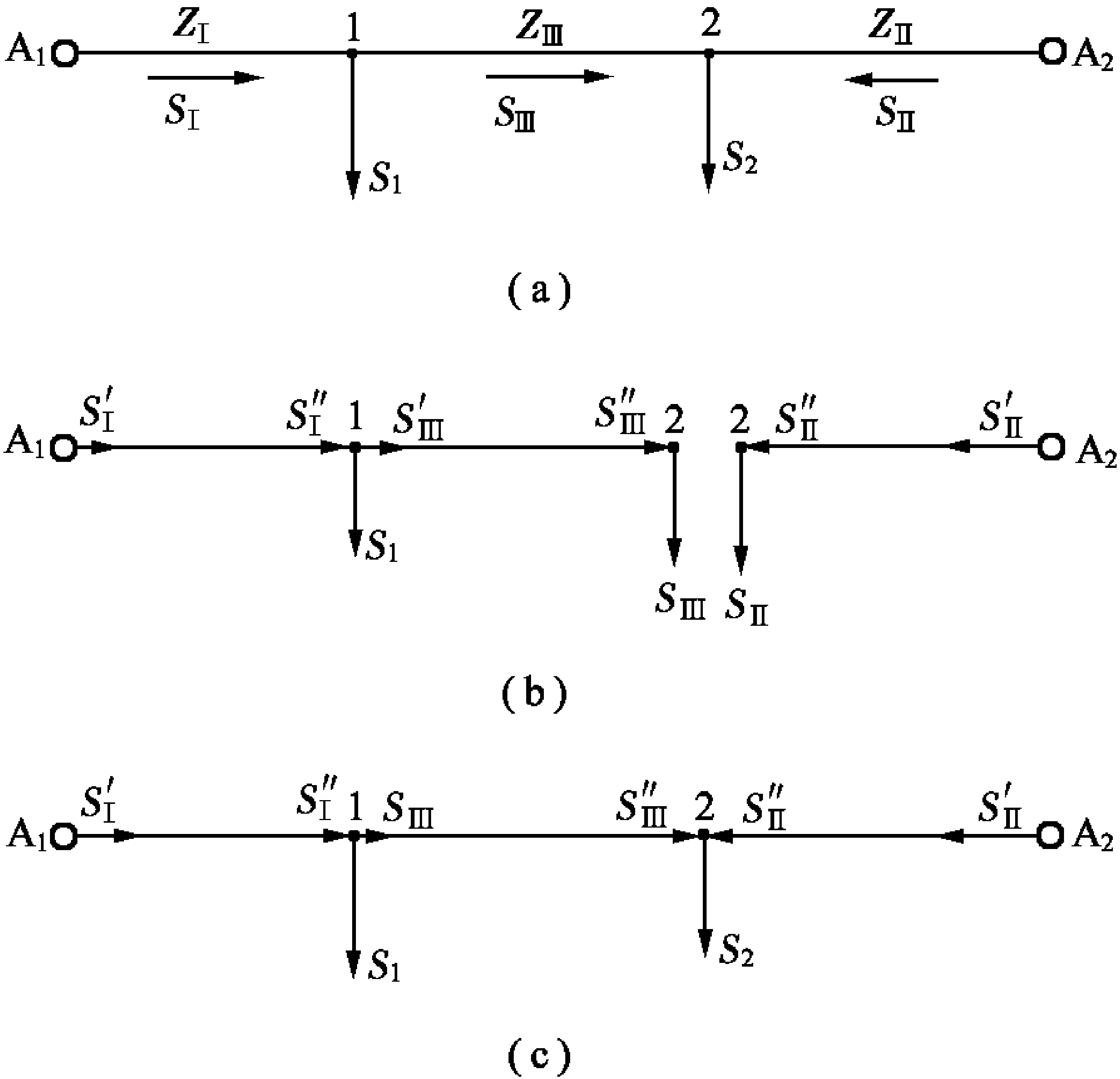
  有功分点和无功分点可能出现在不同节点。

- 将网络在功率分点处解开，形成两个开式网络，用前述的开式网络计算方法进行计算。





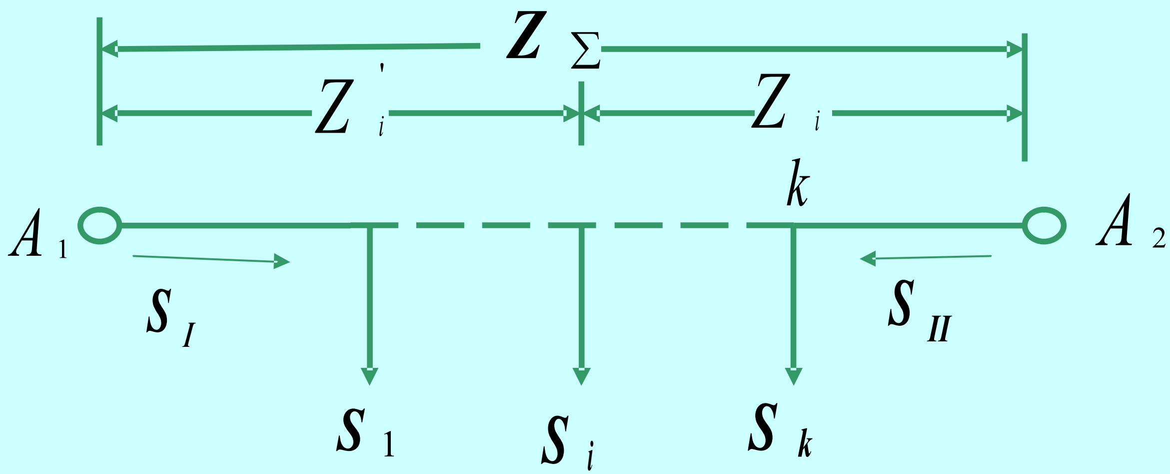
闭式网络的计算过程


A1
ZI
1
ZIII
2
ZII
A2
SI
SIII
SII
S1
S2
(a)
A1
S′I
S″I
1
S′III
S″III
2
2
S″II
S′II
A2
S1
SIII
SII
(b)
A1
S′I
S″I
1
SIII
S″III
2
S″II
S′II
A2
S1
S2
(c)

2. 沿线有k个负荷点的情况

$$S_{\mathrm{I}} = \frac{\sum_{i=1}^{k} \overset{*}{Z}_i S_i}{\overset{*}{Z}_{\Sigma}} + \frac{(\overset{*}{V}_{A1} - \overset{*}{V}_{A2}) V_N}{\overset{*}{Z}_{\Sigma}} = S_{\mathrm{I}LD} + S_{\mathrm{I}C}$$

$$S_{\mathrm{II}} = \frac{\sum_{i=1}^{k} \overset{*}{Z}'_i S_i}{\overset{*}{Z}_{\Sigma}} + \frac{(\overset{*}{V}_{A2} - \overset{*}{V}_{A1}) V_N}{\overset{*}{Z}_{\Sigma}} = S_{\mathrm{II}LD} + S_{\mathrm{II}C}$$



简化方法

(1) 将实部和虚部分开,便于计算

$$S_{1LD} = (G_\Sigma - jB_\Sigma)\sum_{i=1}^{k}(R_i - jX_i)(P_i + jQ_i)$$

$$= (G_\Sigma M - B_\Sigma N) + j(-G_\Sigma N - B_\Sigma M) = P_{1LD} + jQ_{1LD}$$

$$M = \sum_{i=1}^{k}(P_i R_i + Q_i X_i) \qquad N = \sum_{i=1}^{k}(P_i X_i - Q_i R_i)$$

$$G_\Sigma = \frac{R_\Sigma}{R_\Sigma^2 + X_\Sigma^2} \qquad B_\Sigma = \frac{-X_\Sigma}{R_\Sigma^2 + X_\Sigma^2}$$

$$S_{\mathrm{II}LD} = (G_\Sigma M' - B_\Sigma N') + j(-G_\Sigma N' - B_\Sigma M') = P_{\mathrm{II}LD} + jQ_{\mathrm{II}LD}$$

$$M' = \sum_{i=1}^{k}(P_i R_i' + Q_i X_i') \qquad N' = \sum_{i=1}^{k}(P_i X_i' - Q_i R_i')$$

简化方法

(2) $\dot{V}_{A1}=\dot{V}_{A2}$,且网络为均一网(各段线路的R与X的比值相等)

$$S_{\mathrm{I}}=\frac{\sum_{i=1}^{k}S_iR_i(1-j\frac{X_i}{R_i})}{R_{\Sigma}(1-j\frac{X_{\Sigma}}{R_{\Sigma}})}=\frac{\sum_{i=1}^{k}S_iR_i}{R_{\Sigma}}=\frac{\sum_{i=1}^{k}P_iR_i}{R_{\Sigma}}+j\frac{\sum_{i=1}^{k}Q_iR_i}{R_{\Sigma}}$$

$$S_{\mathrm{II}}=\frac{\sum_{i=1}^{k}S_iR_i'}{R_{\Sigma}}=\frac{\sum_{i=1}^{k}P_iR_i'}{R_{\Sigma}}+j\frac{\sum_{i=1}^{k}Q_iR_i'}{R_{\Sigma}}$$

结论:

在均一电力网中有功功率和无功功率的分布彼此无关。

(3) 各段线路的单位阻抗相等

$$S_{\mathrm{I}}=\frac{\sum_{i=1}^{k}S_i\overset{*}{Z}_0 l_i}{\overset{*}{Z}_0 l_{\Sigma}}=\frac{\sum_{i=1}^{k}S_i l_i}{l_{\Sigma}}=\frac{\sum_{i=1}^{k}P_i l_i}{l_{\Sigma}}+j\frac{\sum_{i=1}^{k}Q_i l_i}{l_{\Sigma}}$$

$$S_{\mathrm{II}}=\frac{\sum_{i=1}^{k}S_i l_i'}{l_{\Sigma}}=\frac{\sum_{i=1}^{k}P_i l_i'}{l_{\Sigma}}+j\frac{\sum_{i=1}^{k}Q_i l_i'}{l_{\Sigma}}$$

结论：

各段线路单位长度的阻抗值相等的均一网的功率分布仅与各段长度有关。

5. 闭式网的电压损耗

与开式网计算方法相同

有功和无功分点在同一处时，功率分点处的电压最低；

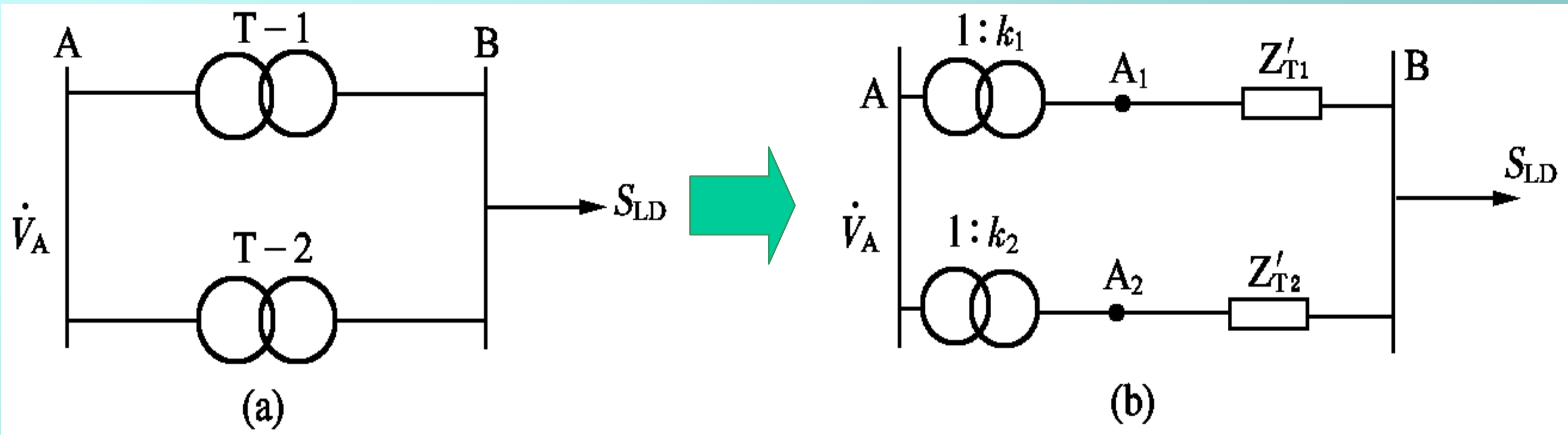
若不在同一点，则需分别计算实际电压值，确定电压最低点。

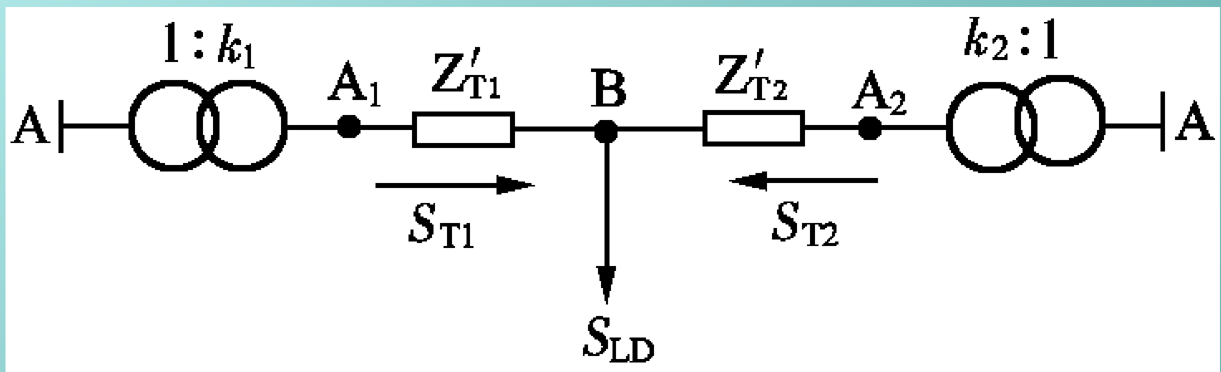
例3－3

例3－4

3.4 多级电压环网的功率分布

一、两台并联变压器构成的多电压级环网

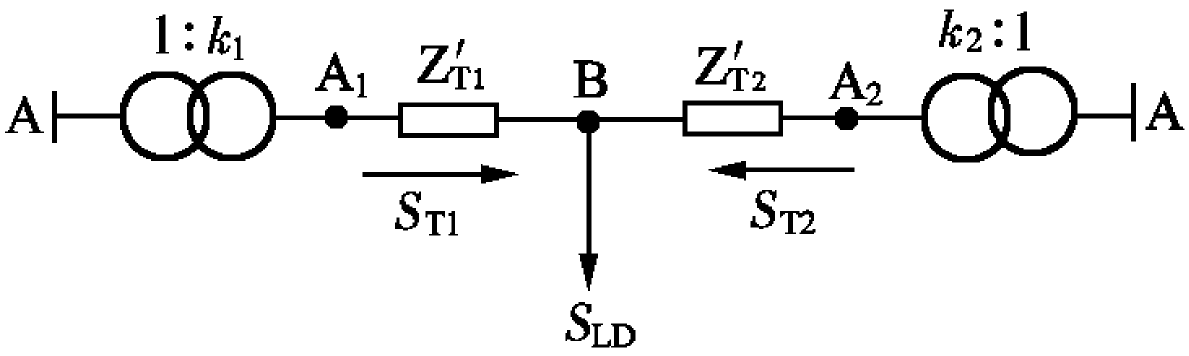




一、两台并联变压器构成的多电压级环网

- 已知一次侧电压，则：$\dot{V}_{A1}=k_1\dot{V}_A$ $\dot{V}_{A2}=k_2\dot{V}_A$

$$\left.\begin{aligned} S_{T1}&=\frac{\overset{*}{Z}'_{T2}S_{LD}}{\overset{*}{Z}'_{T1}+\overset{*}{Z}'_{T2}}+\frac{(\overset{*}{V}_{A1}-\overset{*}{V}_{A2})V_{N\cdot H}}{\overset{*}{Z}'_{T1}+\overset{*}{Z}'_{T2}} \\ S_{T2}&=\frac{\overset{*}{Z}'_{T1}S_{LD}}{\overset{*}{Z}'_{T1}+\overset{*}{Z}'_{T2}}+\frac{(\overset{*}{V}_{A2}-\overset{*}{V}_{A1})V_{N\cdot H}}{\overset{*}{Z}'_{T1}+\overset{*}{Z}'_{T2}} \end{aligned}\right\}$$

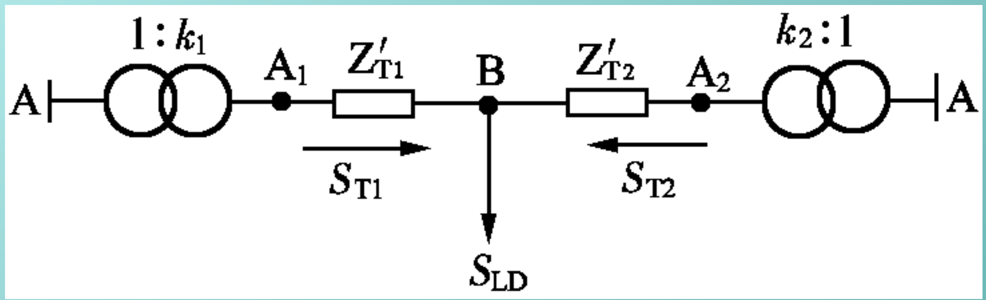


一、两台并联变压器构成的多电压级环网

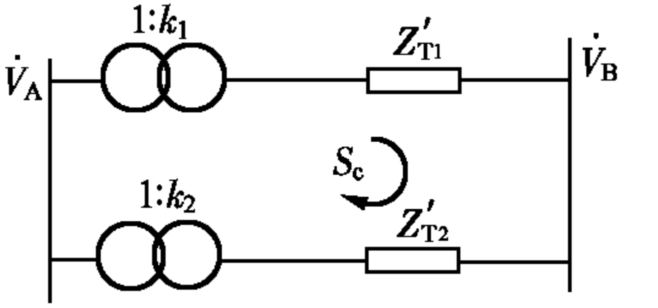
- 循环功率计算

环路电势: $\Delta \dot{E}' = \dot{V}_{A1} - \dot{V}_{A2} = \dot{V}_{A}(k_1 - k_2) = \dot{V}_{A} k_1 \left(1 - \frac{k_2}{k_1}\right)$

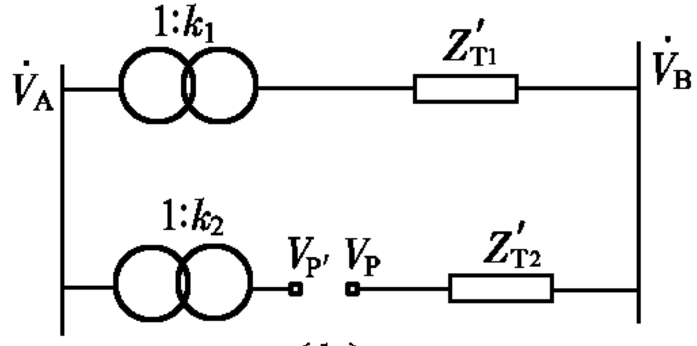
循环功率: $S_c = \frac{(\overset{*}{V}_{A1} - \overset{*}{V}_{A2}) V_{N \cdot H}}{\overset{*}{Z}'_{T1} + \overset{*}{Z}'_{T2}} = \frac{\Delta \overset{*}{E}' V_{N \cdot H}}{\overset{*}{Z}'_{T1} + \overset{*}{Z}'_{T2}}$



环路电势的确定

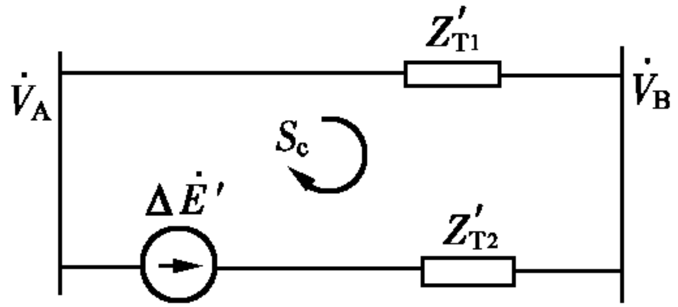


(a)



(b)

空载



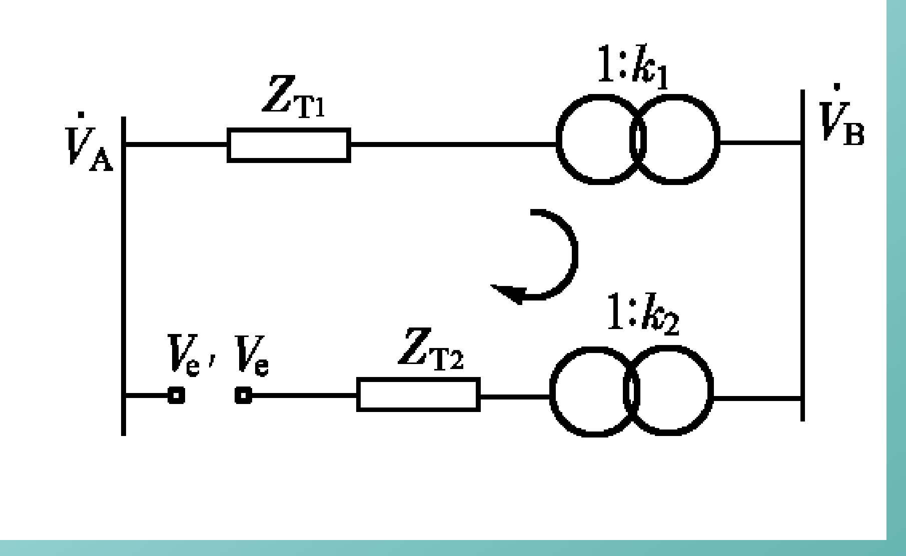
(c)

$$\Delta \dot E' = \dot V_P - \dot V_{P'} = \dot V_A (k_1 - k_2)$$

阻抗归算到低压侧

$$\Delta\dot{E} = \dot{V}_e - \dot{V}_{e'} = \frac{\dot{V}_B}{k_2}\left(1 - \frac{k_2}{k_1}\right) \approx \dot{V}_A\left(\frac{k_1}{k_2} - 1\right)$$

$$S_c = \frac{V_{N\cdot L}}{\overset{*}{Z}_{T1} + \overset{*}{Z}_{T2}} \Delta\overset{*}{E} = \frac{V_{N\cdot L}}{\overset{*}{Z}_{T1} + \overset{*}{Z}_{T2}} \frac{\overset{*}{V}_B}{k_2}\left(1 - \frac{k_2}{k_1}\right)$$



简化计算或电力网电压未知

$$\left.\begin{aligned}\Delta E' &\approx V_{N\cdot H}\left(1-\frac{k_2}{k_1}\right)\\ \Delta E &\approx V_{N\cdot L}\left(1-\frac{k_2}{k_1}\right)\end{aligned}\right\}$$

$$S_c \approx \frac{V_{N\cdot H}^2\left(1-\frac{k_2}{k_1}\right)}{\overset{*}{Z}'_{T1}+\overset{*}{Z}'_{T2}} \approx \frac{V_{N\cdot L}^2\left(1-\frac{k_2}{k_1}\right)}{\overset{*}{Z}_{T1}+\overset{*}{Z}_{T2}}$$

例3－5

二、多个电压级的环网

- 环路电势的确定

  （1）作等值电路并进行参数归算；

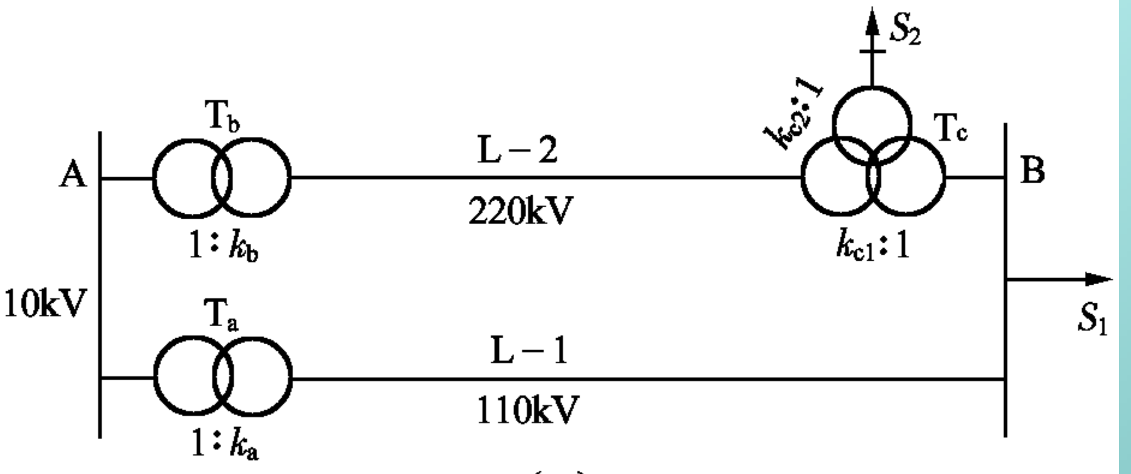
  （2）空载时将环路断开，端口电压即为环路电势。

注意：参数归算等级与断口所在位置一致

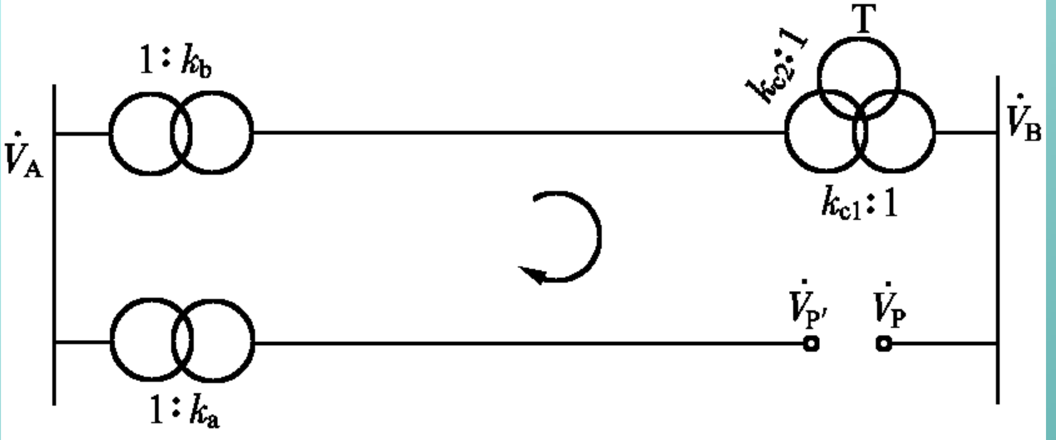
- 循环功率计算

$$S_c \approx \frac{\Delta \overset{*}{E} V_N}{\overset{*}{Z}_{\Sigma}}$$

三级电压环网举例



(a)



(b)

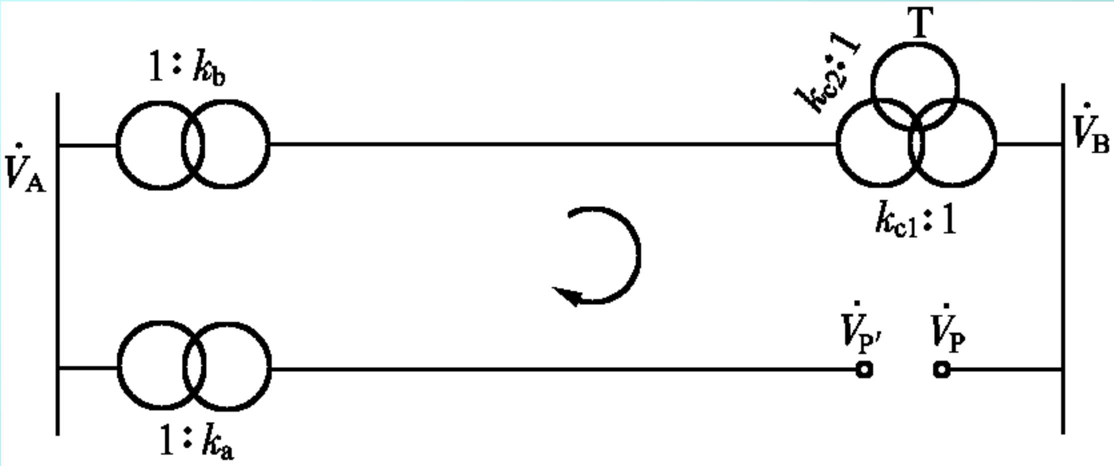
k_a=121/10.5

k_b=242/10.5

k_{c1}=220/121

k_{c2}=220/11

- 选110kV作为参考电压级，断口选在110kV线路



- 若A端电压已知:

$$\Delta\dot{E}=\dot{V}_P-\dot{V}_{P'}=\dot{V}_A\left(\frac{k_b}{k_{c1}}-k_a\right)=\dot{V}_A k_a\left(\frac{1}{k_\Sigma}-1\right)$$

- 若B端电压已知:

$$\Delta\dot{E}=\dot{V}_P-\dot{V}_{P'}=\dot{V}_B\left(1-\frac{k_{c1}k_a}{k_b}\right)=\dot{V}_B(1-k_\Sigma)$$

考虑$k_\Sigma=1$的情况

3.5 电力网的电能损耗

一、电能损耗和损耗率

- 年电能损耗
- 供电量：发电量与厂用电之差
- 损耗率（网损率、线损率）：是衡量供电企业技术和管理水平的重要标志。

$$\text{损耗率}=\frac{\text{电力网损耗电量}}{\text{供电量}}\times 100\%$$

1. 年负荷损耗率法

- 年负荷率 $$k_{my} = \frac{W}{8760 P_{max}} = \frac{T_{max}}{8760}$$
- 线路年负荷损耗率 $$k_{ay} = \frac{\Delta W}{8760 \Delta P_{max}}$$
- 线路年负荷损耗率与年负荷率的近似关系

$$k_{ay} = K k_{my} + (1 - K) k_{my}^2$$

K为经验数值。一般取K=0.1~0.4，k_{my}较低时取较小数值。

计算过程：

$$\left.\begin{array}{r} T_{max} \Rightarrow k_{my} \Rightarrow k_{ay} \\ \text{最大负荷的潮流计算}\Delta P_{max} \end{array}\right\} \Rightarrow \Delta W$$

$$\Delta W = 8760 k_{ay} \Delta P_{max}$$

1. 年负荷损耗率法

- 变压器的年电能损耗：电阻损耗＋空载损耗

$$\Delta W = 8760 k_{ay} \Delta P_{max} + \Delta P_0 t_T$$

t_T为变压器一年中接入运行的小时数，
缺乏具体数据时可取t_T=8000h

2. 最大负荷损耗时间法

- 最大负荷损耗时间：如果线路中输送的功率一直保持为最大负荷S_{max}，在τ小时内的电能损耗等于线路全年的实际电能损耗，则称τ为最大负荷损耗时间。

$$\Delta W=\sum_{i=1}^{n}(\Delta P_i\times\Delta t_i)=\int_0^{8760}\frac{S^2}{V^2}R\times10^{-3}dt$$

$$=\frac{S_{max}^2}{V^2}R\tau\times10^{-3}=\Delta P_{max}\tau\times10^{-3}$$

$$\tau=\frac{\Delta W}{\Delta P_{max}}=\frac{\int_0^{8760}S^2dt}{S_{max}^2}$$

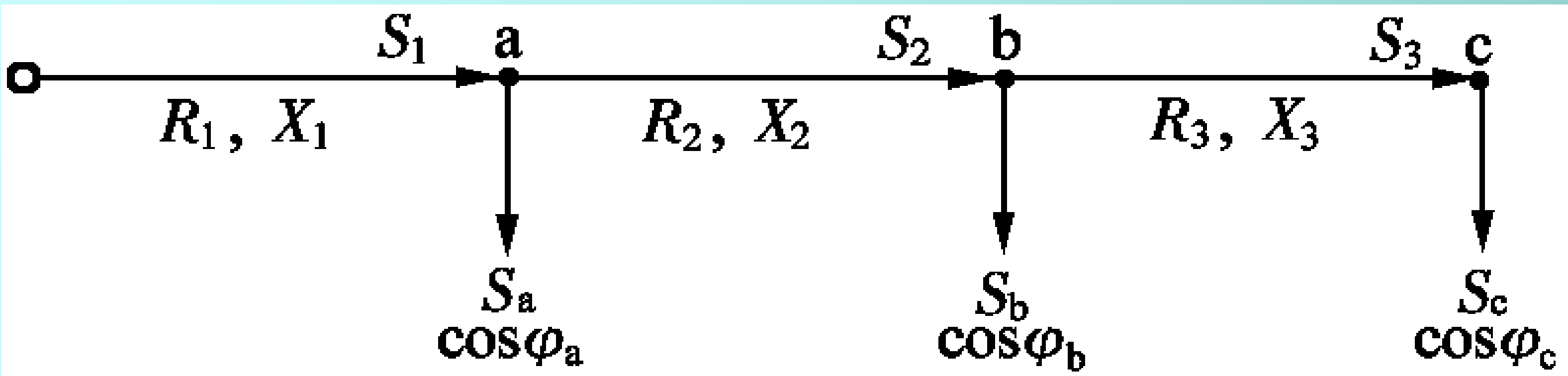
其大小由视在功率表示的负荷曲线决定，因此，与线路负荷的功率因数和最大负荷利用小时数有关

表 3-1 τ 与 T_{max} 和 $\cos\varphi$ 的关系

T_{max}/h \ $\cos\varphi$	0.80	0.85	0.90	0.95	1.00
2 000	1 500	1 200	1 000	800	700
2 500	1 700	1 500	1 250	1 100	950
3 000	2 000	1 800	1 600	1 400	1 250
3 500	2 350	2 150	2 000	1 800	1 600
4 000	2 750	2 600	2 400	2 200	2 000
4 500	3 150	3 000	2 900	2 700	2 500
5 000	3 600	3 500	3 400	3 200	3 000
5 500	4 100	4 000	3 950	3 750	3 600
6 000	4 650	4 600	4 500	4 350	4 200
6 500	5 250	5 200	5 100	5 000	4 850
7 000	5 950	5 900	5 800	5 700	5 600
7 500	6 650	6 600	6 550	6 500	6 400
8 000	7 400		7 350		7 250

线路 $\Delta W = \Delta P_{max}\tau$ 变压器 $\Delta W = \Delta P_{max}\tau + \Delta P_0 T$

一条线路有多个负荷的情况



$$\Delta W=\left(\frac{S_1}{V_a}\right)^2 R_1\tau_1+\left(\frac{S_2}{V_b}\right)^2 R_2\tau_2+\left(\frac{S_3}{V_c}\right)^2 R_3\tau_3$$

S_1, S_2, S_3——分别为各段的最大负荷功率;

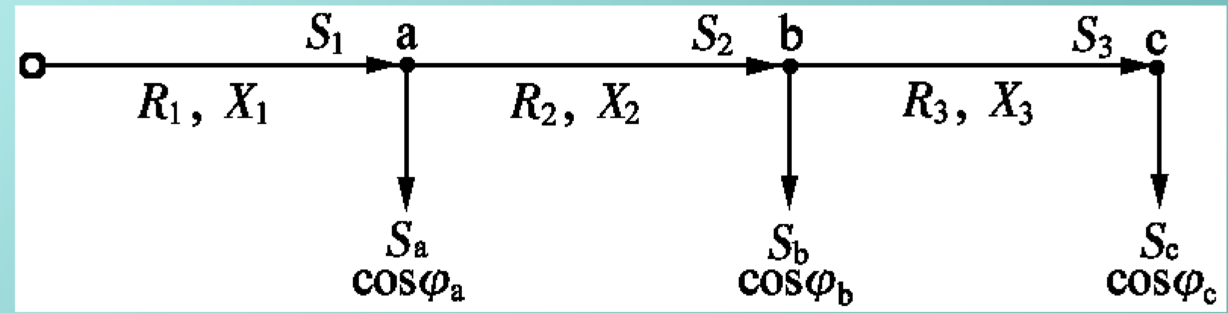
τ_1, τ_2, τ_3 ——分别为各段的最大负荷损耗时间

$$\cos\varphi_1 = \frac{S_a\cos\varphi_a + S_b\cos\varphi_b + S_c\cos\varphi_c}{S_a + S_b + S_c}$$

$$\cos\varphi_2 = \frac{S_b\cos\varphi_b + S_c\cos\varphi_c}{S_b + S_c} \qquad \cos\varphi_3 = \cos\varphi_c$$

$$T_{max\,1} = \frac{P_a T_{max\cdot a} + P_b T_{max\cdot b} + P_c T_{max\cdot c}}{P_a + P_b + P_c}$$

$$T_{max\,2} = \frac{P_b T_{max\cdot b} + P_c T_{max\cdot c}}{P_b + P_c} \qquad T_{max\,3} = T_{max\cdot c}$$



例3－6

二、降低网损的技术措施

1. 减少无功功率的传输

$$\Delta P_L = \frac{P^2}{V^2 \cos^2 \varphi} R$$

如果将功率因数由原来的$\cos\varphi_1$提高到$\cos\varphi_2$，则线路中的功率损耗可降低

$$\delta_{P_L}(\%) = \left[1 - \left(\frac{\cos\varphi_1}{\cos\varphi_2}\right)^2\right] \times 100$$

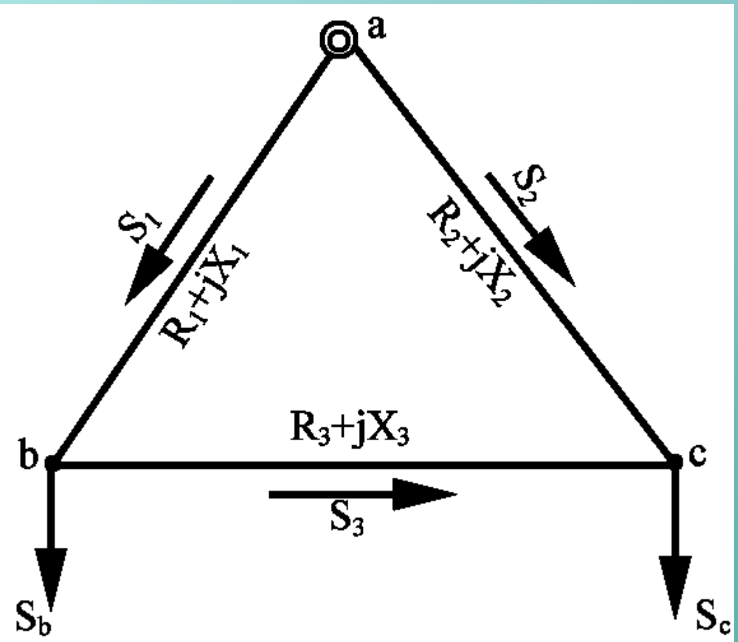
措施： 电机选择 $Q = Q_0 + (Q_N - Q_0)\left(\frac{P}{P_N}\right)^2 = Q_0 + (Q_N - Q_0)\beta^2$

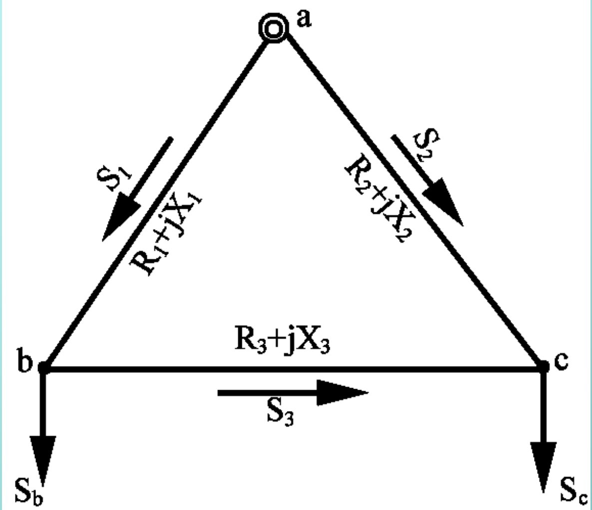
无功补偿：就地无功平衡

2. 闭式网络中功率的经济分布

$$S_1 = \frac{S_c \overset{*}{Z}_2 + S_b(\overset{*}{Z}_2 + \overset{*}{Z}_3)}{\overset{*}{Z}_1 + \overset{*}{Z}_2 + \overset{*}{Z}_3}$$

$$S_2 = \frac{S_b \overset{*}{Z}_1 + S_c(\overset{*}{Z}_1 + \overset{*}{Z}_3)}{\overset{*}{Z}_1 + \overset{*}{Z}_2 + \overset{*}{Z}_3}$$





网络功率损耗

$$P_L=\left(\frac{S_1}{V}\right)^2R_1+\left(\frac{S_2}{V}\right)^2R_2+\left(\frac{S_3}{V}\right)^2R_3$$

$$=\frac{P_1^2+Q_1^2}{V^2}R_1+\frac{P_2^2+Q_2^2}{V^2}R_2+\frac{P_3^2+Q_3^2}{V^2}R_3$$

$$=\frac{P_1^2+Q_1^2}{V^2}R_1+\frac{(P_b+P_c-P_1)^2+(Q_b+Q_c-Q_1)^2}{V^2}R_2+\frac{(P_1-P_b)^2+(Q_1-Q_b)^2}{V^2}R_3$$

分别对P_1和Q_1求偏导，
并令其等于零

$$\frac{\partial P_L}{\partial P_1}=\frac{2P_1}{V^2}R_1-\frac{2(P_b+P_c-P_1)}{V^2}R_2+\frac{2(P_1-P_b)}{V^2}R_3=0$$

$$\frac{\partial P_L}{\partial Q_1}=\frac{2Q_1}{V^2}R_1-\frac{2(Q_b+Q_c-Q_1)}{V^2}R_2+\frac{2(Q_1-Q_b)}{V^2}R_3=0$$

$$\frac{\partial P_L}{\partial P_1} = \frac{2P_1}{V^2}R_1 - \frac{2(P_b + P_c - P_1)}{V^2}R_2 + \frac{2(P_1 - P_b)}{V^2}R_3 = 0$$

$$\frac{\partial P_L}{\partial Q_1} = \frac{2Q_1}{V^2}R_1 - \frac{2(Q_b + Q_c - Q_1)}{V^2}R_2 + \frac{2(Q_1 - Q_b)}{V^2}R_3 = 0$$

$$\left.\begin{aligned} P_{1ec} &= \frac{P_b(R_2 + R_3) + P_c R_2}{R_1 + R_2 + R_3} \\ Q_{1ec} &= \frac{Q_b(R_2 + R_3) + Q_c R_2}{R_1 + R_2 + R_3} \end{aligned}\right\}$$

$$S_1 = \frac{S_c \overset{*}{Z}_2 + S_b(\overset{*}{Z}_2 + \overset{*}{Z}_3)}{\overset{*}{Z}_1 + \overset{*}{Z}_2 + \overset{*}{Z}_3}$$

结论：功率在环网中与电阻成反比分布 时，功率损耗最小。

使自然功率分布接近经济功率分布的措施

(1) 选择适当地点作开环运行。为了限制短路电流或满足继电保护动作选择性要求，需将闭式网络开环运行时，开环点的选择也尽可能兼顾到使开环后的功率分布更接近于经济分布。

(2) 对环网中比值R／X特别小的线段进行串联电容补偿。

(3) 在环网中增设混合型加压调压变压器，由它产生环路电势及相应的循环功率，以改善功率分布(见第5章)。

3. 合理确定电力网的运行电压

- 变压器铁损和电压平方成正比。
- 线路和变压器绕组中的功率损耗与电压平方成反比。
- 一般情况，铁损<50%的电力网，适当提高运行电压可以降低网损；铁损>50％的电力网，适当降低运行电压可以降低网损。

4. 组织变压器的经济运行

- k台变压器的总损耗

$$\Delta P_{T(k)} = k\Delta P_0 + k\Delta P_s \left(\frac{S}{kS_N} \right)^2$$

- K-1台变压器的总损耗

$$\Delta P_{T(k-1)} = (k-1)\Delta P_0 + (k-1)\Delta P_S \left(\frac{S}{(k-1)S_N} \right)^2$$

- 令 $\Delta P_{T(k)} = \Delta P_{T(k-1)}$ 可求得临界负荷功率

$$S_{cr} = S_N \sqrt{k(k-1)\frac{\Delta P_0}{\Delta P_S}}$$