

2011.

二、(2) 证明: $i_c(t) = \frac{dq}{dt} = \frac{u - u_c}{1} = u - u_c = \underline{u - f(q)}$ $q(0) = 0$

$u_L(t) = \frac{d\psi}{dt} = u - i \cdot L = u - i_L = u - f(\psi)$ $\psi(0) = 0$

两式形式相同, 初始条件相同, 故必有 $q(t) = \psi(t)$.

又 $u = u_c + i - i_L = \frac{q}{C} + \dot{q} - \frac{\psi}{L} =$
 $= f(q(t)) + \dot{q} - f(\psi(t)) = \dot{q}$

从端口 $u-i$ 关系来看, 图中一端口网络等效为电压源与线性电阻, 故是端口型线性得证.

三、解: (1) 首先将 CCCS 改为 VCCS.

$i_{36} = \beta i = \beta u_{23} G_1$

可知 VCCS 对不定导纳矩阵的贡献为:

$$\begin{matrix} & 2 & 3 \\ 3 & \beta G_1 & -\beta G_1 \\ 6 & -\beta G_1 & \beta G_1 \end{matrix} = \begin{bmatrix} 2 & -2 \\ -2 & 2 \end{bmatrix}$$

写出所有二端元件对不定导纳矩阵的贡献:

$$Y_{(6)} = \begin{matrix} & 1 & 2 & 3 & 4 & 5 & 6 \\ \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix} & \begin{bmatrix} sC_1 & -sC_1 & 0 & 0 & 0 & 0 \\ -sC_1 & sC_1 + sC_2 + G_1 & -G_1 & 0 & 0 & -sC_2 \\ 0 & \beta G_1 - G_1 & G_1 + G_2 + sG_3 \beta G_1 - sC_3 & 0 & 0 & -G_2 \\ 0 & 0 & -sC_3 & G_3 + G_4 + sG_3 & -G_4 & -G_3 \\ 0 & 0 & 0 & -G_4 & G_4 & 0 \\ 0 & -sC_2 \beta G_1 & \beta G_1 - G_2 & -G_3 & 0 & G_2 + G_3 + sC_2 \end{bmatrix} \end{matrix} = \begin{bmatrix} 5 & -5 & 0 & 0 & 0 & 0 \\ -5 & 2s+1 & -1 & 0 & 0 & -5 \\ 0 & 1 & s & -5 & 0 & -1 \\ 0 & 0 & -5 & 4+s & -2 & -2 \\ 0 & 0 & 0 & -2 & 2 & 0 \\ 0 & -5-2 & 1 & -2 & 0 & 3+s \end{bmatrix}$$

① 先消易的

② 消掉保持原节点位置依次消!

(2) 设6为参考节点得定导纳矩阵:

$$Y_{d(5)} = \begin{bmatrix} 5 & -5 & 0 & 0 & 0 \\ -5 & 2s+1 & -1 & 0 & 0 \\ 0 & 1 & s & -5 & 0 \\ 0 & 0 & -5 & 4+s & -2 \\ 0 & 0 & 0 & -2 & 2 \end{bmatrix} \xrightarrow{\text{消⑤}} \begin{bmatrix} 5 & -5 & 0 & 0 \\ -5 & 2s+1 & -1 & 0 \\ 0 & 1 & s & -5 \\ 0 & 0 & 4+s & -2 \end{bmatrix} \xrightarrow{\text{消④}} \begin{bmatrix} 5 & -5 & 0 \\ -5 & 2s+1 & -1 \\ 0 & 1 & s \end{bmatrix} \xrightarrow{\text{消③}} \begin{bmatrix} 5 & -5 & 0 \\ -5 & 2s+1 & -1 \\ 0 & 1 & s \end{bmatrix} \xrightarrow{\text{消②}} \begin{bmatrix} 5 & -5 & 0 \\ -5 & 2s+1 & -1 \\ 0 & 1 & s \end{bmatrix} \xrightarrow{\text{消①}} \begin{bmatrix} 5 & -5 & 0 \\ -5 & 2s+1 & -1 \\ 0 & 1 & s \end{bmatrix}$$

整理得 $Y_{sc}(s) = \begin{bmatrix} \frac{2s^3+2s^2+5}{4s^2+2s+1} & \frac{-s^2}{4s^2+2s+1} \\ \frac{s^2}{4s^2+2s+1} & \frac{2s^3+9s^2+5s+2}{4s^2+2s+1} \end{bmatrix}$

四、解：(1) 复杂性阶数 $4-1-1=2$

基环(树支)

基支(连支)

按 U_{C1} 所在电割集 KCL 和电感 L_2 所在回路 KVL 列方程如下：

$$-\dot{U}_S - \dot{U}_{L2} - \dot{U}_{R2} + \dot{U}_{C2} + \dot{U}_{C1} = 0 \Rightarrow C_1 \frac{dU_{C1}}{dt} = C_2 \frac{dU_{C2}}{dt} - \dot{U}_{R2} - \dot{U}_{L2} - \dot{U}_S$$

$$U_{C1} + U_{R1} = U_S + U_{L1} + U_{L2} \Rightarrow L_2 \frac{dI_{L2}}{dt} = -L_1 \frac{dI_{L1}}{dt} + \dot{U}_{R1} R_1 + U_{C1} - U_S$$

$$\dot{U}_{R1} = \frac{U_S - U_{C1} - R_2 \dot{U}_{L2}}{R_1 + R_2}$$

$$\dot{U}_{R2} = \frac{-U_S + U_{C1} - R_1 \dot{U}_{L2}}{R_1 + R_2}$$

$$\dot{U}_{C2} = \dot{U}_S - \dot{U}_{C1}$$

$$\dot{I}_{L1} = \dot{I}_S + \dot{I}_{L2}$$

整理得： $\dot{U}_{C1} = -U_{C1} - 0.5 \dot{U}_{L2} + 0.5 \dot{U}_S + U_S - \dot{U}_S$

$\dot{I}_{L2} = +0.5 U_{C1} - 0.5 \dot{U}_{L2} - 0.5 U_S - 0.5 \dot{I}_S$

(2) 拉氏变换得：

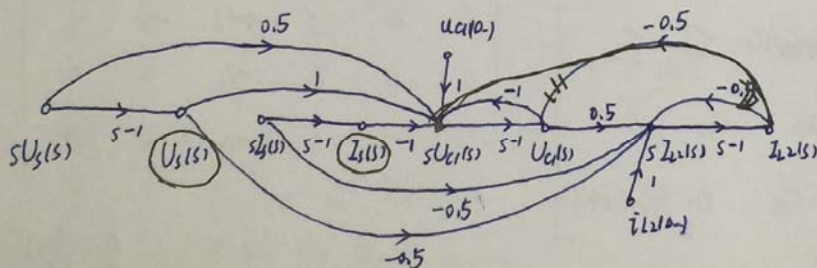
$$s U_{C1}(s) = -U_{C1}(s) - 0.5 I_{L2}(s) + 0.5 s U_S(s) + U_S(s) - I_S(s) + U_{C1}(0-)$$

$$s I_{L2}(s) = 0.5 U_{C1}(s) - 0.5 I_{L2}(s) - 0.5 U_S(s) - 0.5 s I_S(s) + I_{L2}(0-)$$

式中： $U_S(s) = \frac{2}{s+1}$ $I_S(s) = \frac{1}{s+1}$

$$\mathcal{L}[e^{-t}] = \frac{1}{s-(-1)} = \frac{1}{s+1}$$

画状态转移图：



(3) 图行列式 $\Delta = 1 - [(-s-1) + (-0.5s-1) + (-0.25s-2)] + (-s-1)(-0.5s-1) = 1 + 1.75s^{-1} + 0.5s^{-2}$

由 $U_{C1}(0-)$ 至 $U_{C1}(s)$ 的前向路径： $P_{1(11)} = s^{-1}$ $\Delta_{1(11)} = 1 + 0.5s^{-1}$ $\Phi_{11} = \frac{s^{-1} + 0.5s^{-2}}{1 + 1.75s^{-1} + 0.5s^{-2}}$

由 $U_{C1}(0-)$ 至 $I_{L2}(s)$ 的前向路径： $P_{1(21)} = 0.5s^{-2}$ $\Delta_{1(21)} = 1$ $\Phi_{21} = \frac{0.5s^{-2}}{1 + 1.75s^{-1} + 0.5s^{-2}}$

由 $I_{L2}(0-)$ 至 $U_{C1}(s)$ 的前向路径： $P_{1(12)} = -0.5s^{-2}$ $\Delta_{1(12)} = 1$ $\Phi_{12} = \frac{-0.5s^{-2}}{1 + 1.75s^{-1} + 0.5s^{-2}}$

由 $I_{L2}(0-)$ 至 $I_{L2}(s)$ 的前向路径： $P_{1(22)} = s^{-1}$ $\Delta_{1(22)} = 1 + s^{-1}$ $\Phi_{22} = \frac{s^{-1} + s^{-2}}{1 + 1.75s^{-1} + 0.5s^{-2}}$

预解矩阵 $\Phi(s) = \begin{bmatrix} \frac{s+0.5}{s^2+1.75s+0.5} & \frac{-0.5}{s^2+1.75s+0.5} \\ \frac{0.5}{s^2+1.75s+0.5} & \frac{s+1}{s^2+1.75s+0.5} \end{bmatrix}$

$$\frac{1}{s^2+1.75s+0.5} \begin{bmatrix} s+0.5 & -0.5 \\ 0.5 & s+1 \end{bmatrix}$$

$$\begin{aligned}
 (14) \quad I_{L2}(s) &= \Phi_{21} U_{L1}(s) + \Phi_{22} \dot{U}_{L1}(s) + \frac{I_{L2}(s)}{I_{L1}(s)} + \dots \\
 &= \frac{s+1.5}{s^2+1.5s+0.5} \cdot \frac{1}{s} + \frac{I_{L2}(s)}{I_{L1}(s)} + \dots \\
 &= \frac{s+1.5 + s^2 \left[\frac{1}{s+1} \times (-0.5s-2) + (-0.5s-1) \times \frac{(s+1)}{s+2} \right]}{s^2+1.5s+0.5} = \dots
 \end{aligned}$$

$$Z'_{L2}$$

五、解：(1) 以节点③为参考节点，列网络节点方程：

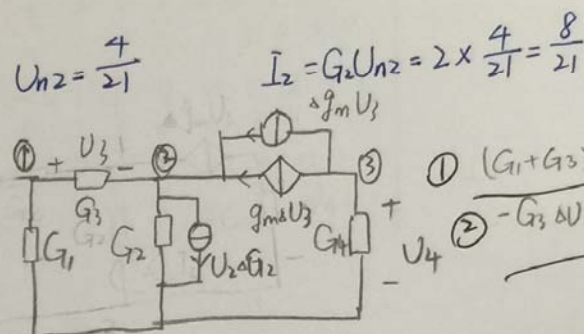
$$(G_3 + G_1) U_{n1} - G_3 U_{n2} = i_s$$

$$-G_3 U_{n1} + (G_3 + G_2) U_{n2} = g_m U_3$$

$$U_3 = U_{n1} - U_{n2}$$

联立求解： $U_{n1} = \frac{5}{21}$ $U_{n2} = \frac{4}{21}$ $I_2 = G_2 U_{n2} = 2 \times \frac{4}{21} = \frac{8}{21}$

(2) 增量网络如图：



列节点方程： $(G_1 + G_3 + G_2) \Delta U_{n2} = \Delta g_m U_3 + \Delta G_2 I_2$

$$U_3 = -\frac{R_3}{R_1 + R_3} \Delta U_{n2}$$

$$U_4 = -\Delta g_m U_3 G_4$$

$$\begin{aligned}
 (1) \quad (G_1 + G_3) \Delta U_{n1} - G_3 \Delta U_{n2} &= 0 \\
 (2) \quad -G_3 \Delta U_{n1} + (G_2 + G_3) \Delta U_{n2} &= -\frac{4}{21} \Delta G_2 + \frac{\Delta g_m}{21} + 2 \Delta U_{n1} - 2 \Delta U_{n2}
 \end{aligned}$$

$$G_4 U_4 = -\Delta g_m \frac{1}{21} + 2 \Delta U_{n2} - 2 \Delta U_{n1}$$

$$\begin{aligned}
 U_4 &= -\frac{1}{147} \Delta g_m + \frac{4}{49} \left(-\frac{2}{21} \Delta G_2 + \frac{1}{42} \Delta g_m \right) + \frac{4}{147} \Delta G_2 \times \frac{3}{7} - \\
 &\quad - \frac{6}{1029} \Delta g_m - \frac{4}{1029} \Delta G_2
 \end{aligned}$$

$$\frac{6}{49} \times \frac{1}{42} \Delta g_m$$

$$\begin{aligned}
 &-\frac{1}{147} \Delta g_m + \frac{4}{49} \times \frac{1}{42} \Delta g_m - \frac{8}{21 \times 49} \Delta G_2 + \frac{12}{147 \times 7} \Delta G_2 \\
 &\quad - \frac{1}{49 \times 7} \Delta g_m
 \end{aligned}$$

$$I_2 = \frac{4.5+1}{4.5+5.5+2}$$

$$-\frac{8}{1029} \Delta g_m + \frac{4}{1029} \Delta G_2$$