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ภาคผนวก ก

การหายาโคบีเมตริกซ์

กำลังไฟฟ้าที่บัสใดๆ มีค่า

$$S_i = V_i I_i^*$$

$$S_i = V_i \sum_{j=1}^{n} Y_{ij}^* V_j^*$$

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij})$$

$$Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij})$$

โดยที่

$V_{i(j)}$ = แรงดันเฟสเซอร์เชิงซ้อน (Complex Power) ที่บัส $i(j)$

$|V_{i(j)}|$ = ขนาดแรงดันที่บัส $i(j)$

I_i = กระแสเฟสเซอร์จำนวนเชิงซ้อนที่บัส i

Y_{ij} = แอดมิตแตนซ์เมตริกซ์

δ_i = มุมของแรงดันเฟสเซอร์ที่บัส i เทียบกับสวิงบัส

θ_{ij} = มุมขององค์ประกอบแอดมิตแตนซ์เมตริกซ์ i,j

ยาโคบีเมตริกซ์ J หาได้จาก

$$J = \begin{pmatrix} \dfrac{\partial P}{\partial \delta} & \dfrac{\partial P}{\partial |V|} \\[2ex] \dfrac{\partial Q}{\partial \delta} & \dfrac{\partial Q}{\partial |V|} \end{pmatrix}$$

$\dfrac{\partial P}{\partial \delta}$ = คือเมตริกซ์ย่อย (Submatrix) ขนาด (n-1) x (n-1) โดยที่

$$\frac{\partial P}{\partial \delta} = \begin{vmatrix} \dfrac{\partial P_2}{\partial \delta_2} & \dfrac{\partial P_2}{\partial \delta_3} & \cdots & \dfrac{\partial P_2}{\partial \delta_n} \\[2ex] \dfrac{\partial P_3}{\partial \delta_2} & \dfrac{\partial P_3}{\partial \delta_3} & \cdots & \dfrac{\partial P_3}{\partial \delta_n} \\[2ex] \dfrac{\partial P_n}{\partial \delta_2} & \dfrac{\partial P_n}{\partial \delta_3} & \cdots & \dfrac{\partial P_n}{\partial \delta_n} \end{vmatrix}$$

ในทำนองเดียวกัน

$\dfrac{\partial P}{\partial |V|}$ = คือเมตริกซ์ย่อย (Submatrix) ขนาด (n-1) x (n-1)

$\dfrac{\partial Q}{\partial \delta}$ = คือเมตริกซ์ย่อย (Submatrix) ขนาด (n-1) x (n-1)

$\dfrac{\partial Q}{\partial |V|}$ = คือเมตริกซ์ย่อย (Submatrix) ขนาด (n-1) x (n-1)

ดังนั้นการหาอนุพันธ์ของ P_i และ Q_i เทียบกับขนาดและมุมของแรงดันบัส จะได้

$$J_1(i,i) = \frac{\partial P_i}{\partial \delta_i} = -\sum_{\substack{j=1 \\ \neq i}}^{n} |V_i||V_j||Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij})$$

$$J_1(i,k) = \frac{\partial P_i}{\partial \delta_k} = |V_i||V_k||Y_{ik}| \sin(\delta_i-\delta_k-\theta_{ik}) \ , \ (k \neq i)$$

$$J_2(i,i) = \frac{\partial P_i}{\partial |V_i|} = \sum_{\substack{j=1 \\ \neq i}}^{n} |V_j||Y_{ij}|\cos(\delta_i-\delta_j-\theta_{ij})+2|V_j||Y_{ii}|\cos(-\theta_{ii})$$

$$J_2(i,k) = \frac{\partial P_i}{\partial |V_k|} = |V_i||Y_{ik}| \cos(\delta_i-\delta_k-\theta_{ik}) \ , \ (k \neq i)$$

$$J_3(i,i) = \frac{\partial Q_i}{\partial \delta_i} = \sum_{\substack{j=1 \\ \neq i}}^{n} |V_i||V_j||Y_{ij}| \cos(\delta_i-\delta_j-\theta_{ij})$$

$$J_3(i,k) = \frac{\partial Q_i}{\partial \delta_k} = - |V_i||V_k||Y_{ik}| \cos(\delta_i-\delta_k-\theta_{ik}) \ , \ (k \neq i)$$

$$J_4(i,i) = \frac{\partial Q_i}{\partial |V_i|} = \sum_{\substack{j=1 \\ \neq i}}^{n} |V_j||Y_{ij}|\sin(\delta_i-\delta_j-\theta_{ij})+2|V_i||Y_{ii}|\sin(-\theta_{ii})$$

$$J_4(i,k) = \frac{\partial Q_i}{\partial |V_k|} = |V_i||Y_{ik}| \sin(\delta_i-\delta_k-\theta_{ik}) \ , \ (k \neq i)$$

นิยามฮาร์มอนิกและลำดับเฟส

(Harmonic Definition and Phase Sequences)

1. นิยาม

- แรงดัน

$$v(t) = a_0 + \sum_{k=1}^{\infty} a_k \sin(k\omega_0 t + \delta_k)$$

- กระแส

$$i(t) = c_0 + \sum_{k=1}^{\infty} c_k \sin(k\omega_0 t + \phi_k)$$

- กำลังไฟฟ้าแอกทีฟ

$$P = a_0 c_0 + \sum_{k=1}^{\infty} a_k c_k \cos(\delta_k - \phi_k)$$

- กำลังไฟฟ้ารีแอกทีฟ

$$Q = \sum_{k=1}^{\infty} a_k c_k \sin(\delta_k - \phi_k)$$

- ค่าอาร์เอ็มเอสของแรงดันและกระแส (RMS Voltage and Current)

$$V_{RMS} = \left(\sum_{k=0}^{\infty} a_k^2 \right)^{\frac{1}{2}}$$

$$I_{RMS} = \left(\sum_{k=0}^{\infty} c_k^2 \right)^{\frac{1}{2}}$$

- กำลังไฟฟ้าปรากฏ (Apparent Power)

$$V_{RMS} \cdot I_{RMS} = \left(\sum_{k=0}^{\infty} a_k{}^2 \right)^{\frac{1}{2}} \cdot \left(\sum_{k=0}^{\infty} c_k{}^2 \right)^{\frac{1}{2}}$$

- โวลต์แอมแปร์เนื่องจากความเพี้ยน (Distortion Voltamperes)

$$D = \sqrt{S^2 - P^2 - Q^2}$$

- ตัวประกอบกำลัง

$$PF = \frac{P}{S}$$

- ตัวประกอบการเพี้ยน (Distortion Factor) ของแรงดันและกระแส

$$DF_V = \frac{\left(\sum_{k=2}^{\infty} a_k{}^2 \right)^{\frac{1}{2}}}{V_{RMS}}$$

$$DF_I = \frac{\left(\sum_{k=2}^{\infty} c_k{}^2 \right)^{\frac{1}{2}}}{I_{RMS}}$$

2. <u>ลำดับเฟสของฮาร์มอนิกในระบบสมดุล (Balanced System)</u>

- ความถี่หลักมูล

$$v_a{}^{(1)}(t) = A_1 \cos[\omega_0 t] \qquad = A_1 \cos[\omega_0 t]$$

$$v_b^{(1)}(t) = A_1 \cos\left[\omega_0 t - \frac{2\pi}{3}\right] = A_1 \cos\left[\omega_0\left(t - \frac{2\pi}{3\omega_0}\right)\right]$$

$$v_c^{(1)}(t) = A_1 \cos\left[\omega_0 t + \frac{2\pi}{3}\right] = A_1 \cos\left[\omega_0\left(t + \frac{2\pi}{3\omega_0}\right)\right]$$

- ฮาร์มอนิกที่สอง

$$v_a^{(2)}(t) = A_2 \cos\left[2\omega_0 t + \phi_2\right] = A_2 \cos\left[2\omega_0 t + \phi_2\right]$$

$$v_b^{(2)}(t) = A_2 \cos\left[2\omega_0\left(t - \frac{2\pi}{3\omega_0 t}\right) + \phi_2\right] = A_2 \cos\left[2\omega_0 t + \frac{2\pi}{3} + \phi_2\right]$$

$$v_c^{(2)}(t) = A_2 \cos\left[2\omega_0\left(t + \frac{2\pi}{3\omega_0 t}\right) + \phi_2\right] = A_2 \cos\left[2\omega_0 t - \frac{2\pi}{3} + \phi_2\right]$$

- ฮาร์มอนิกที่สาม

$$v_a^{(3)}(t) = A_3 \cos\left[3\omega_0 t + \phi_3\right] = A_3 \cos\left[3\omega_0 t + \phi_3\right]$$

$$v_b^{(3)}(t) = A_3 \cos\left[3\omega_0\left(t - \frac{2\pi}{3\omega_0 t}\right) + \phi_3\right] = A_3 \cos\left[3\omega_0 t - 2\pi + \phi_3\right]$$

$$v_c^{(3)}(t) = A_3 \cos\left[3\omega_0\left(t + \frac{2\pi}{3\omega_0 t}\right) + \phi_3\right] = A_3 \cos\left[3\omega_0 t + 2\pi + \phi_3\right]$$

ภาคผนวก ค

การสร้างเมตริกซ์ Y

สมการเวกเตอร์กระแสฉีดฮาร์มอนิกอันดับ k

$$I^{(k)} = Y^{(k)} \cdot V^{(k)}$$

โดยที่

$Y^{(k)}$ = เมตริกซ์แอดมิตแตนซ์ฮาร์มอนิกที่อันดับ k

$V^{(k)}$ = เวกเตอร์แรงดันบัสฮาร์มอนิกที่อันดับ k

ที่บัส 1 ใดๆ กระแสฉีดจะเป็น

$$I_1^{(k)} = \sum_{m=1}^{n} Y_{1,m}^{(k)} \cdot V_m^{(k)} = I_{1,r}^{(k)} + jI_{1,i}^{(k)}$$

โดยที่

$I_{1,r}^{(k)}$ = ส่วนประกอบจริงของกระแส

$I_{1,i}^{(k)}$ = ส่วนประกอบจินตภาพของกระแส

n = จำนวนบัส

รูปเฟสเซอร์ของ $V_m^{(k)}$ และ $Y_{1,m}^{(k)}$ คือ

$$V_m^{(k)} = \left| V_m^{(k)} \right| e^{j\delta_m^{(k)}}$$

$$Y_{1,m}^{(k)} = \left| Y_{1,m}^{(k)} \right| e^{j\theta_{1,m}^{(k)}}$$

ดังนั้นสมการกระแสคือ

$$I_{1,r}^{(k)} + jI_{1,i}^{(k)} = \sum_{m=1}^{n} \left| Y_{1,m}^{(k)} \right| \left| V_m^{(k)} \right| [\cos(\theta_{1,m}^{(k)} + \delta_m^{(k)}) + j\sin(\theta_{1,m}^{(k)} + \delta_m^{(k)})]$$

หาอนุพันธ์บางส่วนของกระแสฉีดเทียบกับแรงดันบัส จะได้

$$\frac{1}{\left| V_m^{(k)} \right|} \frac{\partial I_{1,r}^{(k)}}{\partial \delta_m^{(k)}} = - \left| Y_{1,m}^{(k)} \right| \sin(\theta_{1,m}^{(k)} + \delta_m^{(k)}) \qquad (ค1)$$

$$\frac{\partial I_{1,r}^{(k)}}{\partial \left| V_m^{(k)} \right|} = \left| Y_{1,m}^{(k)} \right| \cos(\theta_{1,m}^{(k)} + \delta_m^{(k)}) \qquad (ค2)$$

$$\frac{1}{\left| V_m^{(k)} \right|} \frac{\partial I_{1,i}^{(k)}}{\partial \delta_m^{(k)}} = - \left| Y_{1,m}^{(k)} \right| \sin(\theta_{1,m}^{(k)} + \delta_m^{(k)}) \qquad (ค3)$$

$$\frac{\partial I_{1,i}^{(k)}}{\partial \left| V_m^{(k)} \right|} = \left| Y_{1,m}^{(k)} \right| \sin(\theta_{1,m}^{(k)} + \delta_m^{(k)}) \qquad (ค4)$$

ดังนั้น $T^{(k,k)}$ หาได้จากความสัมพันธ์

$$\left[\Delta I^{(k)} \right] - \left[T^{(k,k)} \right] \cdot \left[\Delta V_m^{(k)} \right]$$

โดยที่
$$\Delta I^{(k)} - \left[\Delta I_{1,r}^{(k)}, \Delta I_{1,i}^{(k)}, \ldots, \Delta I_{n,r}^{(k)}, \Delta I_{n,i}^{(k)} \right]^T$$

$$\Delta V^{(k)} - \left[V_1^{(k)} \Delta \delta_1^{(k)}, \Delta V_1^{(k)}, \ldots, V_n^{(k)} \Delta \delta_n^{(k)}, \Delta V_n^{(k)} \right]^T$$

ยาโคบีและอนุกรมฟูริเยร์ของเครื่องแปลงผัน

กระแสของเครื่องแปลงผันในรูปอนุกรมฟูริเยร์คือ

$$i_a(t) = \sum_{k=1}^{h} \left[I_i^{(k)}\cos(k\omega_0 t) + I_r^{(k)}\sin(k\omega_0 t) \right]$$

โดยที่

$$g_i^{(k)} = I_i^{(k)} = \frac{2}{\pi} \int_{\alpha}^{\alpha+\pi} i_a(t)\cos(k\omega_0 t)d(\omega_0 t)$$

$$g_r^{(k)} = I_r^{(k)} = \frac{2}{\pi} \int_{\alpha}^{\alpha+\pi} i_a(t)\sin(k\omega_0 t)d(\omega_0 t)$$

กระแส $i_a(t)$ ประกอบด้วยตัวคงที่, เอ็กโปเนนเชียล และพจน์บังคับ (Forcing Term) แสดงในตารางที่ 3.1 และ 3.2 (หน้า 48,49) ซึ่งแสดงค่าในแต่ละช่วงเวลา ค่า $g_i^{(k)}$ และ $g_r^{(k)}$ สามารถคำนวณโดยอินทิเกรตแยกแต่ละช่วงเวลาแล้วหาผลรวม ในแต่ละช่วงเวลาจะมีส่วนประกอบ 3 ตัวดังนี้

$$g_i^{(k)} = \frac{2}{\pi} \sum_{l=1}^{6} \left[\int_{B_1}^{T_1} C^{(1)}\cos(k\omega_0 t)d(\omega_0 t) + \int_{B_1}^{T_1} E^{(1)}e^{p^{(1)}t}\cos(k\omega_0 t)d(\omega_0 t) + \right.$$

$$\left. \int_{B_1}^{T_1} F^{(1)}\cos(k\omega_0 t)d(\omega_0 t) \right] \qquad (\text{ง}1)$$

$$g_r(k) = \frac{2}{\pi} \sum_{l=1}^{6} \left[\int_{B_l}^{T_l} C^{(l)} \sin(k\omega_0 t) d(\omega_0 t) + \int_{B_l}^{T_l} E^{(l)} e^{P^{(l)}t} \sin(k\omega_0 t) d(\omega_0 t) + \right.$$

$$\left. \int_{B_l}^{T_l} F^{(l)} \sin(k\omega_0 t) d(\omega_0 t) \right] \qquad (ง1)$$

โดยที่

l	=	ช่วงเวลา
B_l	=	ลิมิตล่างในช่วง l
T_l	=	ลิมิตบนในช่วง l
$C^{(l)}$	=	ค่าคงที่
$E^{(l)} e^{P^{(l)}t}$	=	ค่าเอ็กซ์โปเนนเชียล
$F^{(l)}(t)$	=	พจน์บังคับ

ผลลัพธ์ของการอินทิเกรต หาได้ดังนี้

$$\int_{B_l}^{T_l} C^{(l)} \cos(k\omega_0 t) d(\omega_0 t) = \left. \frac{C^{(l)}}{k} \sin(k\omega_0 t) \right|_{\omega_0 t = B_l}^{\omega_0 t = T_l}$$

$$\int_{B_l}^{T_l} C^{(l)} \sin(k\omega_0 t) d(\omega_0 t) = \left. -\frac{C^{(l)}}{k} \sin(k\omega_0 t) \right|_{\omega_0 t = B_l}^{\omega_0 t = T_l}$$

$$\int_{B_1}^{T_1} E^{(1)} e^{p^{(1)} t} \cos(k\omega_0 t) d(\omega_0 t) = \frac{E^{(1)} e^{\frac{p^{(1)}}{\omega_0} t}}{\left(\frac{p^{(1)}}{\omega_0}\right)^2 + k^2} \left[\left(\frac{p^{(1)}}{\omega_0}\right) \cos(k\omega_0 t) \right. $$

$$\left. + k\sin(k\omega_0 t) \right] \Bigg|_{\omega_0 t = B_1}^{\omega_0 t = T_1}$$

$$\int_{B_1}^{T_1} E^{(1)} e^{p^{(1)} t} \sin(k\omega_0 t) d(\omega_0 t) = \frac{E^{(1)} e^{\frac{p^{(1)}}{\omega_0} t}}{\left(\frac{p^{(1)}}{\omega_0}\right)^2 + k^2} \left[\left(\frac{p^{(1)}}{\omega_0}\right) \sin(k\omega_0 t) \right. $$

$$\left. - k\cos(k\omega_0 t) \right] \Bigg|_{\omega_0 t = B_1}^{\omega_0 t = T_1}$$

พจน์บังคับประกอบด้วยพจน์อนุกรมของไซน์ (Sine Series Terms) ใน
สมการที่ 3.8, 3.9, และ 3.15 สามารถใช้ความสัมพันธ์ต่อไปนี้หาค่าอินทีเกรตได้

$$\int \sin(ax+b)\cos(cx+d)dx = \frac{-\cos[(a-c)x+b-d]}{2(a-c)} - \frac{\cos[(a+c)x+b+d]}{2(a+c)} \quad , a^2 \neq c^2$$

$$\int \sin(ax+b)\cos(cx+d)dx = \frac{-\sin[(a-c)x+b-d]}{2(a-c)} - \frac{\sin[(a+c)x+b+d]}{2(a+c)} \quad , a^2 \neq c^2$$

$$\int \sin(ax+b)\sin(ax+d)dx = \frac{x}{2}\cos(b-d) - \frac{\sin(2ax+b+d)}{4a}$$

$$\int \sin(ax+b)\cos(ax+d)dx = \frac{x}{2}\sin(b-d) - \frac{\cos(2ax+b+d)}{4a}$$

สมการ $G^{(k,j)}$ แทนด้วยอนุพันธ์บางส่วนของ $g_r^{(k)}$, $g_i^{(k)}$ เทียบกับแรงดัน
ที่ป้อนเข้าในข่ายวงจร(Applied Network Voltages) อนุพันธ์บางส่วนนี้หาโดยตรง
จากยินทิกรัลของพจน์บังคับ ค่า T_1 และ B_1 เป็นฟังก์ชันของมุมสับเปลี่ยนฯ ซึ่งเป็นฟังก์ชัน
ของแรงดันจ่าย โดยทั่วไปค่า K_1, K_2, และ K_3 ก็เป็นฟังก์ชันของแรงดันจ่าย เนื่องจากไม่
สามารถหาความความแปรเปลี่ยนกับแรงดัน(Variation with voltage)ของ K_1, K_2,
K_3, และ μ ได้ ดังนั้นจึงสมมติว่าค่าเหล่านี้คงที่สำหรับการแปรเปลี่ยนของแรงดันช่วงเล็กๆ

เมตริกซ์ $H^{(k)}$ กำหนดโดยใช้วิธีของไฟไนต์ดิฟเฟอเรนซ์(Method of Finite
Differences) กระแส $g_r^{(k)}$, $g_i^{(k)}$ ประมาณโดยการใช้ผลต่างเล็กน้อยของตัวแปร
ควบคุมอุปกรณ์ไม่เชิงเส้น (Nonlinear Device Control Variables) β หรือ γ
ค่าอนุพันธ์ประมาณได้ดังนี้

$$
\begin{vmatrix} \dfrac{\partial g_r^{(k)}}{\partial \beta} & \dfrac{\partial g_r^{(k)}}{\partial \gamma} \\[3mm] \dfrac{\partial g_i^{(k)}}{\partial \beta} & \dfrac{\partial g_i^{(k)}}{\partial \gamma} \end{vmatrix} \equiv \begin{vmatrix} \dfrac{\Delta g_r^{(k)}}{\Delta \beta} & \dfrac{\Delta g_r^{(k)}}{\Delta \gamma} \\[3mm] \dfrac{\Delta g_r^{(k)}}{\Delta \beta} & \dfrac{\Delta g_r^{(k)}}{\Delta \gamma} \end{vmatrix}
$$

ภาคผนวก จ

ค่าฐานกระแสตรงของเครื่องแปลงผัน

ค่ากำลังสองอาร์เอ็มเอสของแรงดันกระแสตรงด้าน DC ของเครื่องแปลงผันโดยไม่คิดผลของการสับเปลี่ยน อยู่ในรูป

$$V_{DC}^2 = \frac{3}{\pi} \int_{-\frac{\pi}{6}+\alpha}^{\frac{\pi}{6}+\alpha} \left[\sqrt{6} \ V_{AC(1-n)} \right]^2 \cos^2\theta \ d\theta$$

$$V_{DC}^2 = 3 \ V_{AC(1-n)}^2 \left[1 + \frac{3\sqrt{3}}{2\pi} \cos 2\alpha \right]$$

โดยที่

$V_{AC(1-n)}$ = ค่าอาร์เอ็มเอสของแรงดันเฟสกระแสสลับด้าน AC ของเครื่องแปลงผัน

นิยามค่าแรงดันฐานดังนี้

$$V_{BDC} = V_{BAC(1-n)}$$

โดยที่

$V_{BAC(1-n)}$ = แรงดันฐานกระแสสลับซึ่งเป็นแรงดันเฟส

V_{BDC} = แรงดันฐานกระแสตรงอาร์เอ็มเอส

เนื่องจากแรงดัน E ของเครื่องแปลงผัน DC ใน HARMONIC มีค่าเป็นเปอร์เซนต์ ดังนั้น

$$E_{DC(volts)} = E_{DC(pu)} \cdot V_{BDC}$$

หรือ

$$E_{DC(volts)} = E_{DC(pu)} \cdot V_{BAC(1-n)} \qquad (\text{จ}1)$$

โดยที่

$E_{DC(volts)}$ = แรงดันกระแสตรงอาร์เอ็มเอส

$E_{DC(pu)}$ = แรงดันกระแสตรงหนึ่งหน่วยใน HARMONIC

อิมพีแดนช์ของเครื่องแปลงผันแสดงเป็นเปอร์เซนต์ของอิมพีแดนช์ฐานด้าน AC ของเครื่องแปลงผัน นั่นคือ

$$Z_{DC(ohms)} = Z_{DC(pu)} \cdot Z_{BAC} \qquad (\text{จ}2)$$

โดยที่

Z_{BAC} = อิมพีแดนช์ฐานด้าน AC ของเครื่องแปลงผัน

$Z_{DC(ohms)}$ = อิมพีแดนช์จริง (50 Hz)

$Z_{DC(pu)}$ = อิมพีแดนช์ DC หนึ่งหน่วยใน HARMONIC

สรุปข้อความแสดงความผิดพลาด

```
*** ERROR CODE    1 ***
CONTROL CODE =    0 IS NOT VALID


*** ERROR CODE    2 ***
EITHER ONE OF THE PRECEEDING BUS NUMBERS IS OUT OF RANGE OR THE
FROM-TO NUMBERS ARE IDENTICAL


*** ERROR CODE    3 ***
NUMBER OF LINES HAS EXCEEDED PROGRAM LIMIT = 0


*** ERROR CODE    4 ***
TRANSFORMER TAP OR CONNECTION TYPE NOT VALID


*** ERROR CODE    5 ***
ONLY ONE CODE 3 SET OF INPUT DATA IS ALLOWED


*** ERROR CODE    6 ***
ONLY ONE CODE 4 SET OF INPUT DATA IS ALLOWED


*** ERROR CODE    7 ***
BUS NUMBER OUT OF RANGE - HIGHEST ALLOWED NUMBER = 0


*** ERROR CODE    8 ***
EITHER BUS TYPE OR BUS SUB-TYPE OUT OF RANGE
```

*** ERROR CODE   9 ***

THIS COMBINATION OF TYPE AND SUB-TYPE NOT ALLOWED

*** ERROR CODE   10 ***

MORE THAN ONE BUS SPECIFIED AS SWING BUS

*** ERROR CODE   11 ***

NO SWING BUS SPECIFIED

*** ERROR CODE   12 ***

TOO MANY BUSSES-MAXIMUM NUMBER OF BUSSES = 0

*** ERROR CODE   13 ***

THIS BUS NUMBER HAS ALREADY BEEN SPECIFIED

*** ERROR CODE   14 ***

ONE OF BOTH OF THESE BUS NUMBERS WAS NOT INCLUDED IN THE CODE 3 DATA

*** ERROR CODE   15 ***

CODE 3 (FUNDAMENTAL LOADFLOW BUS DATA) MUST PRECEED NONLINEAR BUS DATA

*** ERROR CODE   16 ***

ONLY ONE CODE 6 SET OF INPUT DATA IS ALLOWED

*** ERROR CODE   17 ***

THIS BUS NUMBER WAS NOT INCLUDED IN THE CODE 3 DATA

*** ERROR CODE   18 ***

THE NUMBER OF BUSSES HAS EXCEEDED THE NUMBER OF BUSSES OF THIS TYPE AS DETERMINED FROM THE CODE 3 DATA

*** ERROR CODE   19 ***

NONLINEAR DATA WAS NOT SPECIFIED FOR BUS 0

*** ERROR CODE   20 ***

THIS BUS TYPE DOES NOT AGREE WITH THE CODE 3 DATA

*** ERROR CODE   21 ***

NO BUSSES OF THIS TYPE WERE INCLUDED IN THE CODE 3 DATA

*** ERROR CODE   22 ***

CODE 3 DATA MUST PRECEED CODE 4 DATA

*** ERROR CODE   23 ***

THE CONVERTER FILTER REACTANCE SHOULD NOT BE NEGATIVE

*** ERROR CODE   24 ***

THE OVERRIDE HIGHEST HARMONIC = 0 EXCEEDS THE MAXIMUM ALLOWED = 0 (DETERMINED FROM MAXHAR AND THE ABSENCE OR PRESENCE OF ZERO SEQUENCE)

*** ERROR CODE   25 ***

THIS POSITIVE-NEGATIVE SEQUENCE LINE IMPEDANCE IS VERY SMALL

```
*** ERROR CODE    26 ***
```

PASSIVE CONVERTER BUSSES CANNOT HAVE P OR Q GENERATION

```
*** ERROR CODE    27 ***
```

ABS(S) CANNOT BE LESS THAN P AT A PS BUS

```
*** ERROR CODE    28 ***
```

PL OR PG CANNOT BE NEGATIVE AT NONLINEAR BUSSES

```
*** ERROR CODE    29 ***
```

NEGATIVE RESISTANCE NOT ALLOWED

```
*** ERROR CODE    30 ***
```

THE JACOBIAN HAS A ZERO ON THE DIAGONAL. DIAGONAL ELEMENT

POSITION = 0, VALUE = .0

```
*** ERROR CODE    31 ***
```

THERE MUST BE AT LEAST TWO BUSSES TO RUN THE LOADFLOW

```
*** ERROR CODE    32 ***
```

THE FUNDAMENTAL LOADFLOW DID NOT CONVERGE TO THE DESIRED WORST

BUS P,Q MISMATCH TOLERANCE = .0000

```
*** ERROR CODE    33 ***
```

NONLINEAR BUSSES CANNOT HAVE BOTH LOAD AND GENERATION

```
*** ERROR CODE    34 ***
```

XS SHOULD BE GREATER THAN ZERO

*** ERROR CODE   35 ***

R SHOULD NOT BE SPECIFIED

*** ERROR CODE   36 ***

ALPHA SHOULD NOT BE SPECIFIED

*** ERROR CODE   37 ***

ONLY ONE CODE 7 SET OF INPUT DATA IS ALLOWED

*** ERROR CODE   38 ***

THIS ALPHA IS NOT ACCEPTABLE

*** ERROR CODE   39 ***

E SHOULD NOT BE SPECIFIED

*** ERROR CODE   40 ***

PL OR PG MUST BE GREATER THAN ZERO AT A P-ALPHA BUS

*** ERROR CODE   41 ***

SHUNT CONNECTION TYPE NOT VALID

*** ERROR CODE   42 ***

SHUNT ELEMENT CONNECTION TYPE SPECFIED FOR NON SHUNT ELEMENT

*** ERROR CODE   43 ***

THE HARMONIC POWERFLOW HAS BEEN REQUESTED BUT THERE ARE NO
NONLINEAR BUSSES

*** ERROR CODE   44 ***

THE HARMONIC LOADFLOW DID NOT CONVERGE TO THE DESIRED WORST BUS

TOLERANCE = .0000

*** ERROR CODE   45 ***

ZERO SEQUENCE ANALYSIS HAS BEEN REQUESTED, BUT ZERO SEQUENCE

IMPEDANCE IS MISSING FOR THE ELEMENT CONNECTED TO BUSSES 0-0

*** ERROR CODE   46 ***

SHUNT CONNECTION TYPE IS SPECIFIED, BUT THE SHUNT Q IS VERY SMALL

*** ERROR CODE   47 ***

CODE 4 DATA MUST PRECEED CODE 5 DATA

*** ERROR CODE   48 ***

THE ITERATIVE SOLUTION OF THE COMMUTATION ANGLE FOR THE LINE

COMMUTATED CONVERTER AT BUS   0

DID NOT CONVERGE. ITERATIONS = 0, COMMUTATION ANGLE = .00 THE

MISMATCH IS ---F1 = .0, F2 = .0

*** ERROR CODE   49 ***

THE JACOBIN DIMENSION(MAXAJAC) MUST BE AT LEAST TWICE AS LARGE

THE NUMBER OF BUSSES (NB) TO RUN THE FUNDAMENTAL LOADFLOW NB = 0,

MAXJAC = 0

*** ERROR CODE   50 ***

THE END OF PERIOD 2 FOR THE LINE COMMUTATED CONVERTER AT BUS 0

CANNOT BE DETERMINED SINCE THE CURRENT NEVER GOES POSITIVE

*** ERROR CODE   51 ***

THE ITERATIVE SOLUTION OF THE END OF PERIOD 2 FOR A LINE

COMMUTATED CONVERTER AT BUS 0 DID NOT CONVERGE.

ITERATIONS = 0, ENDING ANGLE (PAST DELAY ANGLE) = .00,ERROR = .0

*** ERROR CODE   52 ***

R MUST BE GREATER THAN ZERO

*** ERROR CODE   53 ***

ZERO SEQUENCE HAS BEEN REQUESTED, BUT THERE ARE NO ZERO SEQUENCE

SOURCES

*** ERROR CODE   54 ***

IMPEDANCE FOR HARMONICS ONLY SHOULD NOT BE SPECIFIED AT A NON

SHUNT ELEMENT

*** ERROR CODE   55 ***

ACCORDING TO THE FOLLOWING DIMENTIONS, NB = 0, NOHAR = 0,

NNLIN = 0, THE JACOBIAN DIMENSION

MAXAJAC SHOULD BE AT LEAST = 0

THE SPECIFIED MAXAJAC = 0 IS TOO SMALL

*** ERROR CODE   56 ***

QL CANNOT BE MEGATIVE AND QG CANNOT BE POSITIVE AT A LINE

COMMUTATED CONVERTER

*** ERROR CODE   57 ***

SOME LOAD OR GENERATION PARAMETERS SHOULD BE SPECIFIED AT A

NONLINEAR BUT NON E- ALPHA BUS

*** ERROR CODE   58 ***

THE SUM OF THE DELAY ANGLE PLUS THE COMMUTATION ANGLE AT BUS 0 IS

.00 DEGREES. THIS EXCEEDS THE LIMIT OF .00 DEGREES

*** ERROR CODE   59 ***

LOAD OR GENERATION SHOULD NOT BE SPECIFIED AT AN E-ALPHA BUS

*** ERROR CODE   60 ***

THIS PROGRAM DOES NOT PERMIT ZERO SEQUENCE ANALYSIS

*** ERROR CODE   61 ***

THERE ARE PATHS WITH DIFFERENT PHASE SHIFTS FROM BUS 0 TO THE

SWING BUS

*** ERROR CODE   62 ***

DISCONTINUOUS NETWORK. BUS 0 HAS NO PATH TO THE SWING BUS

*** ERROR CODE   63 ***

A TRANSFORMER TAP OR CONNECTION TYPE SHOULD NOT BE SPECIFIED FOR

A SHUNT ELEMENT

*** ERROR CODE   64 ***

THERE IS NO PATH TO NEUTRAL FOR THE HARMONIC CURRENTS

*** ERROR CODE   65 ***

THE HIGEST HARMONIC MULTIPLE CONTAINED IN VECTOR NHVECT = 0

SHOULD NOT EXCEED THE DIMENSION MAXHMP = 0

*** ERROR CODE   66 ***

NONLINEAR ELEMENT CONNECTION TYPE NOT VALID

*** ERROR CODE   67 ***

VOLTAGE SHOULD NOT BE SPECIFIED AT A PQ BUS OR NONLINEAR BUS

*** ERROR CODE   68 ***

THIS SPECIFIED VOLTAGE IS OUTSIDE THE NORMAL RANGE OF 50% TO 150%

ภาคผนวก ช

สรุปข้อความที่บอกให้ผู้ใช้ทราบ

*** MESSAGE CODE 1 ***

ASSUMED TRANSFORMER CONNECTION TYPE = 1

*** MESSAGE CODE 2 ***

ASSUMED SHUNT CONNECTION TYPE = 1

*** MESSAGE CODE 3 ***

THE ITERATIVE SOLUTION OF THE COMMUTATION ANGLE FOR THE LINE
COMMUTATED CONVERTER AT BUS 0 CONVERGED OUTSIDE THE ACCEPTABLE
RANGE OF 0-60 DEGREES ITER = 0, COMMUTATION ANGLE = .00. THE
COMMUTATION ANGLE WILL BE RESET TO THE NEAREST LIMIT

*** MESSAGE CODE 4 ***

A TRANSFORMER SHOULD NOT HAVE LINE CHARGING - THIS VALUE OF
CHARGING IS IGNORED

*** MESSAGE CODE 5 ***

THE ITERATIVE SOLUTION OF THE END OF PERIOD 2 FOR A LINE
COMMUTATED CONVERTER AT BUS 0 CONVERGED TO .00 DEGREES (PAST
DELAY ANGLE). THIS IS OUTSIDE THE ACCEPTABLE RANGE OF 0 TO 60
DEGREES. RESET TO THE NEAREST LIMIT

*** MESSAGE CODE 6 ***

USING A CONSTANT CURRENT CONVERTER MODEL, P SHOULD NOT EXCEED

3*S/PI CONVERGENCE MAY BE DIFFICULT.

*** MESSAGE CODE 7 ***

THE R AT THE PRECEEDING BUS IS PROBABLY TOO LARGE TO ALLOW THE

SPECIFIED LOAD NON REALISTIC NEGATIVE E MAY RESULT

*** MESSAGE CODE 8 ***

THE R AT THE PRECEEDING BUS IS PROBABLY TOO LARGE TO ALLOW THE

SPECIFIED GENERATION NON REALISTIC POSITIVE E MAY RESULT

*** MESSAGE CODE 9 ***

THE TIME CONSTANTS FOR THE LINE COMMUTATED CONVERTER AT BUS 0 ARE

VERY SMALL PROBLEMS MAY ARISE IN USING EXPONENTIAL FUNCTIONS

*** MESSAGE CODE 10 ***

ASSUMED NONLINEAR ELEMENT CONNECTION TYPE = 1

ภาคผนวก ช

รายละเอียดของตัวแปรในโปรแกรมหลัก

ตัวแปร	ชนิด	รายละเอียด
ACCEL	R	แฟกเตอร์เร่ง (Acceleration Factor) ที่ใช้หา พารามิเตอร์ของอุปกรณ์ไม่เชิงเส้น
AJAC(MAXAJAC)	R	ยาโคบีเมตริกซ์
AK1,AK2,AK3	R	ตัวแปรกระแสของเครื่องแปลงผัน K1, K2, K3
BUSNAME(MAXNB)	A	ชื่อบัส
BTEMPN	A	ตัวแปรชั่วคราวที่ใช้เก็บชื่อบัส
BO(MAXLINE)	R	ประจุสายลำดับศูนย์
B1(MAXLINE)	R	ประจุสายลำดับบวก
CHARGE(MAXLINE)	R	ประจุสาย
CMPONE	C	จำนวนเชิงซ้อนที่มีค่าหนึ่ง
CMPZERO	C	จำนวนเชิงซ้อนที่มีค่าศูนย์
CODE3,CODE4,CODE5 CODE6,CODE7	L	แสดงสภาพของตัวแปรควบคุม
COM(MAXNB)	R	มุมสับเปลี่ยน
COMMENT	A	ตัวบอกจุดประสงค์ของการใช้โปรแกรม
COMTOLE	R	ช่วงกว้างการคอนเวิร์จในการหาคำตอบของมุมสับเปลี่ยน
CONV	L	ตัวแสดงว่าโหลดโฟลว์คอนเวิร์จ
COS30	R	โคไซน์ของมุม 30˚
CSWING	L	ตัวแสดงสวิงบัส
DELTAX(MAXAJAC)	R	เวกเตอร์ที่ใช้หาคำตอบใหม่ (Update Vector) ของ วิธีนิวตัน-ราฟสัน

ตัวแปร	ชนิด	รายละเอียด
DELTAY(MAXAJAC)	R	เวกเตอร์ของค่าที่ไม่รับกัน (Mismatch Vector) ของ วิธีนิวตัน-ราฟสัน
DEPART	R	ช่วง (Step Size) ของการประมาณหาอนุพันธ์บางส่วน ของเครื่องแปลงผัน
DELAY	R	มุมประวิง α
DR	R	แฟกเตอร์การแปลงจากองศาเป็นเรเดียน
ECONV	R	ค่าแรงดันกระแสตรงของเครื่องแปลงผัน
EDUM1, EDUM2, EDUM3	R	ตัวแปรที่ใช้ระหว่างโปรแกรมย่อย
EP3, EP4, EP6, EP9	R	ค่า $10^{-3}, 10^{-4}, 10^{-6}, 10^{-9}$
ER	R	ค่า $\frac{E}{R}$ ของเครื่องแปลงผัน
FALSE	L	ตรรก .FALSE.
FCONV(MAXNB)	R	ค่ารีแอกแตนซ์ F ของเครื่องแปลงผัน
FFANG(2,MAXHAR)	R	มุมแรงดันฮาร์มอนิกในฟังก์ชันบังคับ (Forcing Function)
FFMAG(2,MAXHAR)	R	ขนาดแรงดันฮาร์มอนิกในฟังก์ชันบังคับ
F2TOLE	R	ช่วงกว้างการคอนเวิร์จที่ใช้หาเวลาสิ้นสุดในช่วงที่ 2
GI(MAXNB,MAXHAR)	R	กระแสฮาร์มอนิกส่วนจินตภาพที่เกิดจากเครื่องแปลงผัน
GITEMPO(MAXHAR)	R	ตัวแปรชั่วคราวของ GI
GPATH	L	ตัวแสดงเส้นทางไปนิวตรัลของกระแสฮาร์มอนิก
GR(MAXNB,MAXHAR)	R	กระแสฮาร์มอนิกส่วนจริงที่เกิดจากเครื่องแปลงผัน
GRTEMPO(MAXHAR)	R	ตัวแปรชั่วคราวของ GR
HANG(MAXHAR)	R	ตัวแปรชั่วคราวใช้เก็บมุมของสัญญาณฮาร์มอนิก
HDF	R	แฟกเตอร์ความเพี้ยนที่เกิดจากฮาร์มอนิก (Harmonic Distortion Factor)
HFUND	R	ส่วนประกอบที่ความถี่หลักมูล

ตัวแปร	ชนิด	รายละเอียด
HMAG(MAXHAR)	R	ตัวแปรชั่วคราวใช้เก็บขนาดของสัญญาณฮาร์มอนิก
HPEAK	R	ค่ายอด (Peak Value)
HRMS	R	ค่าอาร์เอ็มเอส
IOPT(14)	I	การเลือกหาคำตอบ
ISDUM1	I	ตัวแปรที่ใช้ระหว่างโปรแกรมย่อย
ISDUM2	I	ตัวแปรที่ใช้ระหว่างโปรแกรมย่อย
ITERCOM	I	จำนวนการวนซ้ำของการหาค่ามุมสับเปลี่ยน
KRENUM(MAXNB)	I	เวกเตอร์ที่ใช้เรียงเลขบัส
KSHAR(MAXNB)	I	แบบการต่อองค์ประกอบชันต์อิมพีแดนซ์ (Shunt Impedance Element) (ถ้าค่าเป็นลบ จะใช้คิดเฉพาะฮาร์มอนิกเท่านั้น)
KSHTYPE(MAXNB)	I	แสดงแบบการต่อรีแอกเตอร์และชันต์คะแปซิเตอร์
KTRCON(MAXNB)	I	แบบการต่อหม้อแปลงของเครื่องแปลงผัน
KTRTYPE(MAXLINE)	I	แบบการต่อหม้อแปลง
LINES(2,MAXLINE)	I	สายส่ง, หม้อแปลง, องค์ประกอบชนานจากบัสไปบัส
MAXAJAC	I	มิติสูงสุดของยาโคบีเมตริกซ์
MAXHAR	I	จำนวนสูงสุดของฮาร์มอนิก (รวมความถี่หลักมูล)
MAXHMP	I	ตัวคูณฮาร์มอนิก (Harmonic multiple) สูงสุด
MAXLINE	I	จำนวนรวมสูงสุดของสายส่ง, หม้อแปลง, องค์ประกอบชนาน
MAXNB	I	จำนวนบัสสูงสุด
MBHUSE	I	จำนวนบัสของผู้ใช้สูงสุด
MXFITER	I	จำนวนการวนซ้ำสูงสุดของการไหลของกำลังไฟฟ้าที่ความถี่หลักมูล

ตัวแปร	ชนิด	รายละเอียด
MXHITER	I	จำนวนการวนช้ำสูงสุดของการไหลของกำลังไฟฟ้าที่ ความถี่ฮาร์มอนิก
NB	I	จำนวนบัส
NBEXT(MAXNB)	I	เกี่ยวข้องกับการจัดบัสในโปรแกรมกับบัสผู้ใช้
NBINT(MAXNB)	I	เกี่ยวข้องกับบัสผู้ใช้กับการจัดบัสในโปรแกรม
NBSHFT(MAXNB)	I	ตัวที่ใช้ตรวจสอบความต่อเนื่องของวงจร
NBSUBT(MAXNB)	I	ชนิดย่อยของบัส (Bus Sub-types)
NBTYPE(MAXNB)	I	ชนิดของบัส
NHAR	I	จำนวนของฮาร์มอนิก
NHIGH	I	ตัวคูณฮาร์มอนิกสูงสุด
NLIN	I	จำนวนบัสเชิงเส้น
NLINES	I	จำนวนองค์ประกอบขนาน, สายส่ง, หม้อแปลง
NNLIN	I	จำนวนบัสไม่เชิงเส้น
NNL1	I	จำนวนบัสไม่เชิงเส้น ชนิด 1 (แบบพาสซีฟ)
NNL2	I	จำนวนบัสไม่เชิงเส้น ชนิด 2 (แบบแอกทีฟ)
NOERMAX	I	จำนวนความผิดพลาดสูงสุด
NOERR	I	จำนวนความผิดพลาด
NOHAR	I	จำนวนฮาร์มอนิก
NPQLIN	I	จำนวนบัสย่อย PQ (บัสเชิงเส้น)
NPVLIN	I	จำนวนบัสย่อย PV (บัสเชิงเส้น)
NPHSEQ(MAXHAR)	I	แสดงลำดับเฟสของฮาร์มอนิก
NSHMAX	I	แบบสูงสุดของการต่อองค์ประกอบขนาน
NSUBS	I	ชนิดของบัสย่อย (Sub-type) สูงสุด
NTRMAX	I	แบบสูงสุดของการต่อหม้อแปลง
NTYPES	I	ชนิดของบัส (Type) สูงสุด

ตัวแปร	ชนิด	รายละเอียด
PATHBTS(MAXNB)	L	ตัวแสดงเส้นทางจากบัสต่าง ๆ ไปสวิงบัส
PG(MAXNB)		ค่ากำลังไฟฟ้าจริงที่จ่ายออก (Generation)
PI	R	ค่า π
PL(MAXNB)	R	ค่ากำลังไฟฟ้าจริงที่รับ (Load)
PSHIFT(MAXHAR)	R	ตัวแปรชั่วคราวของมุมเลื่อนหม้อแปลงที่เครื่องแปลงผัน
P1,P2	R	ค่าคงที่เวลา (Time Constant) ของเครื่องแปลงผัน
QG(MAXNB)	R	ค่ากำลังไฟฟ้ารีแอกทีฟที่จ่ายออก
QL(MAXNB)	R	ค่ากำลังไฟฟ้ารีแอกทีฟที่รับ
RCONV(MAXNB)	R	ความต้านทาน R ของเครื่องแปลงผัน
RTRCON(MAXNB)	R	ความต้านทานหม้อแปลงของเครื่องแปลงผัน
RO(MAXLINE)	R	ความต้านทานลำดับศูนย์ขององค์ประกอบขนาน, สายส่ง
R1(MAXLINE)	R	ความต้านทานลำดับบวกและลบขององค์ประกอบขนาน สายส่ง , หม้อแปลง
R30,R60,R90 R120,R360	R	ค่าเรเดียนของมุม 30˚ 60˚ 90˚ 120˚ 360˚
S(MAXNB)	R	ค่าโวลต์แอมแปร์เสมือน
SIN30	R	ค่าไซน์ของมุม 30˚
SUBNAME(6)	A	รายละเอียดของบัสชนิดย่อย
SRCBL(MAXNB)	R	ค่าซันศ์รีแอกเตอร์หรือคะแปซิเตอร์ที่โหลดบัส
TAP(MAXLINE)	R	แทป (Tap) ของหม้อแปลง
TERMINAL	L	การสิ้นสุดการหาคำตอบ
TITLE	A	ชื่อเรื่อง
TOLE	R	ช่วงคอนเวิร์จของการหากำลังไฟฟ้าและกระแส
TRUE	L	ตรรก .TRUE.
V(MAXNB)	R	แรงดันกำหนดที่บัส PV

ตัวแปร	ชนิด	รายละเอียด
X(MAXAJAC)	R	ตัวแปรแรงดันของวิธีนิวตัน-ราฟสัน
XTRCON(MAXNB)	R	ค่ารีแอกแตนซ์ L ของหม้อแปลงที่เครื่องแปลงผัน
X0(MAXLINE)	R	ค่ารีแอกแตนซ์ลำดับศูนย์ขององค์ประกอบขนาน, สายส่ง
X1(MAXLINE)	R	ค่ารีแอกแตนซ์ลำดับบวกและลบขององค์ประกอบขนาน, สายส่ง, หม้อแปลง
Y(MAXAJAC)	R	ตัวแปรกำลังไฟฟ้าของวิธีนิวตัน-ราฟสัน
YBUS(MAXNB,MAXNB, MAXHAR)	R	เมตริกซ์ YBUS
ZOURCE	L	แสดงแหล่งกำเนิดกระแสลำดับศูนย์ (Zero Sequence Current Source)

โดยที่

A = ตัวอักษร (Character)

C = จำนวนเชิงซ้อน (Complex)

I = จำนวนเต็ม (Integer)

L = ตรรก (Logical)

R = จำนวนจริง (Real)

ตัวอย่างข้อมูลและผลการวิเคราะห์ระบบไฟฟ้ากำลัง 8 บัส

ข้อมูลในไฟล์ DATA.TXT มีดังนี้

```
   1
EIGHT BUS SYSTEM WITH 12 PULSE ACTIVE CONVERTER
   2
TEST SYSTEM FOR HARMONIC POWER FLOW PROGRAM
   3
   1SWING        1                                          105.0
   2BUS 2        3                                                  -100.0
   3BUS 3        3
   4BUS 4        3                            20.0    12.4
   5BUS 5        3                            10.0     6.2
   6BUS 6        3                            10.0     6.2
   7BUS 7        3                            10.0     6.2
   8BUS 8       24              23.5294       20.0
 999
   4
   1    2     .05       .5
   2    3              .833                          1.0
   3    4   1.355    3.987     .012
   4    5   1.355    3.987     .012
   5    6   1.355    3.987     .012
   6    7   1.355    3.987     .012
   7    8   1.355    3.987     .012
   1    0              .5                                   1
 999
   7
   8    25.0    100.0                      13.06
 999
   5
 0 125
   8
```

ผลการวิเคราะห์เป็นดังนี้

HARMONIC   POWER   FLOW   PROGRAM   (1988)

WATSON   CHANSAJCHA   PROGRAMMER
ASST. PROF. PRASIT PITTAYAPAT   ADVISOR

ENERGY SYSTEM RESEARCH LABORATORY
ELECTRICAL ENGINEERING DEPARTMENT
CHULALONGKORN UNIVERSITY

EIGHT BUS SYSTEM WITH 12 PULSE ACTIVE CONVERTER

TEST SYSTEM FOR HARMONIC POWER FLOW PROGRAM

FUNDAMENTAL LOADFLOW BUS DATA (PERCENT VOLTAGE, POWER)

BUS	NAME	TYPE	SUB-TYPE	P GEN	G GEN	S	P LOAD	G LOAD	VOLTAGE	G SHUNT	KEHTYPE
1	SWING	0	1	0.00	0.00	0.00	0.00	0.00	105.00	0.00	0
2	BUS 2	0	3	0.00	0.00	0.00	0.00	0.00	0.00	-100.00	0

*** MESSAGE CODE   2 ***
ASSUMED SHUNT CONNECTION TYPE = 1

BUS	NAME	TYPE	SUB-TYPE	P GEN	G GEN	S	P LOAD	G LOAD	VOLTAGE	G SHUNT	KEHTYPE
3	BUS 3	0	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
4	BUS 4	0	3	0.00	0.00	0.00	20.00	12.40	0.00	0.00	0
5	BUS 5	0	3	0.00	0.00	0.00	10.00	6.20	0.00	0.00	0
6	BUS 6	0	3	0.00	0.00	0.00	10.00	6.20	0.00	0.00	0
7	BUS 7	0	3	0.00	0.00	0.00	10.00	6.20	0.00	0.00	0
8	BUS 8	2	4	0.00	0.00	23.53	20.00	0.00	0.00	0.00	0

END OF CODE 3 BUS DATA

LINE AND TRANSFORMER DATA (PERCENT IMPEDANCE, CHARGING)

FROM BUS	TO BUS	R1	X1	C1	RO	XO	CO	TAP	T-TYPE	Z-TYPE	H-ONLY
1	2	0.05	0.50	0.00	0.00	0.00	0.00	0.000	0	0	5
2	3	0.00	0.83	0.00	0.00	0.00	0.00	1.000	0	0	0

*** MESSAGE CODE   1 ***
ASSUMED TRANSFORMER CONNECTION TYPE = 1

FROM BUS	TO BUS	R1	X1	C1	RO	XO	CO	TAP	T-TYPE	Z-TYPE	H-ONLY
3	4	1.36	3.99	0.01	0.00	0.00	0.00	0.000	0	0	0
4	5	1.36	3.99	0.01	0.00	0.00	0.00	0.000	0	0	0
5	6	1.36	3.99	0.01	0.00	0.00	0.00	0.000	0	0	0
6	7	1.36	3.99	0.01	0.00	0.00	0.00	0.000	0	0	0
7	8	1.36	3.99	0.01	0.00	0.00	0.00	0.000	0	0	0
1	0	0.00	0.50	0.00	0.00	0.00	0.00	0.000	0	0	1

*** MESSAGE CODE   2 ***
ASSUMED SHUNT CONNECTION TYPE = 1

END OF CODE 4 LINE AND TRANSFORMER DATA

NONLINEAR TYPE 2 BUS DATA

BUS	R	F	E	DELAY	RS	XS	KTYPE
8	25.00	100.00	0.00	0.00	0.00	13.00	6

END OF NONLINEAR TYPE 2 BUS DATA

SOLUTION OPTIONS

OPTION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
OPTION VALUE	0	1	25	0	0	0	0	0	0	0	0	0	0	0

STARTING ESTIMATES OF NONLINEAR DEVICE PARAMETERS

BUS	NAME	TYPE	P GEN	G GEN	P LOAD	Q LOAD	DELAY	R	E
8	BUS 8	PS	0.00	0.00	20.00	10.24	27.11	25.00	79.12

END OF STARTING ESTIMATES

FUNDAMENTAL LOADFLOW ITERATION SUMMARY

	ABSOLUTE REAL POWER MISMATCH			ABSOLUTE REACTIVE POWER MISMATCH		
ITERATION	AVERAGE	WORST	WORST BUS	AVERAGE	WORST	WORST BUS
0	24.14	99.01	2	161.61	1090.10	2
1	2.45	9.74	2	9.77	64.77	2
2	0.01	0.05	2	0.03	0.20	2
3	0.00	0.00	2	0.00	0.00	3

FUNDAMENTAL LOADFLOW OUTPUT (PERCENT VOLTAGE, POWER)

FROM BUS	NAME	VOLTAGE	ANGLE	PG	QG	FL	QL	G SHUNT	TO BUS	NAME	P	Q	TAP
1	SWING	105.00	0.00	71.95	-63.02	0.00	0.00	0.00					
									2	BUS 2	71.95	-63.02	
2	BUS 2	105.27	-0.20	0.00	0.00	0.00	0.00	-110.81					
									1	SWING	-71.91	63.43	
									3	BUS 3	71.91	47.38	1.000
3	BUS 3	104.89	-0.51	0.00	0.00	0.00	0.00	0.00					
									2	BUS 2	-71.91	-46.82	
									4	BUS 4	71.91	46.82	
4	BUS 4	102.21	-1.71	0.00	0.00	20.00	12.40	0.00					
									3	BUS 3	-71.00	-44.16	
									5	BUS 5	51.00	31.76	
5	BUS 5	100.30	-2.60	0.00	0.00	10.00	6.20	0.00					
									4	BUS 4	-50.54	-30.40	
									6	BUS 6	40.54	24.20	

6	BUS 6	98.80	-3.35	0.00	0.00	10.00	6.20	0.00				
									5	BUS 5	-40.24	-23.33
									7	BUS 7	30.24	17.13

7	BUS 7	97.70	-3.93	0.00	0.00	10.00	6.20	0.00				
									6	BUS 6	-30.07	-16.64
									8	BUS 8	20.07	10.44

| 8 | BUS 8 | 97.00 | -4.32 | 0.00 | 0.00 | 20.00 | 10.24 | 0.00 | | | | |
| | | | | | | | | | 7 | BUS 7 | -20.00 | -10.24 |

```
------------------------------------------------
TOTAL REAL POWER LOSS =              1.95
------------------------------------------------
```

HARMONIC LOADFLOW ITERATION SUMMARY

			ABSOLUTE REAL MISMATCH		WORST	ABSOLUTE IMAGINARY MISMATCH		WORST	VOLTAMPERE MISMATCH		WORST
ITERATION	QUANTITY	HARMONIC	AVERAGE	WORST	BUS	AVERAGE	WORST	BUS	AVERAGE	WORST	BUS

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PG= 0.00, GG= 0.00, PL= 20.00, GL= 10.24, DELAY= 27.11, R= 25.00, E= 79.12, COM= 2.31, CIT= 2

0	POWER		0.00	0.00	2	0.00	0.00	3	0.00	0.00	0
	CURRENT	1	10.20	10.20	8	5.83	5.83	8			
	CURRENT	11	0.12	0.98	8	3.65	18.18	1			
	CURRENT	13	0.03	0.26	8	3.59	15.38	1			
	CURRENT	23	0.04	0.33	8	3.99	23.00	2			
	CURRENT	25	0.00	0.01	8	4.16	25.00	2			

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PG= 0.00, GG= 0.00, PL= 20.00, GL= 10.24, DELAY= 22.13, R= 25.00, E= 78.77, COM= 5.75, CIT= 2

1	POWER		0.01	0.04	8	0.01	0.09	8	0.90	0.90	8
	CURRENT	1	0.57	0.57	8	1.12	1.12	8			
	CURRENT	11	1.23	2.87	8	1.00	2.24	1			
	CURRENT	13	0.59	1.78	8	0.70	2.50	8			
	CURRENT	23	0.07	0.31	8	0.10	0.50	8			
	CURRENT	25	0.33	1.60	8	0.25	0.70	8			

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PG= 0.00, GG= 0.00, PL= 20.00, GL= 12.16, DELAY= 23.14, R= 25.00, E= 77.68, COM= 6.41, CIT= 2

2	POWER		0.03	0.19	8	0.36	2.52	8	0.25	0.25	8
	CURRENT	1	0.22	0.22	8	0.05	0.05	8			
	CURRENT	11	4.67	9.09	1	2.97	6.53	6			
	CURRENT	13	0.89	2.44	6	1.39	4.32	7			
	CURRENT	23	1.19	3.79	7	0.97	3.10	8			
	CURRENT	25	0.21	0.53	8	0.24	0.90	8			

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PG= 0.00, GG= 0.00, PL= 20.00, GL= 12.10, DELAY= 30.19, R= 25.00, E= 72.85, COM= 4.52, CIT= 2

3	POWER		0.00	0.01	6	0.16	1.13	8	5.39	5.39	6
	CURRENT	1	2.65	2.65	8	1.06	1.06	8			
	CURRENT	11	11.78	25.33	1	6.59	16.66	3			

```
                CURRENT    13          2.49      7.36        6          4.48     10.79       7
                CURRENT    23          4.29     12.89        7          3.39     10.55       6
                CURRENT    25          1.88      5.23        7          3.13      8.81       7
```

NONLINEAR DEVICE PARAMETERS
BUS=   8, TYPE= PS, PG=   0.00, GG=   0.00, PL=   20.00, GL=   12.12, DELAY= 23.09, R=   25.00, E=   76.88, COM=   6.77, CIT= .

```
    4        POWER                    0.07      0.48        8          0.28      1.92       8          3.56      3.56       1

             CURRENT     1           0.50      0.50        8          0.75      0.75       8
             CURRENT    11           7.98     16.45        7          6.62     18.86       1
             CURRENT    13           2.49      7.30        7          3.21     10.11       7
             CURRENT    23           1.84      5.89        6          2.35      6.62       7
             CURRENT    25           0.95      3.55        5          1.50      3.57       5
```

NONLINEAR DEVICE PARAMETERS
BUS=   8, TYPE= PS, PG=   0.00, GG=   0.00, PL=   20.00, GL=   11.79, DELAY= 26.63, R=   25.00, E=   73.99, COM=   7.24, CIT= :

```
    5        POWER                    0.02      0.16        8          0.06      0.39       8          1.35      1.35       1

             CURRENT     1           0.52      0.52        8          0.60      0.60       8
             CURRENT    11           8.02     15.52        7          3.77     10.87       1
             CURRENT    13           1.64      4.34        6          3.48      9.65       7
             CURRENT    23           1.08      2.20        8          2.75      8.65       6
             CURRENT    25           0.48      1.40        8          0.67      2.12       5
```

NONLINEAR DEVICE PARAMETERS
BUS=   8, TYPE= PS, PG=   0.00, GG=   0.00, PL=   20.00, GL=   12.01, DELAY= 26.14, R=   25.00, E=   74.55, COM=   6.97, CIT= 1

```
    6        POWER                    0.03      0.20        8          0.15      1.03       8          3.74      3.74       E

             CURRENT     1           1.10      1.10        8          0.72      0.72       8
             CURRENT    11           4.51     12.10        7          5.24     12.84       7
             CURRENT    13           0.76      2.43        5          4.53     17.01       7
             CURRENT    23           1.04      3.97        6          0.60      1.49       6
             CURRENT    25           0.19      0.45        8          0.09      0.26       8
```

NONLINEAR DEVICE PARAMETERS
BUS=   8, TYPE= PS, PG=   0.00, GG=   0.00, PL=   20.00, GL=   12.13, DELAY= 26.30, R=   25.00, E=   74.90, COM=   6.49, CIT= :

```
    7        POWER                    0.01      0.06        8          0.13      0.91       8          1.24      1.24       E

             CURRENT     1           0.65      0.65        8          0.36      0.36       8
             CURRENT    11           4.46     13.61        7          0.51      1.87       6
             CURRENT    13           2.01      7.92        7          1.00      3.17       7
             CURRENT    23           0.47      1.85        6          0.72      2.76       6
             CURRENT    25           0.01      0.03        2          0.02      0.04       2
```

NONLINEAR DEVICE PARAMETERS
BUS=   8, TYPE= PS, PG=   0.00, GG=   0.00, PL=   20.00, GL=   12.04, DELAY= 27.16, R=   25.00, E=   73.99, COM=   6.48, CIT= 1

```
    8        POWER                    0.00      0.01        8          0.06      0.41       8          1.30      1.30       8

             CURRENT     1           0.13      0.13        8          0.03      0.03       8
             CURRENT    11           6.11     17.19        7          0.82      3.08       7
             CURRENT    13           0.06      0.21        5          0.72      2.77       7
             CURRENT    23           0.59      2.26        6          0.03      0.07       8
             CURRENT    25           0.01      0.02        8          0.00      0.01       2
```

NONLINEAR DEVICE PARAMETERS

BUS= 8, TYPE= PS, PQ= 0.00, GC= 0.00, PL= 20.00, GL= 12.04, DELAY= 26.41, R= 25.00, E= 74.45, COM= 7.13, CIT=

9	POWER		0.02	0.17	8	0.08	0.58	8	0.77	0.77
	CURRENT	1	0.17	0.17	8	0.23	0.23	8		
	CURRENT	11	1.70	4.59	7	3.90	11.66	7		
	CURRENT	13	0.06	0.22	7	0.01	0.06	8		
	CURRENT	23	0.18	0.69	6	0.24	0.91	6		
	CURRENT	25	0.01	0.04	8	0.01	0.04	8		

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PQ= 0.00, GG= 0.00, PL= 20.00, GL= 12.09, DELAY= 27.19, R= 25.00, E= 74.05, COM= 6.66, CIT=

10	POWER		0.00	0.03	8	0.04	0.27	8	0.01	0.01
	CURRENT	1	0.60	0.60	8	0.28	0.28	8		
	CURRENT	11	2.69	7.64	7	1.35	3.92	7		
	CURRENT	13	0.01	0.07	8	0.02	0.11	8		
	CURRENT	23	0.03	0.08	6	0.02	0.07	6		
	CURRENT	25	0.01	0.05	8	0.01	0.04	8		

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PQ= 0.00, GG= 0.00, PL= 20.00, GL= 12.05, DELAY= 27.56, R= 25.00, E= 73.52, COM= 6.76, CIT=

11	POWER		0.01	0.09	8	0.02	0.10	8	0.29	0.29
	CURRENT	1	0.76	0.76	8	0.47	0.47	8		
	CURRENT	11	3.74	11.34	6	1.35	4.19	7		
	CURRENT	13	0.01	0.08	8	0.01	0.08	8		
	CURRENT	23	0.01	0.02	8	0.01	0.02	6		
	CURRENT	25	0.00	0.02	8	0.00	0.02	8		

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PQ= 0.00, GG= 0.00, PL= 20.00, GL= 11.93, DELAY= 26.97, R= 25.00, E= 73.60, COM= 7.27, CIT= 2

12	POWER		0.00	0.00	2	0.01	0.07	8	0.07	0.07
	CURRENT	1	0.27	0.27	8	0.13	0.13	8		
	CURRENT	11	2.19	7.34	6	1.33	4.68	6		
	CURRENT	13	0.00	0.03	8	0.00	0.00	8		
	CURRENT	23	0.00	0.02	8	0.00	0.00	8		
	CURRENT	25	0.00	0.01	8	0.00	0.02	8		

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PQ= 0.00, GG= 0.00, PL= 20.00, GL= 11.95, DELAY= 27.05, R= 25.00, E= 73.65, COM= 7.23, CIT= 1

13	POWER		0.00	0.00	3	0.00	0.02	8	0.01	0.01
	CURRENT	1	0.08	0.08	8	0.04	0.04	8		
	CURRENT	11	0.32	1.28	6	1.41	5.60	6		
	CURRENT	13	0.00	0.01	8	0.00	0.01	8		
	CURRENT	23	0.00	0.01	8	0.00	0.00	8		
	CURRENT	25	0.00	0.00	8	0.00	0.01	8		

NONLINEAR DEVICE PARAMETERS
BUS= 8, TYPE= PS, PQ= 0.00, GG= 0.00, PL= 20.00, GL= 11.95, DELAY= 27.08, R= 25.00, E= 73.60, COM= 7.25, CIT= 1

14	POWER		0.00	0.00	2	0.00	0.01	2	0.00	0.00
	CURRENT	1	0.03	0.03	8	0.01	0.01	8		

```
        CURRENT    11            0.65    2.60     6         0.14    0.58      6
        CURRENT    13            0.00    0.00     8         0.00    0.00      8
        CURRENT    23            0.00    0.00     8         0.00    0.00      8
        CURRENT    25            0.00    0.00     8         0.00    0.00      8

NONLINEAR DEVICE PARAMETERS
BUS=   8, TYPE= PS, PG=   0.00, GG=   0.00, PL=  20.00, GL=  11.95, DELAY=  27.07, R=  25.00, E=  73.60, COM=   7.26, CIT= 1

   15   POWER                   0.00    0.00     7         0.00    0.00      8         0.00    0.00       8

        CURRENT     1            0.00    0.00     8         0.00    0.00      8
        CURRENT    11            0.04    0.15     6         0.12    0.47      6
        CURRENT    13            0.00    0.00     8         0.00    0.00      8
        CURRENT    23            0.00    0.00     8         0.00    0.00      8
        CURRENT    25            0.00    0.00     8         0.00    0.00      8

NONLINEAR DEVICE PARAMETERS
BUS=   8, TYPE= PS, PG=   0.00, GG=   0.00, PL=  20.00, GL=  11.94, DELAY=  27.05, R=  25.00, E=  73.61, COM=   7.26, CIT= 1

   16   POWER                   0.00    0.01     2         0.00    0.00      3         0.00    0.00       0

        CURRENT     1            0.01    0.01     8         0.00    0.00      8
        CURRENT    11            0.00    0.01     6         0.00    0.00      6
        CURRENT    13            0.00    0.00     8         0.00    0.00      8
        CURRENT    23            0.00    0.00     8         0.00    0.00      8
        CURRENT    25            0.00    0.00     8         0.00    0.00      8

NONLINEAR DEVICE PARAMETERS
BUS=   8, TYPE= PS, PG=   0.00, GG=   0.00, PL=  20.00, GL=  11.94, DELAY=  27.05, R=  25.00, E=  73.61, COM=   7.26, CIT= 1

   17   POWER                   0.00    0.00     7         0.00    0.01      2         0.00    0.00       0

        CURRENT     1            0.00    0.00     8         0.00    0.00      8
        CURRENT    11            0.00    0.00     8         0.00    0.00      8
        CURRENT    13            0.00    0.00     8         0.00    0.00      8
        CURRENT    23            0.00    0.00     8         0.00    0.00      8
        CURRENT    25            0.00    0.00     8         0.00    0.00      8
```

FUNDAMENTAL LOADFLOW OUTPUT   (PERCENT VOLTAGE, POWER)

FROM BUS	NAME	VOLTAGE	ANGLE	PG	GG	PL	QL	Q SHUNT	TO BUS	NAME	P	Q	TAP
1	SWING	105.00	0.00	72.03	-60.93	0.00	0.00	0.00					
									2	BUS 2	72.03	-60.93	
2	BUS 2	105.26	-0.20	0.00	0.00	0.00	0.00	-110.79					
									1	SWING	-71.99	61.33	
									3	BUS 3	71.99	49.46	1.000
3	BUS 3	104.87	-0.51	0.00	0.00	0.00	0.00	0.00					
									2	BUS 2	-71.99	-48.88	
									4	BUS 4	71.99	48.59	
4	BUS 4	102.10	-1.70	0.00	0.00	20.00	12.40	0.00					
									3	BUS 3	-71.06	-46.15	
									5	BUS 5	51.06	33.75	

5	BUS 5	100.12	-2.58	0.00	0.00	10.00	6.20	0.00				
									4	BUS 4	-50.57	-32.33
									6	BUS 6	40.57	26.13
6	BUS 6	98.53	-3.31	0.00	0.00	10.00	6.20	0.00				
									5	BUS 5	-40.26	-25.21
									7	BUS 7	30.26	19.01
7	BUS 7	97.35	-3.88	0.00	0.00	10.00	6.20	0.00				
									6	BUS 6	-30.08	-18.50
									8	BUS 8	20.08	12.30
8	BUS 8	96.57	-4.27	0.00	0.00	20.01	12.08	0.00				
									7	BUS 7	-20.00	-12.08

REAL POWER LOSS FOR THIS HARMONIC =   2.02

HARMONIC LOADFLOW OUTPUT FOR HARMONIC NUMBER 11, FREQUENCY =   550 HZ. (PERCENT VOLTAGE, CURRENT, POWER)

FROM		---- VOLTAGE ----		TO				---- CURRENT ----		
BUS	NAME	MAGNITUDE	ANGLE	BUS	NAME	P	Q	MAGNITUDE	ANGLE	TAP
1	SWING	0.5093	65.15							
				2	BUS 2	0.000000	-0.047152	9.259103	155.15	
				NEUT	Z SHUNT	0.000000	0.047152	9.259097	-24.85	
2	BUS 2	1.0185	64.89							
				1	SWING	0.000429	0.094304	9.259103	-24.85	
				3	BUS 3	-0.000429	0.019806	1.945072	-26.35	
										1.000
				NEUT	Q SHUNT	0.000000	-0.114110	11.203633	154.89	
3	BUS 3	0.8403	65.15							
				2	BUS 2	0.000429	-0.016340	1.945072	153.65	
				4	BUS 4	-0.000429	0.016340	1.945074	-26.35	
4	BUS 4	0.0502	168.96							
				3	BUS 3	0.000942	0.000258	1.945620	153.65	
				5	BUS 5	-0.000942	-0.000258	1.945620	-26.35	
5	BUS 5	0.8698	-121.28							
				4	BUS 4	0.001454	0.016854	1.945040	153.65	
				6	BUS 6	-0.001454	-0.016854	1.945039	-26.35	
6	BUS 6	1.7223	-119.72							
				5	BUS 5	0.001967	0.033412	1.943332	153.65	
				7	BUS 7	-0.001967	-0.033412	1.943335	-26.35	
7	BUS 7	2.5743	-119.19							
				6	BUS 6	0.002478	0.049892	1.940503	153.66	
				8	BUS 8	-0.002478	-0.049892	1.940505	-26.34	
8	BUS 8	3.4249	-118.92							
				7	BUS 7	0.002987	0.066257	1.936550	153.66	
				NEUT	NONLIN DEV.	-0.002992	-0.066259	1.936612	-26.33	

REAL POWER LOSS FOR THIS HARMONIC =   0.00

HARMONIC LOADFLOW OUTPUT FOR HARMONIC NUMBER 13, FREQUENCY =   650 HZ   (PERCENT VOLTAGE, CURRENT, POWER)

FROM		---- VOLTAGE ----		TO				---- CURRENT ----		
BUS	NAME	MAGNITUDE	ANGLE	BUS	NAME	P	Q	MAGNITUDE	ANGLE	TAP

1	SWING	0.1163	-3.50							
				2	BUS 2	0.000000	-0.002080	1.789048	66.50	
				NEUT	Z SHUNT	0.000000	0.002080	1.789048	-93.50	
2	BUS 2	0.2326	-3.72							
				1	SWING	0.000016	0.004161	1.789048	-93.50	
				3	BUS 3	-0.000016	0.002871	1.234497	-94.04	
										1.000
				NEUT	Q SHUNT	0.000000	-0.007032	3.023516	66.28	
3	BUS 3	0.0989	-3.29							
				2	BUS 2	0.000016	-0.001221	1.234497	85.96	
				4	BUS 4	-0.000016	0.001221	1.234498	-94.04	
4	BUS 4	0.5413	174.05							
				3	BUS 3	0.000223	0.006677	1.234153	85.96	
				5	BUS 5	-0.000223	-0.006677	1.234154	-94.04	
5	BUS 5	1.1810	174.27							
				4	BUS 4	0.000429	0.014553	1.232811	85.96	
				6	BUS 6	-0.000429	-0.014553	1.232811	-94.04	
6	BUS 6	1.8197	174.34							
				5	BUS 5	0.000634	0.022382	1.230472	85.97	
				7	BUS 7	-0.000634	-0.022382	1.230473	-94.03	
7	BUS 7	2.4569	174.37							
				6	BUS 6	0.000839	0.030138	1.227139	85.97	
				8	BUS 8	-0.000839	-0.030138	1.227142	-94.03	
8	BUS 8	3.0922	174.40							
				7	BUS 7	0.001043	0.037797	1.222815	85.98	
				NEUT	NONLIN DEV	-0.001048	-0.037801	1.222939	-94.02	

REAL POWER LOSS FOR THIS HARMONIC =   0.00

HARMONIC LOADFLOW OUTPUT FOR HARMONIC NUMBER 23, FREQUENCY =   1150 HZ   (PERCENT VOLTAGE, CURRENT, POWER)

FROM		---- VOLTAGE ----		TO				---- CURRENT ----		
BUS	NAME	MAGNITUDE	ANGLE	BUS	NAME	P	Q	MAGNITUDE	ANGLE	TAP

1	SWING	0.0162	1.89							
				2	BUS 2	0.000000	-0.000023	0.141092	91.89	
				NEUT	Z SHUNT	0.000000	0.000023	0.141092	-88.11	
2	BUS 2	0.0325	1.76							
				1	SWING	0.000000	0.000046	0.141092	-88.11	
				3	BUS 3	0.000000	0.000196	0.605286	-88.27	
										1.000
				NEUT	Q SHUNT	0.000000	-0.000242	0.746378	91.76	
3	BUS 3	0.0835	-178.28							
				2	BUS 2	0.000000	0.000506	0.605286	91.73	
				4	BUS 4	0.000000	-0.000506	0.605286	-88.27	

```
------------------------------------------------------------------------------------------------------------
   4  BUS 4          0.6385 -179.00
                                      3  BUS 3           0.000050      0.003858      0.604290    91.73
                                      5  BUS 5          -0.000050     -0.003858      0.604290   -88.27
------------------------------------------------------------------------------------------------------------
   5  BUS 5          1.1919 -179.05
                                      4  BUS 4           0.000099      0.007172      0.601764    91.74
                                      6  BUS 6          -0.000099     -0.007172      0.601763   -88.26
------------------------------------------------------------------------------------------------------------
   6  BUS 6          1.7423 -179.07
                                      5  BUS 5           0.000148      0.010413      0.597715    91.74
                                      7  BUS 7          -0.000148     -0.010413      0.597714   -88.26
------------------------------------------------------------------------------------------------------------
   7  BUS 7          2.2882 -179.08
                                      6  BUS 6           0.000196      0.013549      0.592153    91.75
                                      8  BUS 8          -0.000196     -0.013548      0.592150   -88.25
------------------------------------------------------------------------------------------------------------
   8  BUS 8          2.8284 -179.08
                                      7  BUS 7           0.000243      0.016547      0.585090    91.76
                                   NEUT  NONLIN DEV.    -0.000244     -0.016546      0.585052   -88.24
------------------------------------------------------------------------------------------------------------
REAL POWER LOSS FOR THIS HARMONIC =        0.00
------------------------------------------------------------------------------------------------------------
```

HARMONIC LOADFLOW OUTPUT FOR HARMONIC NUMBER 25, FREQUENCY = 1250 HZ. (PERCENT VOLTAGE, CURRENT, POWER)

FROM		---- VOLTAGE ----		TO				---- CURRENT ----		
BUS	NAME	MAGNITUDE	ANGLE	BUS	NAME	P	Q	MAGNITUDE	ANGLE	TAP

```
------------------------------------------------------------------------------------------------------------
   1  SWING          0.0124  -67.22
                                      2  BUS 2           0.000000     -0.000012      0.099027    22.78
                                   NEUT  Z SHUNT         0.000000      0.000012      0.099027  -157.22
------------------------------------------------------------------------------------------------------------
   2  BUS 2          0.0248  -67.33
                                      1  SWING           0.000000      0.000025      0.099027  -157.22
                                      3  BUS 3           0.000000      0.000129      0.519895  -157.36     1.000
                                   NEUT  G SHUNT         0.000000     -0.000153      0.618922    22.67
------------------------------------------------------------------------------------------------------------
   3  BUS 3          0.0835  112.64
                                      2  BUS 2           0.000000      0.000434      0.519895    22.64
                                      4  BUS 4           0.000000     -0.000434      0.519895  -157.36
------------------------------------------------------------------------------------------------------------
   4  BUS 4          0.6016  111.97
                                      3  BUS 3           0.000037      0.003121      0.516867    22.64
                                      5  BUS 5          -0.000037     -0.003121      0.516867  -157.36
------------------------------------------------------------------------------------------------------------
   5  BUS 5          1.1180  111.92
                                      4  BUS 4           0.000073      0.005771      0.516288    22.65
                                      6  BUS 6          -0.000073     -0.005771      0.516288  -157.35
------------------------------------------------------------------------------------------------------------
   6  BUS 6          1.6309  111.91
                                      5  BUS 5           0.000109      0.008352      0.512165    22.65
                                      7  BUS 7          -0.000109     -0.008352      0.512166  -157.35
------------------------------------------------------------------------------------------------------------
   7  BUS 7          2.1391  111.90
                                      6  BUS 6           0.000144      0.010834      0.506511    22.66
                                      8  BUS 8          -0.000144     -0.010834      0.506511  -157.34
------------------------------------------------------------------------------------------------------------
   8  BUS 8          2.6408  111.90
```

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                           7   BUS 7          0.000178      0.013185      0.499342    22.67
                         NEUT  NONLIN DEV.   -0.000176     -0.013183      0.499244  -157.34
-------------------------------------------------------
REAL POWER LOSS FOR THIS HARMONIC =      0.00
-------------------------------------------------------
TOTAL REAL POWER LOSS =                   2.03
-------------------------------------------------------------------------------------------------------
```

TOTAL CURRENT/POWER SUMMARY   (PERCENT VALUES)

FROM BUS	NAME	TO BUS	NAME	CURRENT FUND VALUE	RMS VALUE	PEAK VALUE	HARMONIC DISTORTION	POWER P	Q	D	S
1	SWING	2	BUS 2	89.85	90.34	99.38	10.44	72.03	-60.98	9.61	94.56
2	BUS 2	1	SWING	89.85	90.34	99.38	10.44	-71.99	61.43	9.35	95.09
2	BUS 2	3	BUS 3	82.98	83.02	82.20	2.94	71.99	49.48	2.26	87.35
2	BUS 2	NEUT	Q SHUNT	105.26	105.90	116.64	11.90	0.00	-110.91	11.16	111.47
3	BUS 3	2	BUS 2	82.98	83.02	82.20	2.94	-71.99	-48.90	2.34	87.06
3	BUS 3	4	BUS 4	82.98	83.02	82.20	2.94	71.99	48.90	2.34	87.06
4	BUS 4	3	BUS 3	82.99	83.02	82.21	2.94	-71.06	-46.14	2.67	84.77
4	BUS 4	5	BUS 5	59.95	60.00	59.16	4.06	51.06	33.73	2.77	61.26
5	BUS 5	4	BUS 4	59.95	60.00	59.17	4.06	-50.57	-32.28	3.28	60.07
5	BUS 5	6	BUS 6	48.20	48.26	47.57	5.05	40.57	26.08	3.09	48.33
6	BUS 6	5	BUS 5	48.21	48.27	47.58	5.04	-40.26	-25.14	3.54	47.57
6	BUS 6	7	BUS 7	36.27	36.35	35.88	6.69	30.26	18.94	3.21	35.84
7	BUS 7	6	BUS 6	36.28	36.36	35.89	6.67	-30.08	-18.40	3.55	35.44
7	BUS 7	8	BUS 8	24.19	24.31	24.07	9.97	20.08	12.20	3.10	23.70
8	BUS 8	7	BUS 7	24.20	24.32	24.07	9.94	-20.00	-11.94	3.31	23.53
8	BUS 8	NEUT	NONLIN DEV.	24.20	24.32	24.07	9.94	20.00	11.94	3.31	23.53

BUS VOLTAGE SUMMARY   (PERCENT VALUES)

BUS	NAME	FUNDAMENTAL VALUE	RMS VALUE	PEAK VALUE	HARMONIC DISTORTION
1	SWING	105.00	105.00	105.03	0.50
2	BUS 2	105.26	105.26	105.54	0.99
3	BUS 3	104.87	104.87	104.94	0.81
4	BUS 4	102.10	102.10	102.20	1.01
5	BUS 5	100.12	100.14	100.93	2.19
6	BUS 6	98.53	98.59	100.13	3.51
7	BUS 7	97.35	97.47	99.76	4.86
8	BUS 8	96.57	96.76	99.83	6.22

END OF RUN
**** STOP

OK, COMO -E

ภาคผนวก ญ

โปรแกรมวิเคราะห์การไหลของกำลังไฟฟ้าฮาร์มอนิก
ที่เกิดจากเครื่องแปลงผัน

```
C
C
C
C    HARMONIC POWER FLOW PROGRAM
C    *** HARMONIC ***
C
C    -------------
C    MAIN PROGRAM
C    -------------
C
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50).
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      OPEN  (5, FILE= 'DATA.TXT', STATUS= 'OLD')
      CMPZERO  = CMPLX(0.0,0.0)
      CMPONE   = CMPLX(1.0,0.0)
      PI       = 3.1415927
      DR       = 180.0 / PI
      R30      = PI / 6.0
      R60      = PI / 3.0
      R90      = PI / 2.0
      R120     = 2.0 * PI / 3.0
      R360     = 2.0 * PI
      COS30    = COS(R30)
      SIN30    = SIN(R30)
      TRUE     = .TRUE.
      FALSE    = .FALSE.
      TERMINAL = .FALSE.
      CODE3    = .FALSE.
      CODE4    = .FALSE.
      CODE5    = .FALSE.
      CODE6    = .FALSE.
      CODE7    = .FALSE.
      CSWING   = .FALSE.
      ZOURCE   = .FALSE.
      GPATH    = .FALSE.
      NOERR    = 0
      NOERMAX = 20
      MXFITER = 20
      NTYPES  = 3
      NSUBS   = 7
      NTRMAX  = 9
      MXHITER = 30
      NSHMAX  = 2
      EP4      = 1.0E-04
      EP6      = 1.0E-06
      EP3      = 1.0E-03
      EP9      = 1.0E-09
      SUBNAME(1) = 'SW'
      SUBNAME(2) = 'PV'
      SUBNAME(3) = 'PQ'
```

```
          SUBNAME(4) = 'PS'
          SUBNAME(5) = 'PA'
          SUBNAME(6) = 'EA'
          MAXNB    = 20
          MAXLINE  = 50
          MAXHAR   = 9
          MAXAJAC  = 368
          MBHUSE   = 100
          MAXHMP   = 49
          TOLE     = EP4
          COMTOLE  = EP4
          F2TOLE   = EP4
          DEPART   = EP3
C
          DO 11 L        = 1,MAXNB
          KTRCON(L)      = 0
          KSHTYPE(L)     = 0
          PATHBTS(L)     = FALSE
          COM(L)         = 0.0
          DELAY(L)       = 0.0
          RCONV(L)       = 0.0
     11 ECONV(L)         = 0.0
C
          DO 12 L        = 1,MAXLINE
          KTRTYPE(L)     = 0
     12 KSHAR(L)         = 0
C
          DO 13 L        = 1,MAXHAR
          DO 13 L1       = 1,MAXNB
          GR(L1,L)       = 0.0
          GI(L1,L)       = 0.0
          DO 13 L2       = 1,MAXNB
     13 YBUS(L1,L2,L)=   CMPZERO
C
          DO 14 L1       = 1,MAXAJAC
          DO 14 L2       = 1,MAXAJAC
     14 AJAC(L1,L2)      = 0.0
C
          DO 15 L        = 1,MBHUSE
     15 NBINT(L)         = 0
C
          DO 16 L        = 1,MAXHMP
     16 MHVECT(L)        = 0
C
          DO 17 L        = 1,14
     17 IOPT(L)          = 0
C
          WRITE (*,30)
     30 FORMAT(//,2X,'HARMONIC   POWER   FLOW   PROGRAM   (1988)',
        1///,2X,
        2'WATSON    CHANSAJCHA             PROGRAMMER',/,2X,
        3'ASST. PROF. PRASIT PITTAYAPAT    ADVISOR',///,2X,
        4'ENERGY SYSTEM RESEARCH LABORATORY',/,2X,
        5'ELECTRICAL ENGINEERING DEPARTMENT',/,2X,
        6'CHULALONGKORN UNIVERSITY')
          WRITE (*,32)
C
      1 READ   (5,1000)ICODE
          ISDUM1 = ICODE
          IF(ICODE .LT. 1 .OR. ICODE .GT. 8)GO TO 2000
          GO TO (100,200,300,400,500,600,700,800), ICODE
   2000 CALL ERROR(1)
          GO TO 1
    100 READ   (5,1002)TITLE
          WRITE (*,1006)TITLE
          GO TO 1
    200 READ   (5,1002)COMMENT
          WRITE (*,1006)COMMENT
          WRITE (*,32)
          GO TO 1
    300 IF(CODE3) CALL ERROR(5)
          CODE3 = TRUE
          CALL LBUSDATA
          CALL ORDER
          GO TO 1
    400 IF(.NOT. CODE3)CALL ERROR(22)
          IF(CODE4) CALL ERROR(6)
          CODE4 = TRUE
          CALL LINEDATA
          GO TO 1
    500 READ   (5,1004)(IOPT(I),I=1,14)
          WRITE (*,32)
          CALL PGHEAD(4)
          WRITE (*,1008)(J,J = 1,14),IOPT
          IF(.NOT.CODE4) CALL ERROR(47)
          IF (NNLIN .EQ. 0) GO TO 502
          LMIN      = NLIN + 1
          DO 501 L = LMIN,NB
          IF (KTRCON(L) .NE. 0) GO TO 501
          ISDUM1    = NBEXT(L)
```

```
         CALL ERROR(19)
501 CONTINUE
502 ISDUM1   = 2 * NB
         IF (MAXAJAC .LT. ISDUM1) CALL ERROR(49)
         IF (.NOT. TERMINAL) GO TO 510
         WRITE (*,1010)
         STOP
510 CALL HARBUILD
         CALL YBUILD
         CALL HARSTART(0)
         KIT = 0
         CALL PGHEAD(7)
         CALL CONVERGE(1,KIT)
         IF(IOPT(4) .GT. 0)MXFITER = IOPT(4)
         DO 520 KIT = 1,MXFITER
         CALL JABUILD(1)
         CALL REDUCE(1,KIT)
         CALL CONVERGE(1,KIT)
         IF(CONV) GO TO 530
520 CONTINUE
         CALL ERROR(32)
530 IF(IOPT(5) .EQ. 0) CALL OUTPUT(1)
         IF(IOPT(1) .NE. 0)GO TO 1
         IF(NNLIN .EQ. 0)CALL ERROR(43)
         ISDUM1 = 2 * (NB * NOHAR + NNLIN)
         IF(MAXAJAC .LT. ISDUM1)CALL ERROR(55)
         IF(IOPT(2) .EQ. 0 .OR. IOPT(2) .EQ. 1)GO TO 535
         IF(.NOT. ZOURCE .AND. NOHAR .GT. 1)CALL ERROR(53)
535 IF(.NOT. GPATH)CALL ERROR(84)
         IF(.NOT. TERMINAL)GO TO 550
         WRITE (*,1010)
         GO TO 1
550 ACCEL = 1.0 + FLOAT(IOPT(10)) / 10.0
         IF(ACCEL .GT. 1.5)ACCEL = 1.5
         IF(ACCEL .LT. 0.5)ACCEL = 0.5
         MIN = NLIN + 1
         IF(IOPT(13) .EQ. 0 .OR. NOHAR .EQ. 1)GO TO 565
         DO 551 M = MIN,NB
551 CALL LOADI(M,1,0)
         CALL HARSTART(1)
565 KIT = 0
         CALL PGHEAD(8)
         KFUND = 2
         IF(IOPT(14) .NE. 0)KFUND = 1
         WRITE (*,1014)
         DO 566 M = MIN,NB
         CALL LOADI(M,KFUND,1)
         AANG = DELAY(M) * DR
         CANG = COM(M) * DR
         IF(NBTYPE(M) .LE. 2)WRITE(*,1012)NBEXT(M),SUBNAME(NBSUBT(M)),PG(M)
     1,QG(M),PL(M),QL(M),AANG,RCONV(M),ECONV(M),CANG,ITERCOM
         IF(NBTYPE(M) .EQ. 3)WRITE(*,1018)NBEXT(M),SUBNAME(NBSUBT(M)),PG(M)
     1,QG(M),PL(M),QL(M)
566 CONTINUE
         WRITE (*,1016)
         CALL CONVERGE(2,KIT)
         IF(TERMINAL)GO TO 580
         IF(IOPT(6) .GT. 0)MXHITER = IOPT(6)
         DO 570 KIT = 1,MXHITER
         CALL JABUILD(2)
         CALL LOADPAR(KFUND)
         CALL REDUCE(2,KIT)
         WRITE (*,1014)
         DO 571 M = MIN,NB
         CALL LOADI(M,KFUND,1)
         AANG = DELAY(M) * DR
         CANG = COM(M) * DR
         IF(NBTYPE(M) .LE. 2)WRITE(*,1012)NBEXT(M),SUBNAME(NBSUBT(M)),PG(M)
     1,QG(M),PL(M),QL(M),AANG,RCONV(M),ECONV(M),CANG,ITERCOM
         IF(NBTYPE(M) .EQ. 3)WRITE(*,1018)NBEXT(M),SUBNAME(NBSUBT(M)),PG(M)
     1,QG(M),PL(M),QL(M)
571 CONTINUE
         WRITE (*,1016)
         CALL CONVERGE(2,KIT)
         IF(CONV .OR. TERMINAL)GO TO 580
         CALL PQMOD(KFUND)
570 CONTINUE
         CALL ERROR(44)
580 DO 572 M = MIN,NB
         IF(NBTYPE(M) .GT. 2)GO TO 572
         ANG     = DELAY(M) + COM(M)
         ISDUM1 = NBEXT(M)
         EDUM1   = ANG * DR
         EDUM2   = R120 * DR
         IF(NBTYPE(M) .EQ. 1 .AND. ANG .GT. R120)CALL ERROR(58)
         EDUM2   = PI * DR
         IF(NBTYPE(M) .EQ. 2 .AND. ANG .GT. PI)CALL ERROR(58)
572 CONTINUE
         CALL OUTPUT(2)
         IF(NOHAR .NE. 1)CALL SUMMARY
```

```
      IF(TERMINAL .OR. IOPT(14) .NE. 2)GO TO 1
      IOPT(14) = 0
      GO TO 565
  600 IF(.NOT.CODE3)CALL ERROR(15)
      IF(CODE6) CALL ERROR(16)
      CODE6 = TRUE
      IF(NNL1 .EQ. 0)CALL ERROR(21)
      CALL NL1DATA
      GO TO 1
  700 IF(.NOT.CODE3) CALL ERROR(15)
      IF(CODE7) CALL ERROR(37)
      CODE7 = TRUE
      IF(NNL2 .EQ. 0)CALL ERROR(21)
      CALL NL2DATA
      GO TO 1
  800 WRITE (*,1020)
      CLOSE (5)
      STOP
   32 FORMAT(1X,130(1H-))
 1000 FORMAT(I4)
 1002 FORMAT(A80)
 1004 FORMAT(28I2)
 1006 FORMAT(/1X,A80)
 1008 FORMAT(1X,'OPTION NUMBER',1X,14I5//1X,'OPTION VALUE',2X,14I5)
 1010 FORMAT(//1X,'DUE TO PREVIOUS ERRORS, SOLUTION WILL NOT BE '
     1'ATTEMPTED'/)
 1012 FORMAT(1X,'BUS=',I4,', TYPE=',A4,', PG=',2PF8.2,', QG=',F8.2,
     1', PL=',F8.2,', QL=',F8.2,', DELAY=',OPF7.2,', R=',2PF8.2,
     2', E=',F8.2,', COM=',OPF7.2,', CIT=',I2)
 1014 FORMAT(1X,'NONLINEAR DEVICE PARAMETERS')
 1016 FORMAT(1X)
 1018 FORMAT(1X,'BUS=',I4,', TYPE=',A4,', PG=',2PF8.2,', QG=',F8.2,
     1', PL=',F8.2,', QL=',F8.2)
 1020 FORMAT(/1X,'END OF RUN')
      END
```

```
C
        FUNCTION AMP2(M,ANGL,ALPHA,KFUND)
        COMPLEX YBUS, CMPZERO, CMPONE
        LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
       1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
        CHARACTER * 2 SUBNAME
        CHARACTER * 12 BUSNAME, BTEMPN
        CHARACTER * 80 TITLE, COMMENT
        COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
        COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
       1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
       2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
       3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
       4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
       5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
       6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
       7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
       8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
       9HPEAK, ACCEL
        COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
        COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
       1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
       2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
       3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
       4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
       5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
       6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
        COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
       1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
        AMP2 = AK3 * EXP(P2 * (ANGL - ALPHA))
       1        + FA2(M,ANGL,0.0,KFUND) - ER
        RETURN
        END
C
        SUBROUTINE COMANGLE(M,ALPHA,KFUND)
        COMPLEX YBUS, CMPZERO, CMPONE
        LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
       1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
        CHARACTER * 2 SUBNAME
        CHARACTER * 12 BUSNAME, BTEMPN
        CHARACTER * 80 TITLE, COMMENT
        COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
        COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
       1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
       2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
       3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
       4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
       5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
       6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
       7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
       8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
       9HPEAK, ACCEL
        COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
        COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
       1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
       2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
       3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
       4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
       5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
       6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
        COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
       1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
        CANG   = COM(M)
        E2R    = ER / 2.0
        A      = E2R - FA1(M,ALPHA,0.0,KFUND)
        B      = FA2(M,ALPHA,R60,KFUND) - FC1(M,ALPHA,0.0,KFUND) - E2R
        C      = A + B
        D      = -EXP(P2 * R60)
        G      = B - A - ER
        ISDUM1 = NBEXT(M)
        IF(IOPT(9) .NE. 0)WRITE (*,1000)ISDUM1,KFUND,ITERCOM,E2R,A,B,C,D,G
       1 H1     = EXP(P1 * CANG)
        H2     = EXP(P2 * CANG)
        ANG    = ALPHA + CANG
        FDUM1  = FA1(M,ANGL,0.0,KFUND) - FA2(M,ANGL,0.0,KFUND)
        FDUM2  = FC1(M,ANGL,0.0,KFUND)
        FUN1   = (D - H2) * AK3 + FDUM1 - FDUM2 - G
        FUN2   = -(H2 + D * H1) * AK3 + FDUM1 + FDUM2 + C * H1
        IF(IOPT(9) .NE. 0)WRITE (*,1000)ISDUM1,KFUND,ITERCOM,AK3,CANG
       1,FUN1,FUN2
        IF(ABS(FUN1) .LT. COMTOLE .AND. ABS(FUN2) .LT. COMTOLE)GO TO 10
        FA1P   = FA1PRI(M,ANGL,KFUND)
        FC1P   = FC1PRI(M,ANGL,KFUND)
        FA2P   = FA2PRI(M,ANGL,KFUND)
        F1PRI  = FA1P - FC1P - FA2P
        F2PRI  = FA1P + FC1P - FA2P
        AJ11   = D - H2
        AJ12   = -AK3 * P2 * H2 + F1PRI
```

```
      AJ21   = -(H2 + D * H1)
      AJ22   = -(P2 * H2 + D * P1 * H1) * AK3 + P1 * C * H1 + F2PRI
      DET    = AJ11 * AJ22 - AJ12 * AJ21
      AK3    = AK3 - (AJ22 * FUN1 - AJ12 * FUN2) / DET
      CANG   = CANG - (-AJ21 * FUN1 + AJ11 * FUN2) / DET
      COM(M) = CANG
      EDUM3  = CANG * DR
      ITERCOM= ITERCOM + 1
      IF(ITERCOM .LT. 10)GO TO 1
      EDUM1  = FUN1
      EDUM2  = FUN2
      CALL ERROR(48)
      GO TO 20
   10 IF(CANG .GE. 0.0 .AND. CANG .LE. R60)GO TO 30
      CALL MESSAGE(3)
      IF(CANG .LT. 0.0)CANG = 0.0
      IF(CANG .GT. R60)CANG = R60
      COM(M) = CANG
   20 WRITE (*,1002)ISDUM1
      DO 21 LHAR = 1,NOHAR
      MPOS = 2 * M + 2 * (LHAR - 1) * NB
      VOLTM = X(MPOS)
      ANGM  = X(MPOS - 1) / VOLTM * DR
      WRITE (*,1004)NHVECT(LHAR),VOLTM,ANGM
   21 CONTINUE
   30 AK1    = (A - B + D * AK3) / 2.0
      AK2    = A - AK1
      IF(IOPT(9) .NE. 0)WRITE (*,1000)ISDUM1,KFUND,ITERCOM,AK1,AK2,AK3
 1000 FORMAT(/1X,'COMANGLE',3I5,6E15.6)
 1002 FORMAT(/1X,'DUE TO APPARENT PROBLEMS IN THE SOLUTION FOR THE'
     1,' COMMUTATION ANGLE AT BUS ',I5,', THE APPLIED VOLTAGES ARE'
     2,' LISTED.'/1X,'HARMONIC',5X,'VOLTAGE MAGNITUDE',5X,'VOLTAGE'
     3,' ANGLE')
 1004 FORMAT(1X,I8,2PF22.4,0PF18.2)
      RETURN
      END
C
      SUBROUTINE CONVERGE(KFUND,KIT)
      COMPLEX YB
      LOGICAL PV,PS
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PQ(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      CONV   = FALSE
      PWORST = 0.0
      PAVG   = 0.0
      KPBUS  = 0
      KP     = 0
      QWORST = 0.0
      QAVG   = 0.0
      KQBUS  = 0
      KPQ    = 0
      SWORST = 0.0
      SAVG   = 0.0
      KSBUS  = 0
      KS     = 0
      IF(KFUND .EQ. 1)LMAX = 1
      IF(KFUND .EQ. 2)LMAX = NOHAR
      DO 1 K1 = 1,NB
      PK1    = 0.0
      QK1    = 0.0
      VRMS   = 0.0
      ARMS   = 0.0
      PV     = FALSE
      PS     = FALSE
```

```
         IF(NBSUBT(K1) .EQ. 1 .OR. NBSUBT(K1) .EQ. 2)PV = TRUE
         IF(KFUND .EQ. 1)GO TO 20
         IF(NBSUBT(K1) .EQ. 4)PS = TRUE
   20 DO 6 L = 1,LMAX
         CR       = 0.0
         CI       = 0.0
         K1POS    = 2 * K1 + 2 * (L - 1) * NB
         VOLTK1   = X(K1POS)
         ANGK1    = X(K1POS - 1) / VOLTK1
         DO 2 K2= 1,NB
         YB       = YBUS(K1,K2,L)
         YMAG     = CABS(YB)
         IF(YMAG .LT. TOLE)GO TO 2
         YANG     = ATAN2(AIMAG(YB),DBLE(YB))
         K2POS    = 2 * K2 + 2 * (L - 1) * NB
         VOLTK2   = X(K2POS)
         ANGK2    = X(K2POS - 1) / VOLTK2
         ANGT     = ANGK1 - ANGK2 - YANG
         IF(K1 .LE. NLIN .AND. L .GT. 1)GO TO 100
         IF(IOPT(14) .NE. 0 .AND. L .GT. 1)GO TO 100
         PK1 = PK1 + VOLTK1 * VOLTK2 * YMAG * COS(ANGT)
         QK1 = QK1 + VOLTK1 * VOLTK2 * YMAG * SIN(ANGT)
  100 IF(KFUND .EQ. 1)GO TO 2
         CR = CR + VOLTK2 * YMAG * COS(ANGK2 + YANG)
         CI = CI + VOLTK2 * YMAG * SIN(ANGK2 + YANG)
    2 CONTINUE
         IF(KFUND .EQ. 1)GO TO 6
         IF(L .EQ. 1 .AND. K1 .LE. NLIN)GO TO 6
         IF(L .EQ. 1)K3POS = 2 * (NB * NOHAR + (K1 - NLIN))
         IF(L .GT. 1)K3POS = 2 * (NB * (L - 1) + K1)
         DELTAY(K3POS - 1) = CR + GR(K1,L)
         DELTAY(K3POS)     = CI + GI(K1,L)
         IF(IOPT(14) .NE. 0 .AND. L .GT. 1)GO TO 6
         VRMS = VRMS + VOLTK1 * VOLTK1
         ARMS = ARMS + CR * CR + CI * CI
    6 CONTINUE
         DELTAY(2 * K1 - 1) = 0.0
         DELTAY(2 * K1) = 0.0
         IF(K1 .NE. 1)GO TO 25
         PQ(1) = PK1 + PL(1)
         QG(1) = QK1 + QL(1)
         GO TO 1
   25 KP      = KP + 1
         PMIS = PK1 -Y(2 * K1 -1)
         DELTAY(2 * K1 -1) = PMIS
         PMIS = ABS(PMIS)
         PAVG = PAVG + PMIS
         IF(PMIS .LT. PWORST)GO TO 21
         PWORST = PMIS
         KPBUS   = NBEXT(K1)
   21 IF(.NOT. PV)GO TO 22
         QG(K1) = QK1 + QL(K1)
         GO TO 1
   22 KPQ     = KPQ + 1
         QMIS = QK1 - Y(2 * K1)
         DELTAY(2 * K1) = QMIS
         QMIS = ABS(QMIS)
         QAVG = QAVG + QMIS
         IF(QMIS .LT. QWORST)GO TO 1
         QWORST = QMIS
         KQBUS   = NBEXT(K1)
         IF(.NOT. PS)GO TO 1
         KS      = KS + 1
         SNET    = SQRT(VRMS * ARMS)
         SMIS    = ABS(SNET - S(K1))
         SAVG    = SAVG + SMIS
         IF(SMIS .LT. SWORST)GO TO 1
         SWORST = SMIS
         KSBUS   = NBEXT(K1)
    1 CONTINUE
         IF(KP .GT. 1)PAVG = PAVG / FLOAT(KP)
         IF(KPQ .GT. 1)QAVG = QAVG / FLOAT(KPQ)
         IF(KFUND .NE. 1)GO TO 50
         WRITE (*,1000)KIT,PAVG,PWORST,KPBUS,QAVG,QWORST,KQBUS
         IF(PWORST .LT. TOLE .AND. QWORST .LT. TOLE)CONV = TRUE
         RETURN
   50 IF(KS .GT. 1)SAVG = SAVG / FLOAT(KS)
         WRITE (*,1002)KIT,PAVG,PWORST,KPBUS,QAVG,QWORST,KQBUS,
       1SAVG,SWORST,KSBUS
         WRITE (*,1000)
         CRWORS = 0.0
         CIWORS = 0.0
         DO 13 L1 = 1,NOHAR
         CRBAD  = 0.0
         CIBAD  = 0.0
         CRAVG  = 0.0
         CIAVG  = 0.0
         KCRBUS = 0
         KCIBUS = 0
         KC     = 0
```

```
      K1MIN  = 1
      IF(L1 .EQ. 1)K1MIN = NLIN + 1
      DO 14 K1 = K1MIN,NB
      KC = KC + 1
      IF(L1 .EQ. 1)K3POS = 2 * (NB * NOHAR + (K1 - NLIN))
      IF(L1 .GT. 1)K3POS = 2 * (NB * (L1 - 1) + K1)
      CR     = ABS(DELTAY(K3POS - 1))
      CI     = ABS(DELTAY(K3POS))
      CRAVG  = CRAVG + CR
      CIAVG  = CIAVG + CI
      IF(CR .LT. CRBAD)GO TO 15
      CRBAD  = CR
      KCRBUS = NBEXT(K1)
   15 IF(CI .LT. CIBAD)GO TO 14
      CIBAD  = CI
      KCIBUS = NBEXT(K1)
   14 CONTINUE
      IF(KC .GT. 1)CRAVG = CRAVG / FLOAT(KC)
      IF(KC .GT. 1)CIAVG = CIAVG / FLOAT(KC)
      IF(CRBAD .GT. CRWORS)CRWORS = CRBAD
      IF(CIBAD .GT. CIWORS)CIWORS = CIBAD
   13 WRITE (*,1004)NHVECT(L1),CRAVG,CRBAD,KCRBUS,CIAVG,CIBAD,
     1KCIBUS
      IF(PWORST.LT.TOLE.AND.QWORST.LT.TOLE.AND.SWORST.LT.TOLE
     1.AND.CRWORS.LT.TOLE.AND.CIWORS.LT.TOLE)CONV=TRUE
      WRITE (*,1000)
      RETURN
 1000 FORMAT(1X,I9,5X,2PF10.2,F10.2,I8,9X,F10.2,F10.2,I8,9X,F10.2,
     1F10.2,I8)
 1002 FORMAT(1X,I6,6X,'POWER',12X,2PF14.2,F10.2,I10,2(F14.2,F10.2,I10))
 1004 FORMAT(13X,'CURRENT',I7,3X,2PF14.2,F10.2,I10,F14.2,F10.2,I10)
      END
C
      SUBROUTINE ERROR(IERROR)
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
     4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      WRITE (*,1000) IERROR
 1000 FORMAT(1X,15H*** ERROR CODE ,I5,4H ***)
      IF(IERROR .LE. 20)GO TO 21
      CALL ERROR1(IERROR)
      GO TO 100
   21 GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20),IERROR
    1 WRITE (*,1001)ISDUM1
 1001 FORMAT(//1X,'CONTROL CODE = ',I5,' IS NOT VALID'/)
      GO TO 100
    2 WRITE (*,1002)
 1002 FORMAT(1X,'EITHER ONE OF THE PRECEEDING BUS NUMBER IS OUT'
     1,' OF RANGE ON THE FROM-TO NUMBERS ARE IDENTICAL'/)
      GO TO 100
    3 WRITE (*,1003)MAXLINE
 1003 FORMAT(1X,'NUMBER OF LINES HAS EXCEEDED PROGRAM LIMIT = '
     1,I5/)
      GO TO 100
    4 WRITE (*,1004)
 1004 FORMAT(1X,'TRANSFORMER TAP OR CONNECTION TYPE NOT VALID'/)
      GO TO 100
    5 WRITE (*,1005)
 1005 FORMAT(1X,'ONLY ONE CODE 3 SET OF INPUT DATA IS ALLOWED'/)
      GO TO 100
    6 WRITE (*,1006)
 1006 FORMAT(1X,'ONLY ONE CODE 4 SET OF INPUT DATA IS ALLOWED'/)
      GO TO 100
    7 WRITE (*,1007)MBHUSE
 1007 FORMAT(1X, 'BUS NUMBER OUT OF RANGE - HIGHEST ALLOWED NUMBER = '
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      1,I5/)
        GO TO 100
    8 WRITE (*,1008)
 1008 FORMAT(1X,'EITHER BUS TYPE OR BUS SUB-TYPE OUT OF RANGE'/)
        GO TO 100
    9 WRITE (*,1009)
 1009 FORMAT(1X,'THIS COMBINATION OF TYPE AND SUB-TYPE NOT',
      1' ALLOWED'/)
        GO TO 100
   10 WRITE (*,1010)
 1010 FORMAT(1X,'MORE THAN ONE BUS SPECIFIED AS SWING BUS'/)
        GO TO 100
   11 WRITE (*,1011)
 1011 FORMAT(1X,'NO SWING BUS SPECIFIED'/)
        GO TO 100
   12 WRITE (*,1012)MAXNB
 1012 FORMAT(1X,'TOO MANY BUSSES - MAXIMUM NUMBER OF BUSSES = '
      1,I5/)
        GO TO 100
   13 WRITE (*,1013)
 1013 FORMAT(1X,'THIS BUS NUMBER HAS ALREADY BEEN SPECIFIED'/)
        GO TO 100
   14 WRITE (*,1014)
 1014 FORMAT(1X,'ONE OF BOTH OF THESE BUS NUMBERS WAS NOT INCLUDED'
      1,' IN THE CODE 3 DATA'/)
        GO TO 100
   15 WRITE (*,1015)
 1015 FORMAT(1X,'CODE 3 (FUNDAMENTAL LOADFLOW BUS DATA) MUST PRECEED'
      1,' NONLINEAR BUS DATA'/)
        GO TO 100
   16 WRITE (*,1016)
 1016 FORMAT(1X,'ONLY ONE CODE 6 SET OF INPUT DATA IS ALLOWED'/)
        GO TO 100
   17 WRITE (*,1017)
 1017 FORMAT(1X,'THIS BUS NUMBER WAS NOT INCLUDED IN THE'
      1,' CODE 3 DATA'/)
        GO TO 100
   18 WRITE (*,1018)
 1018 FORMAT(1X,'THE NUMBER OF BUSSES HAS EXCEEDED THE NUMBER'
      1,' OF BUSSES OF THIS TYPE'/1X,'AS DETERMINED FROM THE'
      2,' CODE 3 DATA'/)
        GO TO 100
   19 WRITE (*,1019)ISDUM1
 1019 FORMAT(1X,'NONLINEAR DATA WAS NOT SPECIFIED FOR BUS ',I5/)
        GO TO 100
   20 WRITE (*,1020)
 1020 FORMAT(1X,'THIS BUS TYPE DOES NOT AGREE WITH THE CODE 3 DATA'/)
  100 TERMINAL = TRUE
        NOERR = NOERR + 1
        IF(NOERR .LT. NOERMAX) RETURN
        WRITE (*,1100)NOERMAX
 1100 FORMAT(//1X,'THE MAXIMUM NUMBER OF ERRORS = ',I5,'HAS'
      1,' OCCURRED - TERMINATE')
        STOP
        END
C
      SUBROUTINE ERROR1(IERROR)
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      IERR = IERROR - 20
      IF(IERROR .LE. 40)GO TO 41
      CALL ERROR2(IERROR)
      RETURN
   41 GO TO (21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,
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     139)  , IERR
  21 WRITE (*,1021)
1021 FORMAT(1X,'NO BUSSES OF THIS TYPE WERE INCLUDED IN THE'
    1,' CODE 3 DATA'/)
     RETURN
  22 WRITE (*,1022)
1022 FORMAT(1X,'CODE 3 DATA MUST PRECEED CODE 4 DATA'/)
     RETURN
  23 WRITE (*,1023)
1023 FORMAT(1X,'THE CONVERTER FILTER REACTANCE SHOULD NOT BE ',
    1'NEGATIVE'/)
     RETURN
  24 WRITE (*,1024) IOPT(3),NHVECT(MAXHAR)
1024 FORMAT(1X,'THE OVERRIDE HIGHEST HARMONIC = ',I5,' EXCEEDS'
    1,' THE MAXIMUM ALLOWED = ',I5/1X,'(DETERMINED FROM MAXHAR'
    2,' AND THE ABSENCE OR PRESENCE OF ZERO SEQUENCE)'/)
     RETURN
  25 WRITE (*,1025)
1025 FORMAT(1X,'THE POSITIVE-NEGATIVE SEQUENCE LINE IMPEDANCE'
    1,' IS VERY SMALL'/)
     RETURN
  26 WRITE (*,1026)
1026 FORMAT(1X,'PASSIVE CONVERTER BUSSES CANNOT HAVE P OR Q '
    1,'GENERATION'/)
     RETURN
  27 WRITE (*,1027)
1027 FORMAT(1X,'ABS(S) CANNOT BE LESS THAN P AT A PS BUS'/)
     RETURN
  28 WRITE (*,1028)
1028 FORMAT(1X,'PL OR PG CANNOT BE NEGATIVE AT NONLINEAR BUSSES'/)
     RETURN
  29 WRITE (*,1029)
1029 FORMAT(1X,'NEGATIVE RESISTANCE NOT ALLOWED'/)
     RETURN
  30 WRITE (*,1030)ISDUM1,EDUM1
1030 FORMAT(1X,'THE JACOBIAN HAS A ZERO ON THE DIAGONAL. ',
    1'DIAGONAL ELEMENT POSITION = ',I5,', VALUE = ',E15.6/)
     RETURN
  31 WRITE (*,1031)
1031 FORMAT(1X,'THERE MUST BE AT LEAST TWO BUSSES TO RUN THE'
    1,' LOADFLOW'/)
     RETURN
  32 WRITE (*,1032)TOLE
1032 FORMAT(1X,'THE FUNDAMENTAL LOADFLOW DID NOT CONVERGE TO THE'
    1' DESIRED WORST BUS P,Q MISMATCH TOLERANCE = ',2PF8.4/)
     RETURN
  33 WRITE (*,1033)
1033 FORMAT(1X,'NONLINEAR BUSSES CANNOT HAVE BOTH LOAD AND'
    1,' GENERATION'/)
     RETURN
  34 WRITE (*,1034)
1034 FORMAT(1X,'XS SHOULD BE GREATER THAN ZERO'/)
     RETURN
  35 WRITE (*,1035)
1035 FORMAT(1X,'R SHOULD NOT BE SPECIFIED'/)
     RETURN
  36 WRITE (*,1036)
1036 FORMAT(1X,'ALPHA SHOULD NOT BE SPECIFIED'/)
     RETURN
  37 WRITE (*,1037)
1037 FORMAT(1X,'ONLY ONE CODE 7 SET OF INPUT DATA IS ALLOWED'/)
     RETURN
  38 WRITE (*,1038)
1038 FORMAT(1X,'THIS ALPHA NOT ACCEPTABLE'/)
     RETURN
  39 WRITE (*,1039)
1039 FORMAT(1X,'E SHOULD NOT BE SPECIFIED'/)
     RETURN
     END
C
     SUBROUTINE ERROR2(IERROR)
     COMPLEX YBUS, CMPZERO, CMPONE
     LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
    1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
     CHARACTER * 2 SUBNAME
     CHARACTER * 12 BUSNAME, BTEMPN
     CHARACTER * 80 TITLE, COMMENT
     COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
     COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
    1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
    2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
    3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
    4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
    5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
    6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
    7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
    8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
    9HPEAK, ACCEL
     COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
     COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
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     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      IERR = IERROR - 39
      GO TO (40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,
     159,60,61,62,63,64,65,67,68) , IERR
   40 WRITE (*,1040)
 1040 FORMAT(1X,'PL OR PG MUST BE GREATER THAN ZERO AT A P-ALPHA'
     1,' BUS'/)
      RETURN
   41 WRITE (*,1041)
 1041 FORMAT(1X,'SHUNT CONNECTION TYPE NOT VALID'/)
      RETURN
   42 WRITE (*,1042)
 1042 FORMAT(1X,'SHUNT ELEMENT CONNECTION TYPE SPECIFIED FOR NON'
     1,' SHUNT ELEMENT'/)
      RETURN
   43 WRITE (*,1043)
 1043 FORMAT(1X,'THE HARMONIC POWERFLOW HAS BEEN REQUESTED BUT THERE'
     1,' ARE NO NONLINEAR BUSSES'/)
      RETURN
   44 WRITE (*,1044)TOLE
 1044 FORMAT(1X,'THE HARMONIC LOADFLOW DID NOY CONVERGE TO THE DESIRED'
     1,' WORST BUS TOLERANCE = ',2PF8.4/)
      RETURN
   45 WRITE (*,1045)ISDUM1,ISDUM2
 1045 FORMAT(1X,'ZERO SEQUENCE ANALYSIS HAS BEEN REQUESTED, BUT ZERO'
     1,' SEQUENCE IMPEDANCE'/1X,'IS MISSING FOR THE ELEMENT CONNECTED'
     2,' TO BUSSES ',I5,' - ',I5/)
      RETURN
   46 WRITE (*,1046)
 1046 FORMAT(1X,'SHUNT CONNECTION TYPE IS SPECIFIED, BUT THE SHUNT'
     1' Q IS VERY SMALL'/)
      RETURN
   47 WRITE (*,1047)
 1047 FORMAT(1X,'CODE 4 DATA MUST PRECEED CODE 5 DATA'/)
      RETURN
   48 WRITE (*,1048)ISDUM1,ITERCOM,EDUM3,EDUM1,EDUM2
 1048 FORMAT(1X,'THE ITERATIVE SOLUTION OF THE COMMUTATION ANGLE FOR'
     1,' THE LINE COMMUTATED CONVERTER AT BUS ',I5/1X,'DID NOT'
     2,' CONVERGE.  ITERATIONS = ',I5,', COMMUTATION ANGLE = ',F12.2/1X
     3,'THE MISMATCH IS - - - F1 = ',E15.6,', F2 = ',E15.6/)
      RETURN
   49 WRITE (*,1049)NB,MAXAJAC
 1049 FORMAT(1X,'THE JACOBIAN DIMENSION (MAXAJAC) MUST BE AT LEAST ',
     1'TWICE AS LARGE THE NUMBER OF BUSSES (NB) TO RUN THE ',
     2'FUNDAMENTAL LOADFLOW'/1X,'NB = ',I5,', MAXAJAC = ',I5/)
      RETURN
   50 WRITE (*,1050)ISDUM1
 1050 FORMAT(1X,'THE END OF PERIOD 2 FOR THE LINE COMMUTATED CONVERTER'
     1,' AT BUS ',I5,' CANNOT BE DETERMINED'/1X,'SINCE THE CURRENT ',
     2'NEVER GOES POSITIVE'/)
      RETURN
   51 WRITE (*,1051)ISDUM1,ISDUM2,EDUM1,EDUM2
 1051 FORMAT(1X,'THE ITERATIVE SOLUTION OF THE END OF PERIOD 2 FOR'
     1,' A LINE COMMUTATED CONVERTER AT BUS ',I5,' DID NOT CONVERGE,'/
     21X,'ITERATIONS = ',I5,', ENDING ANGLE (PAST DELAY ANGLE) = ',
     3F12.2,', ERROR = ',E15.6/)
      RETURN
   52 WRITE (*,1052)
 1052 FORMAT(1X,'R MUST BE GREATER THAN ZERO'/)
      RETURN
   53 WRITE (*,1053)
 1053 FORMAT(1X,'ZERO SEQUENCE HAS BEEN REQUESTED, BUT THERE ARE',
     1' NO ZERO SEQUENCE SOURCES'/)
      RETURN
   54 WRITE (*,1054)
 1054 FORMAT(1X,'IMPEDANCE FOR HARMONICS ONLY SHOULD NOT BE SPECIFIED',
     1' AT A NON SHUNT ELEMENT'/)
      RETURN
   55 WRITE (*,1055)NB,NOHAR,NNLIN,ISDUM1,MAXAJAC
 1055 FORMAT(1X,'ACCORDING TO THE FOLLOWING DIMENSIONS, NB = ',
     1I5,', NOHAR = ',I5,', NNLIN = ',I5,', THE JACOBIAN DIMENSION ',
     2'MAXAJAC SHOULD BE AT LEAST = ',I5/1X,'THE SPECIFIED MAXAJAC = ',
     3I5,' IS TOO SMALL'/)
      RETURN
   56 WRITE (*,1056)
 1056 FORMAT(1X,'QL CANNOT BE NEGATIVE AND QG CANNOT BE POSITIVE'
     1,'AT A LINE COMMUTATED CONVERTER'/)
      RETURN
   57 WRITE (*,1057)
 1057 FORMAT(1X,'SOME LOAD OR GENERATION PARAMETERS SHOULD BE SPECIFI'
     1,'ED AT A NONLINEAR BUT NON E-ALPHA BUS'/)
      RETURN
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   58 WRITE (*,1058)ISDUM1,EDUM1,EDUM2
 1058 FORMAT(1X,'THE SUM OF THE DELAY ANGLE PLUS THE COMMUTATION ANGLE'
      1,' AT BUS ',I5,' IS ',F10.2,' DEGREES.'/1X,'THIS EXCEEDS THE'
      2,' LIMIT OF ',F10.2,' DEGREES'/)
      RETURN
   59 WRITE (*,1059)
 1059 FORMAT(1X,'LOAD OR GENERATION SHOULD NOT BE SPECIFIED AT ',
      1'AN E-ALPHA BUS'/)
      RETURN
   60 WRITE (*,1060)
 1060 FORMAT(1X,'THIS PROGRAM DOES NOT PERMIT ZERO SEQUENCE ',
      1'ANALYSIS'/)
      RETURN
   61 WRITE (*,1061)ISDUM1
 1061 FORMAT(1X,'THERE ARE PATHS WITH DIFFERENT PHASE SHIFTS FROM BUS '
      1,I5,' TO THE SWING BUS'/)
      RETURN
   62 WRITE (*,1062)ISDUM1
 1062 FORMAT(1X,'DISCONTINUOUS NETWORK.  BUS ',I5,' HAS NO PATH TO THE'
      1,' SWING BUS'/)
      RETURN
   63 WRITE (*,1063)
 1063 FORMAT(1X,'A TRANSFORMER TAP OR CONNECTION TYPE SHOULD NOT BE ',
      1'SPECIFIED FOR A SHUNT ELEMENT'/)
      RETURN
   64 WRITE (*,1064)
 1064 FORMAT(1X,'THERE IS NO PATH TO NEUTRAL FOR THE HARMONIC ',
      1'CURRENTS'/)
      RETURN
   65 WRITE (*,1065)ISDUM1,MAXHMP
 1065 FORMAT(1X,'THE HIGHEST HARMONIC MULTIPLE CONTAINED IN VECTOR',
      1' NHVECT = ',I5,' SHOULD NOT EXCEED THE DIMENSION MAXHMP = ',
      2I5/)
      RETURN
   66 WRITE (*,1066)
 1066 FORMAT(1X,'NONLINEAR ELEMENT CONNECTION TYPE NOT VALID'/)
      RETURN
   67 WRITE (*,1067)
 1067 FORMAT(1X,'VOLTAGE SHOULD NOT BE SPECIFIED AT A PQ OR ',
      1'NONLINEAR BUS'/)
      RETURN
   68 WRITE (*,1068)
 1068 FORMAT(1X,'THIS SPECIFIED VOLTAGE IS OUTSIDE THE NORMAL RANGE ',
      1'OF 50% TO 150%'/)
      RETURN
      END
C
      FUNCTION FA1(M,ANGL,SHIFT,KFUND)
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
      1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
      2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
      3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
      4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
      5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
      6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
      7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
      8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
      9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
      1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
      2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
      3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
      4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
      5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
      6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      RR1    = 2.0 * RCONV(M)
      RR2    = RCONV(M)
      XX1    = 3.0 * XTRCON(M) + 2.0 * FCONV(M)
      XX2    = FCONV(M) + XTRCON(M)
      XX3    = XTRCON(M)
      ZK3ANG = R90
      FA1    = 0.0
      LMAX   = 1
      IF(KFUND .EQ. 2)LMAX = NOHAR
      DO 1 L = 1,LMAX
      IF(NPHSEQ(L) .EQ. 0)GO TO 1
      LHAR   = NHVECT(L)
      XX1L   = FLOAT(LHAR) * XX1
      XX2L   = FLOAT(LHAR) * XX2
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          XX3L    = FLOAT(LHAR) * XX3
          ZK1MAG = SQRT(RR1 * RR1 + XX1L * XX1L)
          ZK2MAG = SQRT(RR2 * RR2 + XX2L * XX2L)
          ZK3MAG = XX3L
          ZK1ANG = ATAN2(XX1L,RR1)
          ZK2ANG = ATAN2(XX2L,RR2)
          MPOS    = 2 * M + 2 * (L-1) * NB
          VOLTM   = X(MPOS)
          ANGM        = X(MPOS - 1) / VOLTM + FLOAT(NPHSEQ(L)) * R30
          FFMAG(1,L) = VOLTM / ZK1MAG
          FFANG(1,L) = ANGM - ZK1ANG + PSHIFT(L) + FLOAT(LHAR) * SHIFT
          PS         = FLOAT(NPHSEQ(L)) * R120
          FFMAG(2,L) = -FFMAG(1,L) * ZK2MAG / ZK3MAG
          FFANG(2,L) =  FFANG(1,L) + ZK2ANG - ZK3ANG + PS
          FA1 =   FA1 + FFMAG(1,L) * SIN(FLOAT(LHAR) * ANGL + FFANG(1,L))
         1        + FFMAG(2,L) * SIN(FLOAT(LHAR) * ANGL + FFANG(2,L))
        1 CONTINUE
          RETURN
          END
  C
          FUNCTION FA1PRI(M,ANGL,KFUND)
          COMPLEX YBUS, CMPZERO, CMPONE
          LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
         1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
          CHARACTER * 2 SUBNAME
          CHARACTER * 12 BUSNAME, BTEMPN
          CHARACTER * 80 TITLE, COMMENT
          COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
          COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
         1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
         2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
         3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
         4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
         5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
         6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
         7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
         8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
         9HPEAK, ACCEL
          COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
          COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
         1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
         2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
         3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
         4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
         5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
         6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
          COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
         1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
  C
          RR1     = 2.0 * RCONV(M)
          RR2     = RCONV(M)
          XX1     = 3.0 * XTRCON(M) + 2.0 * FCONV(M)
          XX2     = FCONV(M) + XTRCON(M)
          XX3     = XTRCON(M)
          ZK3ANG = R90
          FA1PRI = 0.0
          LMAX    = 1
          IF(KFUND .EQ. 2)LMAX = NOHAR
          DO 1 L = 1,LMAX
          IF(NPHSEQ(L) .EQ. 0)GO TO 1
          LHAR    = NHVECT(L)
          XX1L    = FLOAT(LHAR) * XX1
          XX2L    = FLOAT(LHAR) * XX2
          XX3L    = FLOAT(LHAR) * XX3
          ZK1MAG = SQRT(RR1 * RR1 + XX1L * XX1L)
          ZK2MAG = SQRT(RR2 * RR2 + XX2L * XX2L)
          ZK3MAG = XX3L
          ZK1ANG = ATAN2(XX1L,RR1)
          ZK2ANG = ATAN2(XX2L,RR2)
          MPOS    = 2 * M + 2 * (L - 1) * NB
          VOLTM   = X(MPOS)
          ANGM    = X(MPOS - 1) / VOLTM + FLOAT(NPHSEQ(L)) * R30
          DMAG    = VOLTM / ZK1MAG
          DANG    = FLOAT(LHAR) * ANGL + ANGM - ZK1ANG + PSHIFT(L)
          PS      = FLOAT(NPHSEQ(L)) * R120
          FA1PRI = FA1PRI + FLOAT(LHAR) * DMAG * (COS(DANG) - ZK2MAG /
         1          ZK3MAG * COS(DANG + ZK2ANG - ZK3ANG + PS))
        1 CONTINUE
          RETURN
          END
  C
          FUNCTION FA2(M,ANGL,SHIFT,KFUND)
          COMPLEX YBUS, CMPZERO, CMPONE
          LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
         1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
          CHARACTER * 2 SUBNAME
          CHARACTER * 12 BUSNAME, BTEMPN
          CHARACTER * 80 TITLE, COMMENT
          COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
          COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
```

```
      1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
      2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
      3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
      4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
      5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
      6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
      7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
      8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
      9HPEAK, ACCEL
       COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
       COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
      1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
      2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
      3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
      4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
      5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
      6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
       COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
       RR4   = RCONV(M)
       XX4   = FCONV(M) + 2.0 * XTRCON(M)
       FA2   = 0.0
       LMAX  = 1
       IF(KFUND .EQ. 2) LMAX = NOHAR
       DO 1 L = 1,LMAX
       IF(NPHSEQ(L) .EQ. 0)GO TO 1
       LHAR  = NHVECT(L)
       XX4L  = FLOAT(LHAR) * XX4
       ZK4MAG = SQRT(RR4 * RR4 + XX4L * XX4L)
       ZK4ANG = ATAN2(XX4L,RR4)
       MPOS  = 2 * M + 2 * (L - 1) * NB
       VOLTM = X(MPOS)
       ANGM       = X(MPOS - 1) / VOLTM + FLOAT(NPHSEQ(L)) * R30
       FFMAG(1,L) = VOLTM / ZK4MAG
       FFANG(1,L) = ANGM - ZK4ANG + PSHIFT(L) + FLOAT(LHAR) * SHIFT
       FFMAG(2,L) = 0.0
       FFANG(2,L) = 0.0
       FA2 = FA2 + FFMAG(1,L)*SIN(FLOAT(LHAR)*ANGL+FFANG(1,L))
     1 CONTINUE
       RETURN
       END
C
       FUNCTION FA2PRI(M,ANGL,KFUND)
       COMPLEX YBUS, CMPZERO, CMPONE
       LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
       CHARACTER * 2 SUBNAME
       CHARACTER * 12 BUSNAME, BTEMPN
       CHARACTER * 80 TITLE, COMMENT
       COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
       COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
      1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
      2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
      3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
      4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
      5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
      6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
      7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
      8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
      9HPEAK, ACCEL
       COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
       COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
      1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
      2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
      3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
      4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
      5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
      6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
       COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING,-CONV, ZOURCE, GPATH
C
       RR4    = RCONV(M)
       XX4    = FCONV(M) + 2.0 * XTRCON(M)
       FA2PRI = 0.0
       LMAX   = 1
       IF(KFUND .EQ. 2)LMAX = NOHAR
       DO 1 L = 1,LMAX
       IF(NPHSEQ(L) .EQ. 0)GO TO 1
       LHAR  = NHVECT(L)
       XX4L  = FLOAT(LHAR) * XX4
       ZK4MAG = SQRT(RR4 * RR4 + XX4L * XX4L)
       ZK4ANG = ATAN2(XX4L,RR4)
       MPOS  = 2 * M + 2 * (L - 1) * NB
       VOLTM = X(MPOS)
       ANGM  = X(MPOS - 1) / VOLTM + FLOAT(NPHSEQ(L)) * R30
       FA2PRI = FA2PRI + FLOAT(LHAR) *(VOLTM / ZK4MAG
     1          * COS(FLOAT(LHAR) * ANGL + ANGM - ZK4ANG
     2          + PSHIFT(L)))
     1 CONTINUE
```

```
      RETURN
      END
C

      FUNCTION FC1(M,ANGL,SHIFT,KFUND)
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
     4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      RR1       = 2.0 * RCONV(M)
      RR4       = RCONV(M)
      XX1       = 3.0 * XTRCON(M) + 2.0 * FCONV(M)
      XX4       = FCONV(M) + 2.0 * XTRCON(M)
      XX3       = XTRCON(M)
      ZK3ANG    = R90
      FC1       = 0.0
      LMAX      = 1
      IF(KFUND .EQ. 2)LMAX = NOHAR
      DO 1 L    = 1,LMAX
      IF(NPHSEQ(L) .EQ. 0)GO TO 1
      LHAR      = NHVECT(L)
      XX1L      = FLOAT(LHAR) * XX1
      XX4L      = FLOAT(LHAR) * XX4
      XX3L      = FLOAT(LHAR) * XX3
      ZK1MAG    = SQRT(RR1 * RR1 + XX1L * XX1L)
      ZK4MAG    = SQRT(RR4 * RR4 + XX4L * XX4L)
      ZK3MAG    = XX3L
      ZK1ANG    = ATAN2(XX1L,RR1)
      ZK4ANG    = ATAN2(XX4L,RR4)
      MPOS      = 2 * M + 2 * (L - 1) * NB
      VOLTM     = X(MPOS)
      ANGM      = X(MPOS - 1) / VOLTM + FLOAT(NPHSEQ(L)) * R30
      FFMAG(1,L) = VOLTM / ZK1MAG
      FFANG(1,L) = ANGM - ZK1ANG + PSHIFT(L) + FLOAT(LHAR) * SHIFT
      PS        = FLOAT(NPHSEQ(L)) * R120
      FFMAG(2,L) = FFMAG(1,L) * ZK4MAG / ZK3MAG
      FFANG(2,L) = FFANG(1,L) + ZK4ANG - ZK3ANG + PS
      FC1       = FC1+FFMAG(1,L)*SIN(FLOAT(LHAR)*ANGL+FFANG(1,L))
     1           +FFMAG(2,L)*SIN(FLOAT(LHAR)*ANGL+FFANG(2,L))
    1 CONTINUE
      RETURN
      END
C

      FUNCTION FC1PRI(M,ANGL,KFUND)
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
     4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
```

```
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      RR1     = 2.0 * RCONV(M)
      RR4     = RCONV(M)
      XX1     = 3.0 * XTRCON(M) + 2.0 * FCONV(M)
      XX4     = FCONV(M) + 2.0 * XTRCON(M)
      XX3     = XTRCON(M)
      ZK3ANG  = R90
      FC1PRI  = 0.0
      LMAX    = 1
      IF(KFUND .EQ. 2)LMAX = NOHAR
      DO 1 L  = 1,LMAX
      IF(NPHSEQ(L) .EQ. 0)GO TO 1
      LHAR    = NHVECT(L)
      XX1L    = FLOAT(LHAR) * XX1
      XX4L    = FLOAT(LHAR) * XX4
      XX3L    = FLOAT(LHAR) * XX3
      ZK1MAG  = SQRT(RR1 * RR1 + XX1L * XX1L)
      ZK4MAG  = SQRT(RR4 * RR4 + XX4L * XX4L)
      ZK3MAG  = XX3L
      ZK1ANG  = ATAN2(XX1L,RR1)
      ZK4ANG  = ATAN2(XX4L,RR4)
      MPOS    = 2 * M + 2 * (L - 1) * NB
      VOLTM   = X(MPOS)
      ANGM = X(MPOS - 1) / VOLTM + FLOAT(NPHSEQ(L)) * R30
      DMAG = VOLTM / ZK1MAG
      DANG = FLOAT(LHAR) * ANGL + ANGM - ZK1ANG + PSHIFT(L)
      PS      = FLOAT(NPHSEQ(L)) * R120
      FC1PRI  = FC1PRI + FLOAT(LHAR) * DMAG * (COS(DANG) + ZK4MAG /
     1          ZK3MAG * COS(DANG + ZK4ANG - ZK3ANG + PS))
    1 CONTINUE
      RETURN
      END
C
      SUBROUTINE FFINT(M,ANGL,KFUND,ISIG,KPART)
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(368), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(8), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      DERIV = TRUE
      IF(KPART .NE. 1)DERIV = FALSE
      L2MAX = 1
      IF(KFUND .EQ. 2)L2MAX = NOHAR
      DO 1 L1 = 1,NOHAR
      IF(NPHSEQ(L1) .EQ. 0)GO TO 1
      L1F = NHVECT(L1)
      DO 2 L2 = 1,L2MAX
      IF(NPHSEQ(L2) .EQ. 0)GO TO 2
      L2F    = NHVECT(L2)
      MCOL   = 2 * NB * (L2 - 1) + 2 * M
      VOLTM = X(MCOL)
      DGRDA = 0.0
      DGIDA = 0.0
      DGRDV = 0.0
      DGIDV = 0.0
      IF(L1F .EQ. L2F)GO TO 10
      FLM = FLOAT(L2F - L1F)
      FLP = FLOAT(L2F + L1F)
      DO 3 L3 = 1,2
      CL = FFMAG(L3,L2) / FLM / 2.0
      CR = FFMAG(L3,L2) / FLP / 2.0
      AL = FLM * ANGL + FFANG(L3,L2)
      AR = FLP * ANGL + FFANG(L3,L2)
```

```
      BI = FLOAT(ISIG) * (-CL * COS(AL) - CR * COS(AR))
      BR = FLOAT(ISIG) * ( CL * SIN(AL) - CR * SIN(AR))
      GI(M,L1) = GI(M,L1) + BI
      GR(M,L1) = GR(M,L1) + BR
      IF(.NOT. DERIV)GO TO 3
      DGIDA = DGIDA + FLOAT(ISIG) * (CL * SIN(AL) + CR * SIN(AR))
     1          / VOLTM
      DGIDV = DGIDV + BI / VOLTM
      DGRDA = DGRDA + FLOAT(ISIG) * (CL * COS(AL) - CR * COS(AR))
     1          / VOLTM
      DGRDV = DGRDV + BR / VOLTM
    3 CONTINUE
      GO TO 5
   10 DO 4  L3 = 1,2
      T1 = ANGL / 2.0 * SIN(FFANG(L3,L2))
      T2 = ANGL / 2.0 * COS(FFANG(L3,L2))
      T3 = COS(2.0*FLOAT(L2F)*ANGL+FFANG(L3,L2))/4.0/FLOAT(L2F)
      T4 = SIN(2.0*FLOAT(L2F)*ANGL+FFANG(L3,L2))/4.0/FLOAT(L2F)
      BI = FLOAT(ISIG) * FFMAG(L3,L2) * (T1 - T3)
      BR = FLOAT(ISIG) * FFMAG(L3,L2) * (T2 - T4)
      GI(M,L1) = GI(M,L1) + BI
      GR(M,L1) = GR(M,L1) + BR
      IF(.NOT. DERIV)GO TO 4
      DGIDA = DGIDA + FLOAT(ISIG) * FFMAG(L3,L2) * (T2 + T4) / VOLTM
      DGIDV = DGIDV + BI / VOLTM
      DGRDA = DGRDA + FLOAT(ISIG) * FFMAG(L3,L2) * (-T1 -T3) / VOLTM
      DGRDV = DGRDV + BR / VOLTM
    4 CONTINUE
    5 IF(.NOT. DERIV)GO TO 2
      CALL ROTATE(DGRDA,DGIDA,-PSHIFT(L1))
      CALL ROTATE(DGRDV,DGIDV,-PSHIFT(L1))
      IF(L1 .EQ. 1)MROW = 2 * (NB * NOHAR + (M - NLIN))
      IF(L1 .GT. 1)MROW = 2 * (NB * (L1 - 1) + M)
      AJAC(MROW - 1,MCOL - 1) = AJAC(MROW - 1,MCOL - 1) + DGRDA
     1                        * 2.0 / PI
      AJAC(MROW - 1,MCOL)     = AJAC(MROW - 1,MCOL) + DGRDV
     1                        * 2.0 / PI
      AJAC(MROW,MCOL - 1)     = AJAC(MROW,MCOL - 1) + DGIDA
     1                        * 2.0 / PI
      AJAC(MROW,MCOL)         = AJAC(MROW,MCOL) + DGIDV
     1                        * 2.0 / PI
    2 CONTINUE
    1 CONTINUE
      RETURN
      END
C
      SUBROUTINE F2END(M,AEND,ALPHA,KFUND)
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(368,368), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      EDUM2  = ALPHA * DR
      EDUM3  = AEND * DR
      ISDUM1 = NBEXT(M)
      STEP   = 1.0 / DR
    1 CHECK  = AMP2(M,AEND,ALPHA,KFUND)
      IF(CHECK .GT. 0.0)GO TO 5
      AEND   = AEND - STEP
      IF(AEND .GE. ALPHA)GO TO 1
      CALL ERROR(50)
      GO TO 20
    5 ITER   = 0
    6 AEND   = AEND - CHECK / (P2 * AK3 * EXP(P2 * (AEND - ALPHA))
     1            + FA2PRI(M,AEND,KFUND))
      EDUM1  = (AEND - ALPHA) * DR
      ITER   = ITER + 1
```

```
       ISDUM2 = ITER
       CHECK  = AMP2(M,AEND,ALPHA,KFUND)
       IF(IOPT(9) .NE. 0)WRITE (*,1000)ISDUM1,KFUND,ISDUM2,EDUM1,EDUM2
      1,EDUM3,CHECK
       IF(ABS(CHECK) .LT. F2TOLE)GO TO 10
       IF(ITER .LT. 10)GO TO 6
       EDUM2  = CHECK
       CALL ERROR(51)
       GO TO 20
   10 IF(AEND .GE. ALPHA .AND. AEND .LE. ALPHA + R60)RETURN
       CALL MESSAGE(5)
       IF(AEND .GT. ALPHA + R60)AEND = ALPHA + R60
       IF(AEND .LT. ALPHA)AEND = ALPHA
   20 WRITE (*,1002)ISDUM1
       DO 21 LHAR = 1,NOHAR
       MPOS   = 2 * M + 2 * (LHAR - 1) * NB
       VOLTM  = X(MPOS)
       ANGM   = X(MPOS - 1) / VOLTM * DR
       WRITE (*,1004)NHVECT(LHAR),VOLTM,ANGM
   21 CONTINUE
       RETURN
 1000 FORMAT(/1X,'F2END ',3I5,6F12.6)
 1002 FORMAT(/1X,'DUE TO APPARENT PROBLEMS IN THE SOLUTION FOR THE'
      1,' END OF PERIOD 2 AT BUS ',I5,', THE APPLIED VOLTAGES ARE'
      2,' LISTED.'/1X,'HARMONIC',5X,'VOLTAGE MAGNITUDE',5X,'VOLTAGE'
      3,' ANGLE')
 1004 FORMAT(1X,I8,2PF22.4,0PF18.2)
       END
```

```
C
      SUBROUTINE HARBUILD
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      NHVECT(1) = 1
      NHIGH     = 1
      NOHAR     = 1
      NPHSEQ(1) = 1
      IF(IOPT(1) .NE. 0)RETURN
      IF (MAXHAR .EQ. 1) GO TO 504
      IF(IOPT(2) .EQ. 0) GO TO 502
      IF(IOPT(2) .EQ. 1) GO TO 520
      DO 503 L1  = 2,MAXHAR
  503 NHVECT(L1) = 2 * L1 - 1
      GO TO 504
  502 KADD = 1
      DO 505 L2  = 2,MAXHAR
      NHVECT(L2) = NHVECT(L2-1) + 3 + KADD
      KADD       = -KADD
  505 CONTINUE
      GO TO 504
  520 KADD = 4
      DO 521 L2  = 2,MAXHAR
      NHVECT(L2) = NHVECT(L2-1) + 6 + KADD
      KADD       = -KADD
  521 CONTINUE
  504 IF(IOPT(3) .GT. NHVECT(MAXHAR)) CALL ERROR(24)
      NHIGH = IOPT(3)
      IF(NHIGH .LT. 1) NHIGH = NHVECT(MAXHAR)
      IF(MAXHAR .EQ. 1) GO TO 550
      NOHAR = 1
      DO 508 L1 = 2,MAXHAR
      IF(NHVECT(L1) .GT. NHIGH) GO TO 507
  508 NOHAR      = NOHAR + 1
  507 NPHSEQ(1) = 1
      IF(NOHAR .EQ. 1) GO TO 550
      L1 = 0
      L2 = -1
      DO 510 L3  = 2,MAXHAR
      NPHSEQ(L3) = 1
      IF(IOPT(2) .LE. 1 .OR. L1 .NE. 0)GO TO 508
      NPHSEQ(L3) = 0
      GO TO 509
  508 IF(IOPT(2) .GE. 2 .AND. L1 .EQ. 1)NPHSEQ(L3) = -1
      IF(IOPT(2) .LE. 1 .AND. L2 .EQ. -1)NPHSEQ(L3) = -1
  509 L1 = L1 + 1
      IF(L1 .EQ. 3) L1 = 0
      L2 = -L2
  510 CONTINUE
  550 ISDUM1 = NHVECT(MAXHAR)
      IF(ISDUM1 .GT. MAXHMP) CALL ERROR(65)
      DO 511 L1 = 1,MAXHAR
      MHVECT(NHVECT(L1)) = L1
  511 CONTINUE
      IF(IOPT(9) .EQ. 0)RETURN
      WRITE (*,1000)NHIGH,NOHAR,MAXHAR
 1000 FORMAT(/1X,'HARBUILD',20I5)
      WRITE (*,1000)NPHSEQ
      WRITE (*,1000)NHVECT
      WRITE (*,1000)MHVECT
      RETURN
      END
C
      SUBROUTINE HARSTART(KUP)
```

```
      COMPLEX YB
      LOGICAL PV,PS
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      IF(KUP .NE. 0)GO TO 8
      HFLAT = 1.0E-2
      IF(IOPT(7) .EQ. 1)HFLAT = 1.0E-01
      IF(IOPT(7) .EQ. 3)HFLAT = 1.0E-03
      IF(IOPT(7) .EQ. 4)HFLAT = 1.0E-04
      DO 1 K1 = 1,NB
      FLAT    = 1.0
      IF(V(K1) .LT. EP6)V(K1) = 1.0
      IF(NBSUBT(K1) .EQ. 1 .OR. NBSUBT(K1) .EQ. 2)FLAT = V(K1)
      K3      = 2 * K1 -1
      X(K3) = FLAT * NBSHFT(K1) * R30
    1 X(K3 + 1) = FLAT
      IF(IOPT(1) .NE. 0 .OR. NOHAR .EQ. 1)GO TO 8
      DO 2 K1 = 1,NB
      SHIFT   = NBSHFT(K1) * R30
      DO 2 K2 = 2,NOHAR
      K3 = 2 * K1 - 1 + 2 * (K2 - 1) * NB
      X(K3)   = NPHSEQ(K2) * HFLAT * SHIFT
    2 X(K3 + 1) = HFLAT
    8 KCHECK  = 0
      DO 3 K1 = 1,NB
      ITYPE   = NBTYPE(K1)
      ISUB    = NBSUBT(K1)
      K3 = 2 * K1 - 1
      IF(ITYPE .NE. 0)GO TO 5
      Y(K3)   = PG(K1) - PL(K1)
      Y(K3 + 1) = QG(K1) - QL(K1)
      GO TO 3
    5 IF(KCHECK .EQ. 0)CALL PGHEAD(9)
      KCHECK  = KCHECK + 1
      VOLTS   = X(2 * K1)
      GO TO (10,20) , ITYPE
   10 Y(K3)   = -PL(K1)
      IF(ISUB .NE. 3)GO TO 11
      Y(K3 + 1) = -QL(K1)
      GO TO 15
   11 IF(ISUB .NE. 4)GO TO 12
      P2 = Y(K3)**2
      Q2 = (S(K1) * 3.0 / PI)**2 - P2
      IF(Q2 .LT. 0.0)Q2 = 0.0
      Y(K3 + 1) = -SQRT(Q2)
      QL(K1)    = -Y(K3 + 1)
      GO TO 15
   12 ANG = (DELAY(K1) + COM(K1) / 2.0) * DR
      IF(ANG .GT. 80.0 .AND. ANG .LT. 100.0)ANG = 80.0
      ANG = ANG / DR
      Y(K3 + 1) = -ABS(Y(K3) * SIN(ANG) / COS(ANG))
      QL(K1)    = -Y(K3 + 1)
      GO TO 16
   15 DELAY(K1) = R90
      IF(PL(K1) .GT. EP6)DELAY(K1) = ATAN2(QL(K1),PL(K1))
      IF(KUP .NE. 0)DELAY(K1) = DELAY(K1) - COM(K1) / 2.0
      IF(DELAY(K1) .LT. 0.0)DELAY(K1) = 0.0
   16 RCONV(K1) = 1.0 / EP6
      IF(PL(K1) .LT. EP6)GO TO 7
      ANG = DELAY(K1) + COM(K1) / 2.0
      VB2 = 1.0 + 3.0 * SQRT(3.0) / 2.0 / PI
      IF(ANG .LE. R60)V2 = 1.0 + 3.0 * SQRT(3.0) / 2.0 / PI *
     1                     COS(2.0 * ANG)
      IF(ANG .GT. R60)V2 = 2.0 - 3.0 / PI * (ANG +
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      1                          SIN(2.0 * ANG - R60) /2.0)
       RCONV(K1) = V2 / VB2 / PL(K1) * VOLTS * VOLTS
       GO TO 7
   20 IF(ISUB .EQ. 6)GO TO 23
       Y(K3) = PG(K1) - PL(K1)
       IF(ISUB .NE. 3)GO TO 21
       Y(K3 + 1) = QG(K1) - QL(K1)
       GO TO 25
   21 IF(ISUB .NE. 4)GO TO 22
       P2 = Y(K3)**2
       Q2 = (S(K1) * 3.0 / PI)**2 - P2
       IF(Q2 .LT. 0.0)Q2 = 0.0
       Y(K3 + 1) = -SQRT(Q2)
       IF(Y(K3) .GT. 0.0)QG(K1) = Y(K3 + 1)
       IF(Y(K3) .LE. 0.0)QL(K1) = -Y(K3 + 1)
       GO TO 25
   22 ANG = (DELAY(K1) + COM(K1) / 2.0) * DR
       IF(ANG .GT. 80.0 .AND. ANG .LT. 100.0)ANG = 80.0
       ANG = ANG / DR
       Y(K3 + 1) = -ABS(Y(K3) * SIN(ANG) / COS(ANG))
       IF(Y(K3) .GT. 0.0)QG(K1) = Y(K3 + 1)
       IF(Y(K3) .LE. 0.0)QL(K1) = -Y(K3 + 1)
       GO TO 26
   25 DELAY(K1) = ATAN2(-Y(K3 + 1),-Y(K3))
       IF(KUP .NE. 0)DELAY(K1) = DELAY(K1) - COM(K1) / 2.0
       IF(DELAY(K1) .LT. 0.0)DELAY(K1) = 0.0
   26 ANG = DELAY(K1) + COM(K1) / 2.0
       AMAX = ANG + R120
       IF(Y(K3) .LE. 0.0 .AND. ANG .GT. R60)AMAX = PI
       IF(Y(K3) .GT. 0.0 .AND. ANG .GT. PI)AMAX = PI + R120
       VAVG = 3.0 / PI * (COS(ANG + R60) - COS(AMAX))
       VAVG = VAVG * VOLTS
       ECONV(K1) = 0.0
       IF(ABS(VAVG) .GT. EP6)ECONV(K1)=VAVG + Y(K3) * RCONV(K1) / VAVG
       GO TO 7
   23 ANG  = DELAY(K1) + COM(K1) / 2.0
       AMAX = ANG + R120
       IF(ECONV(K1) .GE. 0.0 .AND. ANG .GT. R60)AMAX = PI
       IF(ECONV(K1) .LT. 0.0 .AND. ANG .GT. PI) AMAX = PI + R120
       VAVG = 3.0 / PI * (COS(ANG + R60) - COS(AMAX))
       VAVG = VAVG * VOLTS
       CURENT = (VAVG - ECONV(K1)) / RCONV(K1)
       Y(K3)  = -CURENT * (CURENT * RCONV(K1) + ECONV(K1))
       ANG = ANG * DR
       IF(ANG .GT. 80.0 .AND. ANG .LT. 100.0)ANG = 80.0
       ANG = ANG / DR
       Y(K3 + 1) = -ABS(Y(K3) * SIN(ANG) / COS(ANG))
       IF(Y(K3) .LT. 0.0)GO TO 6
       PG(K1) = Y(K3)
       QG(K1) = Y(K3 + 1)
       GO TO 7
    6 PL(K1) = -Y(K3)
       QL(K1) = -Y(K3 + 1)
    7 ANGLE  = DELAY(K1) * DR
       WRITE (*,1000)NBEXT(K1), BUSNAME(K1), SUBNAME(NBSUBT(K1)), PG(K1),
      1QG(K1), PL(K1), QL(K1), ANGLE, RCONV(K1), ECONV(K1)
       IF(ITYPE .EQ. 2 .AND. Y(K3) .LT. 0.0 .AND. ECONV(K1) .LT. 0.0)
      1CALL MESSAGE(7)
       IF(ITYPE .EQ. 2 .AND. Y(K3) .GT. 0.0 .AND. ECONV(K1) .GT. 0.0)
      1CALL MESSAGE(8)
    3 CONTINUE
       WRITE (*,1002)
 1002 FORMAT(/1X,'END OF STARTING ESTIMATES')
       RETURN
 1000 FORMAT(1X,I4,2X,A12,2X,A4,2PF10.2,3F10.2,0PF10.2,2PF10.2,
      1F10.2,0PF10.4)
       END
C
       SUBROUTINE HARSTAT
       COMPLEX YBUS, CMPZERO, CMPONE
       LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
       CHARACTER * 2 SUBNAME
       CHARACTER * 12 BUSNAME, BTEMPN
       CHARACTER * 80 TITLE, COMMENT
       COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
       COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
      1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
      2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
      3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
      4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
      5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
      6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
      7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
      8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
      9HPEAK, ACCEL
       COMMON /CHAR/ BUSNAME(20), SUBNAME(8), BTEMPN
       COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
      1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
      2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
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      3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
      4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
      5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
      6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
       COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
       HFUND   = HMAG(1)
       HRMS    = HFUND * HFUND
       HDF     = 0.0
       DO 2 LHAR = 2,NOHAR
       HDF     = HDF + HMAG(LHAR) * HMAG(LHAR)
     2 CONTINUE
       HRMS    = SQRT(HRMS + HDF)
       HDF     = SQRT(HDF) / HRMS
       NSTEPS  = 36 * NHVECT(NOHAR)
       DSTEP   = PI / FLOAT(NSTEPS)
       HPEAK   = 0.0
       DO 3 JS = 1,NSTEPS
       DEG     = FLOAT(JS) * DSTEP
       HH      = 0.0
       DO 4 LHAR = 1,NOHAR
       HH      = HH + HMAG(LHAR) * SIN(FLOAT(NHVECT(LHAR)) * DEG
      1              + HANG(LHAR))
     4 CONTINUE
       HH = ABS(HH)
       IF(HH .GT. HPEAK)HPEAK = HH
     3 CONTINUE
       RETURN
       END
C
       SUBROUTINE JABUILD(KFUND)
       COMPLEX YB
       LOGICAL PV
       COMPLEX YBUS, CMPZERO, CMPONE
       LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
       CHARACTER * 2 SUBNAME
       CHARACTER * 12 BUSNAME, BTEMPN
       CHARACTER * 80 TITLE, COMMENT
       COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
       COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
      1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
      2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
      3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
      4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
      5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
      6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
      7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
      8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
      9HPEAK, ACCEL
       COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
       COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
      1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
      2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
      3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
      4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
      5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
      6MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
       COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
      1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
       IF(KFUND .EQ. 2)LMAX = NOHAR
       IF(KFUND .EQ. 1 .OR. IOPT(14) .NE. 0)LMAX = 1
       DO 3 L1 = 1,LMAX
       IF(L1 .EQ. 1)K1MIN = 2
       IF(L1 .GT. 1)K1MIN = NLIN + 1
       DO 1 K1 = K1MIN,NB
       K1POS   = 2 * K1
       K3POS   = 2 * K1 + 2 * (L1 - 1) * NB
       VOLTK1  = X(K3POS)
       ANGK1   = X(K3POS - 1)/VOLTK1
       YB      = YBUS(K1,K1,L1)
       YMAG    = CABS(YB)
       YANG    = ATAN2(AIMAG(YB),DBLE(YB))
       AJAC(K1POS - 1,K3POS) = 2.0 * VOLTK1 * YMAG * COS(-YANG)
       AJAC(K1POS   ,K3POS) = 2.0 * VOLTK1 * YMAG * SIN(-YANG)
       PV = FALSE
       IF(NBSUBT(K1) .EQ. 1 .OR. NBSUBT(K1) .EQ. 2)PV = TRUE
       IF(PV .AND. L1 .EQ. 1)AJAC(K1POS,K3POS) = 1.0
       IF(PV .AND. L1 .NE. 1)AJAC(K1POS,K3POS) = 0.0
       DO 10 K2 = 1,NB
       IF(K1 .EQ. K2)GO TO 10
       YB      = YBUS(K1,K2,L1)
       YMAG    = CABS(YB)
       IF(YMAG .LT. EP6)GO TO 10
       YANG    = ATAN2(AIMAG(YB),DBLE(YB))
       K2POS   = 2 * K2 + 2 * (L1 - 1) * NB
       VOLTK2  = X(K2POS)
       ANGK2   = X(K2POS - 1) / VOLTK2
```

```
      ANGT    = ANGK1 - ANGK2 - YANG
      AJAC(K1POS - 1,K2POS - 1) = VOLTK1 * YMAG * SIN(ANGT)
      AJAC(K1POS - 1,K2POS)     = VOLTK1 * YMAG * COS(ANGT)
      IF(PV) GO TO 11
      AJAC(K1POS,K2POS - 1) = -AJAC(K1POS - 1,K2POS)
      AJAC(K1POS,K2POS)     =  AJAC(K1POS - 1,K2POS - 1)
   11 AJAC(K1POS - 1,K3POS - 1) = AJAC(K1POS - 1,K3POS - 1) -
     1                            VOLTK2 * YMAG * SIN(ANGT)
      AJAC(K1POS - 1,K3POS)     = AJAC(K1POS - 1,K3POS) +
     1                            VOLTK2 * YMAG * COS(ANGT)
      IF(PV) GO TO 10
      AJAC(K1POS,K3POS - 1)     = AJAC(K1POS,K3POS - 1) +
     1                            VOLTK2 * YMAG * COS(ANGT)
      AJAC(K1POS,K3POS)         = AJAC(K1POS,K3POS) +
     1                            VOLTK2 * YMAG * SIN(ANGT)
   10 CONTINUE
    1 CONTINUE
    3 CONTINUE
      IF(KFUND .EQ. 1)RETURN
      DO 20 L1 = 1,NOHAR
      IF(L1 .EQ. 1)K1MIN = NLIN + 1
      IF(L1 .GT. 1)K1MIN = 1
      DO 21 K1 = K1MIN,NB
      IF(L1 .EQ. 1)K1POS = 2 * (NB * NOHAR + (K1 - NLIN))
      IF(L1 .GT. 1)K1POS = 2 * (NB * (L1 - 1) + K1)
      DO 22 K2 = 1,NB
      YB    = YBUS(K1,K2,L1)
      YMAG = CABS(YB)
      IF(YMAG .LT. EP6)GO TO 22
      YANG = ATAN2(AIMAG(YB),DBLE(YB))
      K2POS  = 2 * K2 + 2 * (L1 - 1) * NB
      VOLTK2 = X(K2POS)
      ANGK2  = X(K2POS - 1) / VOLTK2
      ANGT   = ANGK2 + YANG
      AJAC(K1POS - 1,K2POS - 1) = AJAC(K1POS - 1,K2POS - 1) -
     1                            YMAG * SIN(ANGT)
      AJAC(K1POS - 1,K2POS)     = AJAC(K1POS - 1,K2POS) +
     1                            YMAG * COS(ANGT)
      AJAC(K1POS,K2POS - 1)     = AJAC(K1POS,K2POS - 1) +
     1                            YMAG * COS(ANGT)
      AJAC(K1POS,K2POS)         = AJAC(K1POS,K2POS) +
     1                            YMAG * SIN(ANGT)
   22 CONTINUE
   21 CONTINUE
   20 CONTINUE
      RETURN
      END
C
      SUBROUTINE LBUSDATA
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 60 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
     4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      NB     = 0
      NLIN   = 0
      NNL1   = 0
      NNL2   = 0
      NNL3   = 0
      NPVLIN = 0
      NPQLIN = 0
      NNLIN  = 0
      CALL PGHEAD(1)
  301 READ   (5,1000)KBUS,BTEMPN,ITYPE,ISUB,D,E,C,A,B,F,G,KSTYPE
      IF (KBUS .EQ. 999) GO TO 302
      C = ABS(C)
      WRITE (*,1002)KBUS,BTEMPN,ITYPE,ISUB,D,E,C,A,B,F,G,KSTYPE
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      IF(KBUS .LT. 1 .OR. KBUS .GT. MBHUSE)CALL ERROR(7)
      IF(ITYPE .LT. 0 .OR. ITYPE .GT. NTYPES .OR. ISUB .LT. 1 .OR.
     1ISUB .GT. NSUBS)CALL ERROR(8)
      IF(NBINT(KBUS) .NE. 0)CALL ERROR(13)
      IF(ISUB .EQ. 1 .AND. CSWING)CALL ERROR(10)
      IF(ISUB .EQ. 1)CSWING = TRUE
      IF(ABS(G) .LT. EP6 .AND. KSTYPE .NE. 0)CALL ERROR(46)
      IF(ABS(G) .LT. EP6)GO TO 304
      GPATH    = TRUE
      IF(KSTYPE .NE. 0)GO TO 303
      CALL MESSAGE(2)
      KSTYPE = 1
  303 IF(KSTYPE .LT. 1 .OR. KSTYPE .GT. NSHMAX)CALL ERROR(41)
  304 IF (ISUB .GE. 3 .AND. ABS(F) .GT. EP6)CALL ERROR(67)
      IF (ITYPE .NE. 0) GO TO 310
      IF (ISUB .GT. 3)CALL ERROR(9)
      IF (ISUB .EQ. 3) GO TO 305
      IF (ABS(F) .LT. EP6) F = 1.0
      IF (F .LT. 0.5 .OR. F .GT. 1.5)CALL ERROR(68)
      GO TO 305
  310 BL = SQRT(A**2 + B**2)
      BG = SQRT(D**2 + E**2)
      IF (BL .GT. EP6 .AND. BG .GT. EP6)CALL ERROR(33)
      IF (ISUB .NE. 6 .AND. (BL + BG) .LT. EP6)CALL ERROR(57)
      IF (A .LT. 0.0 .OR. D .LT. 0.0)CALL ERROR(28)
      IF (ITYPE .GT. 2) GO TO 305
      IF (B .LT. 0.0 .OR. E .GT. 0.0)CALL ERROR(56)
      IF (ISUB .EQ. 4 .AND. (A + D) .GT. 3.0 * C / PI)CALL MESSAGE(6)
      IF (ITYPE .NE. 1) GO TO 311
      IF (ISUB .LT. 3 .OR. ISUB .GT. 5)CALL ERROR(9)
      IF (D .GT. EP6 .OR. ABS(E) .GT. EP6)CALL ERROR(26)
      IF (ISUB .EQ. 4 .AND. ABS(C) .LT. A)CALL ERROR(27)
      IF (ISUB .EQ. 5 .AND. A .LT. EP6)CALL ERROR(40)
      GO TO 305
  311 IF (ITYPE .NE. 2) GO TO 305
      IF (ISUB .LT. 3 .OR. ISUB .GT. 6)CALL ERROR(9)
      IF (ISUB .EQ. 4 .AND. ABS(C) .LT. (A+D))CALL ERROR(27)
      IF (ISUB .EQ. 5 .AND. (A+D) .LT. EP6)CALL ERROR(40)
      IF (ISUB .EQ. 6 .AND. (BL + BG) .GT. EP6)CALL ERROR(55)
      GO TO 305
  305 NB = NB + 1
      IF (NB .GT. MAXNB)CALL ERROR(12)
      IF (ITYPE .EQ. 0) NLIN  = NLIN  + 1
      IF (ITYPE .NE. 0) NNLIN = NNLIN + 1
      IF (ITYPE .EQ. 1) NNL1  = NNL1  + 1
      IF (ITYPE .EQ. 2) NNL2  = NNL2  + 1
      IF (ISUB .EQ. 1 .OR. ISUB .EQ. 2)    NPVLIN = NPVLIN + 1
      IF (ITYPE .EQ. 0 .AND. ISUB .EQ. 3) NPQLIN = NPQLIN + 1
      NBEXT(NB)    = KBUS
      NBINT(KBUS) = NB
      BUSNAME(NB) = BTEMPN
      NBTYPE(NB)  = ITYPE
      NBSUBT(NB)  = ISUB
      PG(NB)      = D
      QG(NB)      = E
      S(NB)       = C
      PL(NB)      = A
      QL(NB)      = B
      V(NB)       = F
      SRCBL(NB)   = G
      KSHTYPE(NB) = KSTYPE
      GO TO 301
  302 IF(.NOT. CSWING)CALL ERROR(11)
      IF(NB .LE. 1)CALL ERROR(31)
      WRITE (*,1004)
      RETURN
 1000 FORMAT(I4,A12,2I1,2PF8.0,4F8.0,F8.1,F8.0,I1)
 1002 FORMAT(1X,I4,2X,A12,I6,I10,2PF10.2,6F10.2,I10)
 1004 FORMAT(/1X,'END OF CODE 3 BUS DATA')
      END
C
      SUBROUTINE LINEDATA
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANQ(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5QITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
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        COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
       1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
       2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
       3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
       4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
       5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
       6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
        COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
       1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
        NLINES = 0
        WRITE (*,22)
   22 FORMAT(1X,130(1H-))
        CALL PGHEAD(2)
  401 READ   (5,1000)KFROM,KTO,A,B,C,D,E,F,T,KTYPE,KSTYPE,KHAR
        IF(KFROM .EQ. 999 .OR. KTO .EQ. 999)GO TO 5
        WRITE (*,1002)KFROM,KTO,A,B,C,D,E,F,T,KTYPE,KSTYPE,KHAR
        IF(KFROM .LT. 0 .OR. KTO .LT. 0 .OR. KFROM .GT. MBHUSE
       1.OR. KTO .GT. MBHUSE)CALL ERROR(2)
        IF(KFROM .EQ. KTO)CALL ERROR(2)
        LFROM  = 0
        LTO    = 0
        IF (KFROM .EQ. 0) GO TO 405
        LFROM  = NBINT(KFROM)
        IF (LFROM .EQ. 0)CALL ERROR(14)
  405 IF (KTO .EQ. 0) GO TO 406
        LTO = NBINT(KTO)
        IF(LTO .EQ. 0)CALL ERROR(14)
  406 FF = SQRT(A**2 + B**2)
        IF (FF .LE. EP6)CALL ERROR(25)
        IF(A .LT. 0.0 .OR. D .LT. 0.0)CALL ERROR(29)
        NLINES  = NLINES + 1
        IF(NLINES .GT. MAXLINE)CALL ERROR(3)
        LINES(1,NLINES) = LFROM
        LINES(2,NLINES) = LTO
        R1(NLINES)      = A
        X1(NLINES)      = B
        B1(NLINES)      = C
        IF(ABS(C) .GT. EP6)GPATH = TRUE
        RO(NLINES) = D
        XO(NLINES) = E
        BO(NLINES) = F
        IF (LFROM .NE. 0 .AND. LTO .NE. 0)GO TO 407
        GPATH = TRUE
        IF(ABS(T) .GT. EP6 .OR. KTYPE .NE. 0)CALL ERROR(63)
        IF (KSTYPE .NE. 0) GO TO 408
        CALL MESSAGE(2)
        KSTYPE = 1
  408 IF (KSTYPE .LT. 1 .OR. KSTYPE .GT. NSHMAX)CALL ERROR(41)
        IF (KHAR .NE. 0) KSTYPE = -KSTYPE
        KSHAR(NLINES) = KSTYPE
        GO TO 401
  407 IF(KSTYPE .NE. 0)CALL ERROR(42)
        IF(KHAR .NE. 0)CALL ERROR(54)
        IF (ABS(T) .LT. EP6 .AND. KTYPE .EQ. 0) GO TO 401
        IF (KTYPE .NE. 0) GO TO 402
        CALL MESSAGE(1)
        KTYPE = 1
  402 IF(ABS(C) .GT. EP6 .OR. ABS(F) .GT. EP6)CALL MESSAGE(4)
        B1(NLINES)     = 0.0
        BO(NLINES)     = 0.0
        IF(T .LT. 0.8 .OR. T .GT. 1.2)CALL ERROR(4)
        IF(KTYPE .LT. 1 .OR. KTYPE .GT. NTRMAX)CALL ERROR(4)
        TAP(NLINES)      = T
        KTRTYPE(NLINES) = KTYPE
        GO TO 401
    5 PATHBTS(1) = TRUE
        NBSHFT(1)  = 0
        NOPROC     = 1
   15 NOPOLD      = NOPROC
        DO 10 KBUS = 1,NB
        IF (.NOT. PATHBTS(KBUS)) GO TO 10
        DO 11 KLINE = 1,NLINES
        KFROM  = LINES(1,KLINE)
        KTO    = LINES(2,KLINE)
        IF(KFROM .NE. KBUS .AND. KTO .NE. KBUS) GO TO 11
        IF(KFROM .EQ. 0 .OR. KTO .EQ. 0) GO TO 11
        ISIG = 1
        IF(KFROM .EQ. KBUS) GO TO 12
        KDUM  = KFROM
        KFROM = KTO
        KTO   = KDUM
        ISIG  = -1
   12 ISHIFT = 0
        IF(KTRTYPE(KLINE) .EQ. 6 .OR. KTRTYPE(KLINE) .EQ. 7) ISHIFT = 1
        IF(KTRTYPE(KLINE) .EQ. 8 .OR. KTRTYPE(KLINE) .EQ. 9) ISHIFT = -1
        ISHIFT = NBSHFT(KBUS) + ISIG * ISHIFT
        ISDUM1 = NBEXT(KTO)
        IF(PATHBTS(KTO) .AND. ISHIFT .NE. NBSHFT(KTO))CALL ERROR(61)
        IF(PATHBTS(KTO)) GO TO 11
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      NOPROC = NOPROC + 1
      PATHBTS(KTO) = TRUE
      NBSHFT(KTO)  = ISHIFT
   11 CONTINUE
   10 CONTINUE
      IF(NOPROC .GT. NOPOLD) GO TO 15
      DO 13 KBUS = 2,NB
      ISDUM1 = NBEXT(KBUS)
      IF(.NOT. PATHBTS(KBUS))CALL ERROR(62)
   13 CONTINUE
      WRITE (*,1004)
      RETURN
 1000 FORMAT(2I4,2PF8.2,5F8.2,0PF6.3,3I1)
 1002 FORMAT(1X,I4,I8,2PF10.2,5F10.2,0PF10.3,I8,2I7)
 1004 FORMAT(/1X,'END OF CODE 4 LINE AND TRANSFORMER DATA')
      END
C
      SUBROUTINE LOADI(K1,KFUND,KPART)
      LOGICAL COMYES
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
     4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      DO 7 L1   = 1,NOHAR
      GI(K1,L1) = 0.0
    7 GR(K1,L1) = 0.0
      ISDUM1    = NBEXT(K1)
      DO 13 K2  = 1,NOHAR
      ANGL = 0.0
      IF(KTRCON(K1) .EQ. 6 .OR. KTRCON(K1) .EQ. 7)ANGL = R30
      IF(KTRCON(K1) .EQ. 8 .OR. KTRCON(K1) .EQ. 9)ANGL = -R30
   13 PSHIFT(K2) = FLOAT(NPHSEQ(K2)) * ANGL
      ER     = ECONV(K1) / RCONV(K1)
      K1POS  = 2 * K1
      VOLTK1 = X(K1POS)
      ANGK1  = X(K1POS - 1) / VOLTK1
      ALPHA  = DELAY(K1) + R30 - ANGK1 - PSHIFT(1)
      P1     = -2.0 * RCONV(K1) / (3.0 * XTRCON(K1) + 2.0 * FCONV(K1))
      P2     = -RCONV(K1) / (2.0 * XTRCON(K1) + FCONV(K1))
      IF(P1 .LT. -50.0 .OR. P2 .LT. -50.0)CALL MESSAGE(9)
      AK3 = ER - FA2(K1,ALPHA,0.0,KFUND)
      IF(IOPT(9) .NE. 0)WRITE (*,1000)ISDUM1,KFUND,KPART,P1,P2,
     1AK3,ALPHA
      AEND   = ALPHA + R60
      CHECK  = AMP2(K1,AEND,ALPHA,KFUND)
      ITERCOM = 0
      IF(CHECK .GE. COMTOLE)GO TO 11
      COMYES = FALSE
      COM(K1) = 0.0
      IF(CHECK .LE. -COMTOLE)CALL F2END(K1,AEND,ALPHA,KFUND)
      GO TO 12
   11 COMYES  = TRUE
      CALL COMANGLE(K1,ALPHA,KFUND)
   12 CALL SERIES(K1,ALPHA,AEND,KFUND,COMYES,KPART)
      IF(IOPT(11) .EQ. 0)RETURN
      DO 20 J = 1,181
      JDEG     = J - 1
      RAD      = ALPHA + FLOAT(JDEG) / DR
      DEG      = RAD * DR
      ASER     = 0.0
      ACAL     = 0.0
      DO 21 K = 1,NOHAR
   21 ASER = ASER + GI(K1,K) * COS(FLOAT(NHVECT(K)) * RAD)
     1            + GR(K1,K) * SIN(FLOAT(NHVECT(K)) * RAD)
      IF(RAD .GE. ALPHA + COM(K1))GO TO 32
      ACAL = AK1 - ER / 2.0 + AK2 * EXP(P1 * (RAD - ALPHA)) +
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     1FA1(K1,RAD,0.0,KFUND)
       GO TO 40
   32 IF(RAD .GE. ALPHA + R60)GO TO 33
       ACAL = -ER + AK3 * EXP(P2 * (RAD - ALPHA)) + FA2(K1,RAD,0.0,KFUND)
       GO TO 40
   33 IF(RAD .GE. ALPHA + COM(K1) + R60)GO TO 34
       ACAL = -ER + 2.0 * AK2 * EXP(P1 * (RAD - ALPHA - R60)) +
     1       FA1(K1,RAD,-R60,KFUND) + FC1(K1,RAD,-R60,KFUND)
       GO TO 40
   34 IF(RAD .GE. ALPHA + R120)GO TO 35
       ACAL = -ER + AK3 * EXP(P2 * (RAD - ALPHA - R60)) +
     1       FA2(K1,RAD,-R60,KFUND)
       GO TO 40
   35 IF(RAD .GE. ALPHA + COM(K1) + R120)GO TO 40
       ACAL = -AK1 - ER / 2.0 + AK2 * EXP(P1 * (RAD - ALPHA - R120)) +
     1       FC1(K1,RAD,-R120,KFUND)
   40 DIFF = ACAL - ASER
   20 WRITE (*,1002)DEG,ACAL,ASER,DIFF
       RETURN
 1000 FORMAT(/1X,'LOADI ',3I5,7E15.6)
 1002 FORMAT(1X,'LOADI',5E15.6)
       END
C
       SUBROUTINE LOADPAR(KFUND)
       COMPLEX YBUS, CMPZERO, CMPONE
       LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
       CHARACTER * 2 SUBNAME
       CHARACTER * 12 BUSNAME, BTEMPN
       CHARACTER * 80 TITLE, COMMENT
       COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
       COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
       COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
       COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
       COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
       MIN = NLIN + 1
       DO 1 M = MIN,NB
       DO 2 L = 1,NOHAR
       GRTEMPO(L) = GR(M,L)
    2 GITEMPO(L) = GI(M,L)
       AOLD      = DELAY(M)
       DELAY(M) = DELAY(M) + DEPART
       CALL LOADI(M,KFUND,0)
       DO 3 L    = 1,NOHAR
       IF(L .EQ. 1)KROW = 2 * (NB * NOHAR + (M - NLIN))
       IF(L .GT. 1)KROW = 2 * (NB * (L - 1) + M)
       KCOL = 2 * (NB * NOHAR + (M - NLIN))
       AJAC(KROW - 1,KCOL - 1) = (GR(M,L) - GRTEMPO(L)) / DEPART
    3 AJAC(KROW,KCOL - 1)     = (GI(M,L) - GITEMPO(L)) / DEPART
       DELAY(M) = AOLD
       ROLD = RCONV(M)
       EOLD = ECONV(M)
       IF(NBTYPE(M) .EQ. 1)RCONV(M) =. RCONV(M) + DEPART
       IF(NBTYPE(M) .EQ. 2)ECONV(M) = ECONV(M) + DEPART
       CALL LOADI(M,KFUND,0)
       DO 11 L = 1,NOHAR
       IF(L .EQ. 1)KROW = 2 * (NB * NOHAR + (M -NLIN))
       IF(L .GT. 1)KROW = 2 * (NB * (L - 1) + M)
       KCOL = 2 * (NB * NOHAR + (M - NLIN))
       AJAC(KROW - 1,KCOL) = (GR(M,L) - GRTEMPO(L)) / DEPART
       AJAC(KROW,KCOL)     = (GI(M,L) - GITEMPO(L)) / DEPART
       GR(M,L)   = GRTEMPO(L)
   11 GI(M,L)   = GITEMPO(L)
       RCONV(M) = ROLD
       ECONV(M) = EOLD
    1 CONTINUE
       RETURN
       END
C
       SUBROUTINE MESSAGE(IMES)
       COMPLEX YBUS, CMPZERO, CMPONE
       LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
```

```
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
     4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      WRITE (*,1000)IMES
 1000 FORMAT(1X,17H*** MESSAGE CODE ,I5,4H ***)
      GO TO (1,2,3,4,5,6,7,8,9,10) , IMES
    1 WRITE (*,1001)
 1001 FORMAT(1X,'ASSUMED TRANSFORMER CONNECTION TYPE = 1'/)
      RETURN
    2 WRITE (*,1002)
 1002 FORMAT(1X,'ASSUMED SHUNT CONNECTION TYPE = 1'/)
      RETURN
    3 WRITE (*,1003)
 1003 FORMAT(1X,'THE ITERATIVE SOLUTION OF THE COMMUTATION ANGLE FOR'
     1,' THE LINE COMMUTATED CONVERTER AT BUS ',I5/1X,'CONVERGED'
     2,' OUTSIDE THE ACCEPTABLE RANGE OF 0 - 60 DEGREES'/1X,'ITER = ',
     3I5,', COMMUTATION ANGLE = ',F12.2,'   THE COMMUTATION ANGLE '
     4,'WILL BE RESET TO THE NEAREST LIMIT'/)
      RETURN
    4 WRITE (*,1004)
 1004 FORMAT(1X,'A TRANSFORMER SHOULD NOT HAVE LINE CHARGING',
     1' - THIS VALUE OF CHARGING IS IGNORED'/)
      RETURN
    5 WRITE (*,1005)ISDUM1,EDUM1
 1005 FORMAT(1X,'THE ITERATIVE SOLUTION OF THE END OF PERIOD 2 FOR'
     1,' A LINE COMMUTATED CONVERTER AT BUS ',I5,' CONVERGED TO '/
     221X,F12.2,' DEGREES (PAST DELAY ANGLE).  THIS IS OUTSIDE THE ',
     3'ACCEPTABLE RANGE OF 0 TO 60 DEGREES.  RESET TO THE ',
     4'NEAREST LIMIT'/)
      RETURN
    6 WRITE (*,1006)
 1006 FORMAT(1X,'USING A CONSTANT CURRENT CONVERTER MODEL, P SHOULD ',
     1'NOT EXCEED 3 * S / PI.'/1X,'CONVERGENCE MAY BE DIFFICULT,'/)
      RETURN
    7 WRITE (*,1007)
 1007 FORMAT(1X,'THE R AT THE PRECEEDING BUS IS PROBABLY TOO LARGE ',
     1'TO ALLOW THE SPECIFIED LOAD.'/1X,'NON REALISTIC NEGATIVE '
     2,'E MAY RESULT'/)
      RETURN
    8 WRITE (*,1008)
 1008 FORMAT(1X,'THE R AT THE PRECEEDING BUS IS PROBABLY TOO LARGE ',
     1'TO ALLOW THE SPECIFIED GENERATION.'/1X,'NON REALISTIC POSITIVE '
     2,'E MAY RESULT'/)
      RETURN
    9 WRITE (*,1009)ISDUM1
 1009 FORMAT(1X,'THE TIME CONSTANTS FOR THE LINE COMMUTATED CONVERTER '
     1,' AT BUS ',I5,' ARE VERY SMALL'/1X,'PROBLEMS MAY ARISE IN ',
     2'USING EXPONENTIAL FUNCTIONS'/)
      RETURN
   10 WRITE (*,1010)
 1010 FORMAT(1X,'ASSUMED NONLINEAR ELEMENT CONNECTION TYPE = 1'/)
      RETURN
      END
```

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C
      SUBROUTINE NL1DATA
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20)
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      WRITE (*,22)
   22 FORMAT(1X,130(1H-))
      CALL PGHEAD(3)
 1101 READ   (5,1000)KBUS,R,F,E,ALPHA,RS,XS,KTYPE
      IF(KBUS .EQ. 999)GO TO 5
      KINT = NBINT(KBUS)
      WRITE (*,1004)KBUS,R,F,E,ALPHA,RS,XS,KTYPE
      IF(KBUS .LT. 1 .OR. KBUS .GT. MBHUSE)CALL ERROR(7)
      IF(KINT .EQ. 0)CALL ERROR(17)
      IF(NBTYPE(KINT) .NE. 1)CALL ERROR(20)
      ISUB = NBSUBT(KINT)
      IF(KTRCON(KINT) .NE. 0)CALL ERROR(13)
      IF(KTYPE .NE. 0)GO TO 1103
      CALL MESSAGE(1)
      KTYPE = 1
 1103 IF(KTYPE .LT. 1 .OR. KTYPE .GT. NTRMAX)CALL ERROR(4)
      IF(RS .LT. 0.0)CALL ERROR(29)
      IF(XS .LT. EP6)CALL ERROR(34)
      IF(F .LT. 0.0)CALL ERROR(23)
      IF(ABS(R) .GT. EP6)CALL ERROR(35)
      IF(ISUB .LT. 5 .AND. ABS(ALPHA) .GT. EP6)CALL ERROR(36)
      IF(ABS(E) .GT. EP6)CALL ERROR(39)
      IF(ISUB .NE. 5)GO TO 1104
      IF(ALPHA .LT. 0.0 .OR. ALPHA .GT. 120.0)CALL ERROR(38)
 1104 RCONV(KINT)  = R
      FCONV(KINT)  = F
      ECONV(KINT)  = E
      DELAY(KINT)  = ALPHA / DR
      RTRCON(KINT) = RS
      XTRCON(KINT) = XS
      KTRCON(KINT) = KTYPE
      GO TO 1101
    5 WRITE (*,1002)
      RETURN
 1000 FORMAT(I4,2PF8.2,2F8.2,0PF8.2,2PF8.2,F8.2,I1)
 1002 FORMAT(/1X,'END OF NONLINEAR TYPE 1 BUS DATA')
 1004 FORMAT(1X,I4,2PF10.2,2F10.2,0PF10.2,2PF10.2,F10.2,I10)
      END
C
      SUBROUTINE NL2DATA
      COMPLEX YBUS, CMPZERO, CMPONE -
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
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     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      WRITE (*,22)
   22 FORMAT(1X,130(1H-))
      CALL PGHEAD(6)
 1201 READ  (5,1000)KBUS,R,F,E,ALPHA,RS,XS,KTYPE
      IF(KBUS .EQ. 999)GO TO 5
      KINT = NBINT(KBUS)
      WRITE (*,1004)KBUS,R,F,E,ALPHA,RS,XS,KTYPE
      IF(KBUS .LT. 1 .OR. KBUS .GT. MBHUSE)CALL ERROR(7)
      IF(KINT .EQ. 0)CALL ERROR(17)
      IF(NBTYPE(KINT) .NE. 2)CALL ERROR(20)
      ISUB = NBSUBT(KINT)
      IF(KTRCON(KINT) .NE. 0)CALL ERROR(13)
      IF(KTYPE .NE. 0)GO TO 1203
      CALL MESSAGE(1)
      KTYPE = 1
 1203 IF(KTYPE .LT. 1 .OR. KTYPE .GT. NTRMAX)CALL ERROR(4)
      IF(RS .LT. 0.0 .OR. R .LT. 0.0)CALL ERROR(29)
      IF(XS .LT. EP6)CALL ERROR(34)
      IF(F .LT. 0.0)CALL ERROR(23)
      IF(R .LT. EP6)CALL ERROR(52)
      IF(ISUB .LT. 5 .AND. ABS(ALPHA) .GT. EP6)CALL ERROR(36)
      IF(ISUB .LT. 6 .AND. ABS(E) .GT. EP6)CALL ERROR(39)
      IF(ISUB .LT. 5)GO TO 1204
      IF(ALPHA .LT. 0.0 .OR. ALPHA .GE. 180.0)CALL ERROR(38)
      IF(ISUB .GT. 5)GO TO 1205
      IF(PL(KINT) .GT. 0.0 .AND. ALPHA .GT. 90.0)CALL ERROR(38)
      IF(PG(KINT) .GT. 0.0 .AND. ALPHA .LT. 90.0)CALL ERROR(38)
      GO TO 1204
 1205 IF(E .GT. 0.0 .AND. ALPHA .GT. 90.0)CALL ERROR(38)
      IF(E .LT. 0.0 .AND. ALPHA .LT. 90.0)CALL ERROR(38)
 1204 RCONV(KINT)   = R
      FCONV(KINT)   = F
      ECONV(KINT)   = E
      DELAY(KINT)   = ALPHA / DR
      RTRCON(KINT) = RS
      XTRCON(KINT) = XS
      KTRCON(KINT) = KTYPE
      GO TO 1201
    5 WRITE (*,1002)
      RETURN
 1000 FORMAT(I4,2PF8.2,2F8.2,0PF8.2,2PF8.2,F8.2,I1)
 1002 FORMAT(/1X,'END OF NONLINEAR TYPE 2 BUS DATA')
 1004 FORMAT(1X,I4,2PF10.2,2F10.2,0PF10.2,2PF10.2,F10.2,I10)
      END
C
      SUBROUTINE ORDER
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      DO 10 LBUS = 1,NB
      IF (NBSUBT(LBUS) .EQ. 1) GO TO 11
   10 CONTINUE
   11 KRENUM(1) = LBUS
      IPOS = 2
      KNUM = 1
      IF (NPVLIN .EQ. 1) GO TO 30
      DO 21 LBUS = 1,NB
```

```
      IF (NBSUBT(LBUS) .NE. 2) GO TO 21
      KNUM = KNUM + 1
      KRENUM(IPOS) = LBUS
      IPOS = IPOS + 1
      IF (IPOS .GT. NB) GO TO 60
      IF (KNUM .EQ. NPVLIN) GO TO 30
   21 CONTINUE
   30 KNUM = 0
      IF (NPQLIN .EQ. 0) GO TO 40
      DO 31 LBUS = 1,NB
      IF (NBTYPE(LBUS) .NE. 0 .OR. NBSUBT(LBUS) .NE. 3) GO TO 31
      KNUM = KNUM + 1
      KRENUM(IPOS) = LBUS
      IPOS = IPOS + 1
      IF (IPOS .GT. NB) GO TO 60
   31 CONTINUE
   40 KNUM = 0
      NDUM = NNL1 + NNL2
      IF (NDUM .EQ. 0) GO TO 60
      DO 41 LBUS = 1,NB
      IF (NBTYPE(LBUS) .NE. 1 .AND. NBTYPE(LBUS) .NE. 2) GO TO 41
      KNUM = KNUM + 1
      KRENUM(IPOS) = LBUS
      IPOS = IPOS + 1
      IF (IPOS .GT. NB) GO TO 60
      IF(KNUM .EQ. NDUM)GO TO 60
   41 CONTINUE
   60 DO 70 IPOS = 1,NB
      KEXT  = NBEXT(IPOS)
      INDEX = KRENUM(IPOS)
      IF (IPOS .EQ. INDEX) GO TO 70
      BTEMPN   = BUSNAME(IPOS)
      KNBT     = NBTYPE(IPOS)
      KNBS     = NBSUBT(IPOS)
      DUMA     = PL(IPOS)
      DUMB     = QL(IPOS)
      DUMC     = S(IPOS)
      DUMD     = PG(IPOS)
      DUME     = QG(IPOS)
      DUMF     = V(IPOS)
      DUMG     = SRCBL(IPOS)
      KSH      = KSHTYPE(IPOS)
C
      KXDUM         = NBEXT(INDEX)
      NBEXT(IPOS)   = KXDUM
      NBINT(KXDUM)  = IPOS
      BUSNAME(IPOS) = BUSNAME(INDEX)
      NBTYPE(IPOS)  = NBTYPE(INDEX)
      NBSUBT(IPOS)  = NBSUBT(INDEX)
      PL(IPOS)      = PL(INDEX)
      QL(IPOS)      = QL(INDEX)
      S(IPOS)       = S(INDEX)
      PG(IPOS)      = PG(INDEX)
      QG(IPOS)      = QG(INDEX)
      V(IPOS)       = V(INDEX)
      SRCBL(IPOS)   = SRCBL(INDEX)
      KSHTYPE(IPOS) = KSHTYPE(INDEX)
C
      NBEXT(INDEX)   = KEXT
      NBINT(KEXT)    = INDEX
      BUSNAME(INDEX) = BTEMPN
      NBTYPE(INDEX)  = KNBT
      NBSUBT(INDEX)  = KNBS
      PL(INDEX)      = DUMA
      QL(INDEX)      = DUMB
      S(INDEX)       = DUMC
      PG(INDEX)      = DUMD
      QG(INDEX)      = DUME
      V(INDEX)       = DUMF
      SRCBL(INDEX)   = DUMG
      KSHTYPE(INDEX) = KSH
      IF (IPOS .EQ. NB) GO TO 70
      IPOS1 = IPOS + 1
      DO 71 K = IPOS1,NB
      IF (KRENUM(K) .NE. IPOS) GO TO 71
      KRENUM(K) = INDEX
      GO TO 70
   71 CONTINUE
   70 CONTINUE
      RETURN
      END
C
      SUBROUTINE OUTPUT(KFUND)
      COMPLEX VK1, VK2, VV1, VV2, AMPS, ZLIN, SK1K2, T
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
```

```
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      PTLOSS = 0.0
      LMAX   = 1
      IF(KFUND .EQ. 2 .AND. IOPT(8) .EQ. 0)LMAX = NOHAR
      ISDUM2 = 0
      IF(KFUND .EQ. 2 .AND. IOPT(14) .NE. 0)ISDUM2 = 1
      DO 5 LHAR = 1,LMAX
      KHAR   = NHVECT(LHAR)
      ISDUM1 = KHAR
      KSEQ   = NPHSEQ(LHAR)
      PLOSS  = 0.0
      IF(LHAR .EQ. 1)CALL PGHEAD(5)
      IF(LHAR .GT. 1)CALL PGHEAD(10)
      KBUS   = 0
      DO 1 J = 1,MBHUSE
      IF(KBUS .EQ. NB)GO TO 11
      K1 = NBINT(J)
      IF(K1 .EQ. 0)GO TO 1
      KBUS   = KBUS + 1
      K1POS  = 2 * K1 + 2 * (LHAR - 1) * NB
      VOLTK1 = X(K1POS)
      ANGK1  = X(K1POS - 1) / VOLTK1
      DEGK1  = ANGK1 * DR
      VK1    = VOLTK1 * CMPLX(COS(ANGK1),SIN(ANGK1))
      QSHUNT = VOLTK1 * VOLTK1 * SRCBL(K1)
      IF(QSHUNT .GT. 0.0)QSHUNT = QSHUNT / FLOAT(KHAR)
      IF(QSHUNT .LT. 0.0)QSHUNT = QSHUNT * FLOAT(KHAR)
      PPL = PL(K1)
      QQL = QL(K1)
      PPG = PG(K1)
      QQG = QG(K1)
      IF(KFUND .EQ. 1 .OR. LHAR .GT. 1 .OR. NBTYPE(K1) .EQ. 0)GO TO 9
      PPL = 0.0
      QQL = 0.0
      PPG = 0.0
      QQG = 0.0
      AMPS   = CMPLX(GR(K1,LHAR),GI(K1,LHAR))
      SK1K2  = VK1 * CONJG(AMPS)
      PREAL  = DBLE(SK1K2)
      PREACT = AIMAG(SK1K2)
      IF(PREAL .GE. 0.0)GO TO 10
      PPG = -PREAL
      QQG = -PREACT
      GO TO 9
   10 PPL = PREAL
      QQL = PREACT
    9 IF(LHAR .EQ. 1)WRITE (*,1000)J,BUSNAME(K1),VOLTK1,DEGK1,PPG,QQG,
     1                      PPL,QQL,QSHUNT
      IF(LHAR .GT. 1)WRITE (*,1008)J,BUSNAME(K1),VOLTK1,DEGK1
      IF(LHAR .EQ. 1)PLOSS = PLOSS + PPG - PPL
      DO 2 K = 1,NLINES
      IF(KSHAR(K) .LT. 0 .AND. LHAR .EQ. 1)GO TO 2
      KFROM = LINES(1,K)
      KTO   = LINES(2,K)
      IF(KFROM .NE. K1 .AND. KTO .NE. K1)GO TO 2
      K2     = KTO
      IF(K1 .EQ. KTO)K2 = KFROM
      RR     = R1(K)
      XX     = X1(K)
      GG     = 0.0
      BB     = B1(K)
      T      = CMPONE
      VK2    = CMPZERO
      IF(K2 .EQ. 0)GO TO 3
      K2POS  = 2 * K2 + 2 *(LHAR - 1) * NB
      VOLTK2 = X(K2POS)
      ANGK2  = X(K2POS - 1) / VOLTK2
      VK2    = VOLTK2 * CMPLX(COS(ANGK2),SIN(ANGK2))
    3 VV1    = VK1
```

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      VV2    = VK2
      IF(KTRTYPE(K) .NE. 0 .OR. K2 .EQ. 0)GO TO 52
      IF(KSEQ .NE. 0)GO TO 51
      RR = RO(K)
      XX = XO(K)
      BB = BO(K)
   51 CALL ZLINE(RR,XX,GG,BB,KHAR)
      GO TO 6
   52 IF(KTRTYPE(K) .NE. 0)GO TO 53
      IF(KSEQ .EQ. 0 .AND. IABS(KSHAR(K)) .NE. 1)GO TO 2
      IF(XX .GE. 0.0) XX = XX * FLOAT(KHAR)
      IF(XX .LT. 0.0) XX = XX / FLOAT(KHAR)
      GO TO 6
   53 CALL ZTRAN(RR,XX,KHAR)
      IF(KSEQ .EQ. 0)GO TO 55
      T = CMPLX(TAP(K),0.0)
      IF(KTRTYPE(K) .EQ. 6 .OR. KTRTYPE(K) .EQ. 7) T = T *
     1CMPLX(COS30,-FLOAT(KSEQ) * SIN30)
      IF(KTRTYPE(K) .EQ. 8 .OR. KTRTYPE(K) .EQ. 9) T = T *
     1CMPLX(COS30, FLOAT(KSEQ) * SIN30)
      IF(K1 .EQ. KFROM)VV1 = VK1 / T
      IF(K2 .EQ. KFROM)VV2 = VK2 / T
      GO TO 6
   55 IF(KTRTYPE(K) .EQ. 1)GO TO 6
      IF(KTRTYPE(K) .NE. 6 .AND. KTRTYPE(K) .NE. 8)GO TO 2
      IF(K1 .EQ. KFROM .AND. KTRTYPE(K) .NE. 8)GO TO 2
      IF(K1 .EQ. KTO .AND. KTRTYPE(K) .NE. 8)GO TO 2
      VV2    = CMPZERO
      K2     = -1
    6 ZLIN   = CMPLX(RR,XX)
      AMPS   = (VV1 - VV2) / ZLIN + VV1 * CMPLX(GG,BB)
      SK1K2 = VV1 * CONJG(AMPS)
      P      = DBLE(SK1K2)
      Q      = AIMAG(SK1K2)
      AMAG   = CABS(AMPS)
      IF(K1 .EQ. KFROM .AND. KSEQ .NE. 0)AMAG = AMAG / CABS(T)
      AANG   = 0.0
      IF(AMAG .GT. EP9)AANG = ATAN2(AIMAG(AMPS),DBLE(AMPS)) * DR
      IF(K2 .LE. 0)PLOSS = PLOSS - P
      IF(LHAR .GT. 1)GO TO 7
      IF(K2 .NE. 0)WRITE (*,1002)NBEXT(K2),BUSNAME(K2),P,Q
      IF(K2 .EQ. 0)WRITE (*,1006)P,Q
      IF(KTRTYPE(K) .NE. 0 .AND. K1 .EQ. KFROM)WRITE (*,1004)TAP(K)
      GO TO 2
    7 IF(K2 .GT. 0)WRITE (*,1010)NBEXT(K2),BUSNAME(K2),P,Q,AMAG,AANG
      IF(K2 .EQ. 0)WRITE (*,1014)P,Q,AMAG,AANG
      IF(K2 .LT. 0)WRITE (*,1024)P,Q,AMAG,AANG
      IF(KTRTYPE(K) .NE. 0 .AND. K1 .EQ. KFROM .AND. K2 .NE. -1)WRITE
     1(*,1012)TAP(K)
    2 CONTINUE
      IF(LHAR .EQ. 1)GO TO 1
      IF(ABS(SRCBL(K1)) .LT. EP6)GO TO 8
      AMPS   = CMPLX(0.0,-QSHUNT) / CONJG(VK1)
      AMAG   = CABS(AMPS)
      AANG   = ATAN2(AIMAG(AMPS),DBLE(AMPS)) * DR
      P      = 0.0
      WRITE (*,1016)P,QSHUNT,AMAG,AANG
    8 IF(NBTYPE(K1) .EQ. 0)GO TO 1
      AMPS   = CMPLX(GR(K1,LHAR),GI(K1,LHAR))
      SK1K2 = VK1 * CONJG(AMPS)
      P      = DBLE(SK1K2)
      PLOSS = PLOSS - P
      Q      = AIMAG(SK1K2)
      AMAG   = CABS(AMPS)
      AANG   = 0.0
      IF(AMAG .GT. EP9)AANG = ATAN2(AIMAG(AMPS),DBLE(AMPS)) * DR
      WRITE (*,1018)P,Q,AMAG,AANG
    1 CONTINUE
   11 IF(KFUND .EQ. 2)WRITE (*,1020)PLOSS
      PTLOSS = PTLOSS + PLOSS
    5 CONTINUE
      WRITE (*,1022)PTLOSS
      RETURN
 1000 FORMAT(1X,130(1H-)/1X,I4,2X,A12,2PF7.2,0PF8.2,2PF10.2,4F10.2)
 1002 FORMAT(85X,I5,2X,A12,2PF10.2,F10.2)
 1004 FORMAT(1H-,123X,F7.3)
 1006 FORMAT(86X,'NEUT',2X,'Z SHUNT',2PF15.2,F10.2)
 1008 FORMAT(1X,112(1H-)/1X,I4,2X,A12,2PF9.4,0PF8.2)
 1010 FORMAT(36X,I6,2X,A12,2PF14.6,2F14.6,0PF8.2)
 1012 FORMAT(1H-,105X,F7.3)
 1014 FORMAT(38X,'NEUT',2X,'Z SHUNT',5X,2PF14.6,2F14.6,0PF8.2)
 1016 FORMAT(38X,'NEUT',2X,'Q SHUNT',5X,2PF14.6,2F14.6,0PF8.2)
 1018 FORMAT(38X,'NEUT',2X,'NONLIN DEV.',1X,2PF14.6,2F14.6,0PF8.2)
 1020 FORMAT(1X,46(1H-)/1X,'REAL POWER LOSS FOR THIS HARMONIC = ',
     12PF10.2)
 1022 FORMAT(1X,46(1H-)/1X,'TOTAL REAL POWER LOSS = ',2PF22.2)
 1024 FORMAT(38X,'NEUT',2X,'T SHUNT',5X,2PF14.6,2F14.6,0PF8.2)
      END
C
      SUBROUTINE PGHEAD(IPTYPE)
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```
          COMPLEX YB
          LOGICAL PV,PS
          COMPLEX YBUS, CMPZERO, CMPONE
          LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
         1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
          CHARACTER * 2 SUBNAME
          CHARACTER * 12 BUSNAME, BTEMPN
          CHARACTER * 80 TITLE, COMMENT
          COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
          COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
         1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
         2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
         3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
         4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
         5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
         6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
         7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
         8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
         9HPEAK, ACCEL
          COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
          COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
         1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
         2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
         3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
         4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
         5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
         6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
          COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
         1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
    C
          IF(IPTYPE .EQ. 0)RETURN
          GO TO (1,2,3,4,5,6,7,8,9,10,11,12) , IPTYPE
        1 WRITE (*,1001)
     1001 FORMAT(/1X,'FUNDAMENTAL LOADFLOW BUS DATA   (PERCENT VOLTAGE, ',
         1'POWER)'/2X,'BUS',2X,
         2'NAME',10X,'TYPE',2X,'SUB-TYPE',5X,'P GEN',5X,'Q GEN',4X,
         3'   S',4X,'P LOAD',4X,'Q LOAD',3X,'VOLTAGE',3X,'Q SHUNT',
         44X,'KSHTYPE'/)
          RETURN
        2 WRITE (*,1002)
     1002 FORMAT(/1X,'LINE AND TRANSFORMER DATA   (PERCENT IMPEDANCE,  ',
         1'CHARGING)'/1X,'FROM',6X,'TO'/2X,'BUS',5X,'BUS',8X,'R1',8X,'X1'
         2,8X,'C1',8X,'RO',8X,'XO',8X,'CO',7X,'TAP',7X,'T-TYPE',6X,
         3'Z-TYPE',6X,'H-ONLY'/)
          RETURN
        3 WRITE (*,1003)
     1003 FORMAT(/1X,'NONLINEAR TYPE 1 BUS DATA'/2X,'BUS',
         19X,'R',9X,'F',9X,'E',5X,'DELAY',8X,'RS',8X,'XS',5X,'KTYPE'/)
          RETURN
        4 WRITE (*,1004)
     1004 FORMAT(/1X,'SOLUTION OPTIONS'/)
          RETURN
        5 IF(TERMINAL)WRITE (*,1099)
          IF(ISDUM2 .NE. 0)WRITE (*,1100)
          WRITE (*,1005)
     1005 FORMAT(/1X,'FUNDAMENTAL LOADFLOW OUTPUT   (PERCENT VOLTAGE, ',
         1'POWER)'/1X,'FROM',83X,'TO',
         2/2X,'BUS',2X,'NAME',8X,'VOLTAGE',3X,'ANGLE',8X,'PG',8X,'QG',
         38X,'PL',8X,'QL',3X,'Q SHUNT',3X,'BUS',2X,'NAME',15X,'P',9X,
         4'Q',6X,'TAP'/)
          RETURN
        6 WRITE (*,1006)
     1006 FORMAT(/1X,'NONLINEAR TYPE 2 BUS DATA'/2X,'BUS'
         1,9X,'R',9X,'F',9X,'E',5X,'DELAY',8X,'RS',8X,'XS',5X,'KTYPE'/)
          RETURN
        7 WRITE (*,22)
       22 FORMAT(1X,130(1H-))
          WRITE (*,1007)
     1007 FORMAT(/1X,'FUNDAMENTAL LOADFLOW ITERATION SUMMARY'//
         115X,'ABSOLUTE REAL POWER MISMATCH',5X,'ABSOLUTE REACTIVE'
         2,' POWER MISMATCH'/38X,'WORST',32X,'WORST'/1X,'ITERATION'
         3,2(8X,'AVERAGE',5X,'WORST',5X,'BUS',4X)/)
          RETURN
        8 WRITE (*,22)
          WRITE (*,1008)
     1008 FORMAT(/1X,'HARMONIC LOADFLOW ITERATION SUMMARY'//42X,'ABSOLUTE'
         1,' REAL MISMATCH',7X,'ABSOLUTE IMAGINARY MISMATCH',15X,'VOLTAMP'
         2,'ERE MISMATCH'/30X,3(29X,'WORST')/1X,'ITERATION',2X,'QUANTITY',
         32X,'HARMONIC',3(7X,'AVERAGE',5X,'WORST',7X,'BUS')/)
          RETURN
        9 WRITE (*,22)
          WRITE (*,1009)
     1009 FORMAT(/1X,'STARTING ESTIMATES OF NONLINEAR DEVICE PARAMETERS'//
         12X,'BUS',2X,'NAME',10X,'TYPE',5X,'P GEN',5X,'Q GEN',4X,'P LOAD',
         24X,'Q LOAD',5X,'DELAY',9X,'R',9X,'E'/)
          RETURN
       10 IF(TERMINAL)WRITE(*,1099)
          IF(IOPT(14) .NE. 0)WRITE (*,1100)
          WRITE (*,22)
          KF = ISDUM1 * 50
```

```
      WRITE (*,1010)ISDUM1,KF
1010 FORMAT(/1X,'HARMONIC LOADFLOW OUTPUT FOR HARMONIC NUMBER ',I3,
   1', FREQUENCY = ',I5,' HZ.   (PERCENT VOLTAGE, CURRENT, POWER)'/
   21X,'FROM',14X,'---- VOLTAGE ----',3X,'TO',48X,'---- CURRENT '
   3,'----'/2X,'BUS',2X,'NAME',8X,'MAGNITUDE',3X,'ANGLE',3X,
   4'BUS',2X,'NAME',19X,'P',13X,'Q',7X,'MAGNITUDE',
   53X,'ANGLE',4X,'TAP'/)
      RETURN
   11 IF(TERMINAL)WRITE(*,1099)
      IF(IOPT(14) .NE. 0)WRITE(*,1100)
      WRITE (*,22)
      WRITE (*,1011)
1011 FORMAT(/1X,'TOTAL CURRENT/POWER SUMMARY   (PERCENT VALUES)'
   1//41X,16('-'),1X,
   2'CURRENT',1X,15('-'),4X,16('-'),1X,'POWER',1X,15('-')/1X,
   3'FROM',17X,'TO',20X,' FUND',6X,'RMS',6X,'PEAK',4X,'HARMONIC'
   4/2X,'BUS',2X,'NAME',11X,'BUS',2X,'NAME',8X,3(5X,'VALUE'),2X,
   5'DISTORTION',11X,'P',9X,'Q',9X,'D',9X,'S'/)
      RETURN
   12 IF(TERMINAL)WRITE (*,1099)
      IF(IOPT(14) .NE. 0)WRITE (*,1100)
      WRITE (*,22)
      WRITE (*,1012)
1012 FORMAT(/1X,'BUS VOLTAGE SUMMARY   (PERCENT VALUES)'//
   121X,'FUNDAMENTAL',
   27X,'RMS',10X,'PEAK',8X,'HARMONIC'/2X,'BUS',2X,'NAME',13X,
   3'VALUE',2(9X,'VALUE'),6X,'DISTORTION'/)
      RETURN
1099 FORMAT(1X,'N O N C O N V E R G E N T    C A S E')
1100 FORMAT(1X,'NOTE - NONLINEAR DEVICE CURRENTS WERE SOLVED WITHOUT '
   1,'USING HARMONIC VOLTAGES')
      END
C
      SUBROUTINE PQMOD(KFUND)
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
   1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
   1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
   2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
   3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
   4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
   5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
   6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
   7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
   8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
   9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
   1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
   2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
   3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
   4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
   5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
   6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
   1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      LMAX = 1
      IF(KFUND .EQ. 2)LMAX = NOHAR
      K1MIN = NLIN + 1
      DO 1 K1 = K1MIN,NB
      IF(NBTYPE(K1) .NE. 3 .AND. NBSUBT(K1) .LT. 4)GO TO 1
      V2 = 0.0
      A2 = 0.0
      PP = 0.0
      QQ = 0.0
      DO 2 L = 1,LMAX
      K1POS = 2 * K1 + 2 * NB * (L - 1)
      VMAG  = X(K1POS)
      VANG  = X(K1POS - 1) / VMAG
      AMAG  = SQRT(GR(K1,L)**2 + GI(K1,L)**2)
      AANG  = ATAN2(GI(K1,L),GR(K1,L))
      V2    = V2 + VMAG * VMAG
      A2    = A2 + AMAG * AMAG
      PP    = PP + VMAG * AMAG * COS(VANG - AANG)
    2 QQ    = QQ + VMAG * AMAG * SIN(VANG - AANG)
      IF(NBSUBT(K1) .NE. 6)GO TO 10
      PL(K1) = 0.0
      PG(K1) = 0.0
      IF(PP .GT. 0.0)PL(K1) = PP
      IF(PP .LE. 0.0)PG(K1) = -PP
      Y(2 * K1 - 1) = PG(K1) - PL(K1)
   10 IF(NBSUBT(K1) .EQ. 4)GO TO 20
      QL(K1) = 0.0
      QG(K1) = 0.0
```

```
      IF(PG(K1) .GT. 0.0)QG(K1) = -QQ
      IF(PG(K1) .LE. 0.0)QL(K1) =  QQ
      GO TO 30
20 D2 = V2 * A2 - PP * PP - QQ * QQ
   Q2 = S(K1)**2 - (PG(K1) - PL(K1))**2 - D2
   IF(Q2 .LT. 0.0)Q2 = 0.0
   QQ       = SQRT(Q2)
   QL(K1) = 0.0
   QG(K1) = 0.0
   IF(PG(K1) .GT. 0.0)QG(K1) = -QQ
   IF(PG(K1) .LE. 0.0)QL(K1) =  QQ
30 Y(2 * K1) = QG(K1) - QL(K1)
 1 CONTINUE
   RETURN
   END
C
   SUBROUTINE REDUCE(KFUND,KIT)
   COMPLEX YBUS, CMPZERO, CMPONE
   LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
  1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
   CHARACTER * 2 SUBNAME
   CHARACTER * 12 BUSNAME, BTEMPN
   CHARACTER * 80 TITLE, COMMENT
   COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
   COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
  1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
  2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
  3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), G0(50),
  4B0(50), R0(50), X0(50), TAP(50), PSHIFT(9), GRTEMPO(9),
  5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
  6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
  7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
  8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
  9HPEAK, ACCEL
   COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
   COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
  1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
  2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
  3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
  4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
  5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
  6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
   COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
  1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
   IF(KFUND .EQ. 1)JSIZE = 2 * NB
   IF(KFUND .EQ. 2)JSIZE = 2 * (NB * NOHAR + NNLIN)
   JS1 = JSIZE - 1
   DO 1 KDIAG = 3,JS1
   ISDUM1 = KDIAG
   KDP1    = KDIAG + 1
   DO 2 KROW = KDP1,JSIZE
   EDUM1      = AJAC(KDIAG,KDIAG)
   IF(ABS(AJAC(KDIAG,KDIAG)) .LT. EP6)CALL ERROR(30)
   FACTOR = AJAC(KROW,KDIAG) / AJAC(KDIAG,KDIAG)
   DELTAY(KROW) = DELTAY(KROW) - DELTAY(KDIAG) * FACTOR
   DO 3 KCOL = KDIAG,JSIZE
 3 AJAC(KROW,KCOL) = AJAC(KROW,KCOL) - AJAC(KDIAG,KCOL) * FACTOR
 2 CONTINUE
 1 CONTINUE
   ISDUM1 = JSIZE
   EDUM1   = AJAC(JSIZE,JSIZE)
   IF(ABS(AJAC(JSIZE,JSIZE)) .LT. EP6)CALL ERROR(30)
   DELTAX(JSIZE) = -DELTAY(JSIZE) / AJAC(JSIZE,JSIZE)
   JS3 = JSIZE - 3
   DO 5 JDUM = 1,JS3
   J = JSIZE - JDUM
   DELTAX(J) = -DELTAY(J)
   JP1 = J + 1
   DO 6 K = JP1,JSIZE
 6 DELTAX(J) = DELTAX(J) - AJAC(J,K) * DELTAX(K)
   ISDUM1 = J
   EDUM1   = AJAC(J,J)
   IF(ABS(AJAC(J,J)) .LT. EP6)CALL ERROR(30)
 5 DELTAX(J) = DELTAX(J) / AJAC(J,J)
   DO 15 KROW = 1,JSIZE
   DO 15 KCOL = 1,JSIZE
15 AJAC(KROW,KCOL) = 0.0
   IF(NPVLIN .EQ. 1)GO TO 12
   JMAX = 2 * NPVLIN - 1
   DO 7 J = 3,JMAX,2
 7 X(J) = X(J) + DELTAX(J)
   IF(NPVLIN .EQ. NB)RETURN
12 JMAX = 2 * NB - 1
   IF(KFUND .EQ. 2)JMAX = 2 * NB * NOHAR - 1
   JMIN = 2 * NPVLIN + 1
   DO 8 J = JMIN,JMAX,2
   VMAG = X(J + 1)
   VANG = X(J) / VMAG
   VANG = VANG + DELTAX(J) / VMAG
```

```
            VMAG = VMAG + DELTAX(J + 1)
            IF(VMAG .GT. 0.0)GO TO 9
            VMAG = -VMAG
            VANG = VANG + PI
          9 IF(VANG .GE. -PI .AND. VANG .LE. PI) GO TO 11
            IF(VANG .GT.  PI)VANG = VANG - R360
            IF(VANG .LT. -PI)VANG = VANG + R360
            GO TO 9
         11 X(J) = VMAG * VANG
            IF(VMAG .LT. EP9)VMAG = EP9
            X(J + 1) = VMAG
          8 CONTINUE
            IF(KFUND .EQ. 1 .OR. KIT .LE. IOPT(12))RETURN
            JMIN = 2 * NB * NOHAR + 1
            JMAX = JSIZE - 1
            K1   = NLIN + 1
            DO 10 J = JMIN,JMAX,2
            ITYPE = NBTYPE(K1)
            ISUB  = NBSUBT(K1)
            IF(ITYPE .GT. 2)GO TO 10
            IF(ISUB .EQ. 3 .OR. ISUB .EQ. 4)DELAY(K1) = DELAY(K1)
           1+ DELTAX(J) * ACCEL
            IF(DELAY(K1) .LT. 0.0)DELAY(K1) = 0.0
            IF(ITYPE .EQ. 1)RCONV(K1) = RCONV(K1) + DELTAX(J + 1) * ACCEL
            IF(RCONV(K1) .LT. 0.0)RCONV(K1) = EP6
            IF(ITYPE .EQ. 2 .AND. ISUB .NE. 6)ECONV(K1) = ECONV(K1) +
           1DELTAX(J + 1) * ACCEL
         10 K1 = K1 + 1
            RETURN
            END
C
            SUBROUTINE ROTATE(AR,AI,ANGL)
            A     = SQRT(AR * AR + AI * AI)
            THETA = ATAN2(AI,AR) + ANGL
            AR    = A * COS(THETA)
            AI    = A * SIN(THETA)
            RETURN
            END
C
            SUBROUTINE SERIES(M,ALPHA,AEND,KFUND,COMYES,KPART)
            LOGICAL COMYES
            COMPLEX YBUS, CMPZERO, CMPONE
            LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
           1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
            CHARACTER * 2 SUBNAME
            CHARACTER * 12 BUSNAME, BTEMPN
            CHARACTER * 80 TITLE, COMMENT
            COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
            COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
           1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
           2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
           3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
           4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
           5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
           6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
           7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
           8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
           9HPEAK, ACCEL
            COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
            COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
           1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
           2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
           3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
           4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
           5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
           6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
            COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
           1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
            CANG = COM(M)
            DO 11 LP = 1,5
            IF(COMYES)GO TO 10
            IF(LP .EQ. 1 .OR. LP .EQ. 3 .OR. LP .EQ. 5)GO TO 11
         10 GO TO (1,2,3,4,5) , LP
          1 ABOT = ALPHA
            ATOP = ALPHA + CANG
            CC   = AK1 - ER / 2.0
            CE   = AK2
            P    = P1
            ANG  = ALPHA
            GO TO 6
          2 ABOT = ALPHA + CANG
            ATOP = ALPHA + R60
            IF(.NOT. COMYES)ATOP = AEND
            CC   = -ER
            CE   = AK3
            P    = P2
            ANG  = ALPHA
            GO TO 6
          3 ABOT = ALPHA + R60
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      ATOP = ALPHA + R60 + CANG
      CC   = -ER
      CE   = 2.0 * AK2
      P    = P1
      ANG  = R60 + ALPHA
      GO TO 6
    4 ABOT = ALPHA + R60 + CANG
      ATOP = ALPHA + R120
      IF(.NOT. COMYES)ATOP = AEND + R60
      CC   = -ER
      CE   = AK3
      P    = P2
      ANG  = R60 + ALPHA
      GO TO 6
    5 ABOT = ALPHA + R120
      ATOP = ALPHA + R120 + CANG
      CC   = -AK1 - ER / 2.0
      CE   = AK2
      P    = P1
      ANG  = R120 + ALPHA
    6 DO 16 L1 = 1,NOHAR
      IF(NPHSEQ(L1) .EQ. 0)GO TO 16
      LHAR = NHVECT(L1)
      GI(M,L1) = GI(M,L1) + CC / FLOAT(LHAR) * (SIN(FLOAT(LHAR) *
     1           ATOP) - SIN(FLOAT(LHAR) * ABOT))
      GR(M,L1) = GR(M,L1) - CC / FLOAT(LHAR) * (COS(FLOAT(LHAR) *
     1           ATOP) - COS(FLOAT(LHAR) * ABOT))
      BTOP = CE * EXP(P * (ATOP - ANG)) / (P * P + FLOAT(LHAR) *
     1       FLOAT(LHAR))
      BBOT = CE * EXP(P * (ABOT - ANG)) / (P * P + FLOAT(LHAR) *
     1       FLOAT(LHAR))
      FTOP = FLOAT(LHAR) * ATOP
      FBOT = FLOAT(LHAR) * ABOT
      GI(M,L1) = GI(M,L1)    + BTOP * (P * COS(FTOP) + FLOAT(LHAR) *
     1           SIN(FTOP)) - BBOT * (P * COS(FBOT) + FLOAT(LHAR) *
     2           SIN(FBOT))
      GR(M,L1) = GR(M,L1)    + BTOP * (P * SIN(FTOP) - FLOAT(LHAR) *
     1           COS(FTOP)) - BBOT * (P * SIN(FBOT) - FLOAT(LHAR) *
     2           COS(FBOT))
   16 CONTINUE
C
      GO TO (21,22,23,24,25) , LP
   21 EDUM1 = FA1(M,ATOP,0.0,KFUND)
      GO TO 26
   22 EDUM1 = FA2(M,ATOP,0.0,KFUND)
      GO TO 26
   23 EDUM1 = FA1(M,ATOP,-R60,KFUND)
      CALL FFINT(M,ATOP        ,KFUND,+1,KPART)
      EDUM1 = FC1(M,ATOP,-R60,KFUND)
      GO TO 26
   24 EDUM1 = FA2(M,ATOP,-R60,KFUND)
      GO TO 26
   25 EDUM1 = FC1(M,ATOP,-R120,KFUND)
   26 CALL FFINT(M,ATOP,KFUND,+1,KPART)
C
      GO TO (31,32,33,34,35) , LP
   31 EDUM1 = FA1(M,ABOT,0.0,KFUND)
      GO TO 36
   32 EDUM1 = FA2(M,ABOT,0.0,KFUND)
      GO TO 36
   33 EDUM1 = FA1(M,ABOT,-R60,KFUND)
      CALL FFINT(M,ABOT        ,KFUND,-1,KPART)
      EDUM1 = FC1(M,ABOT,-R60,KFUND)
      GO TO 36
   34 EDUM1 = FA2(M,ABOT,-R60,KFUND)
      GO TO 36
   35 EDUM1 = FC1(M,ABOT,-R120,KFUND)
   36 CALL FFINT(M,ABOT,KFUND,-1,KPART)
   11 CONTINUE
      IF(IOPT(9) .NE. 0)WRITE (*,1000)NBEXT(M),(GR(M,L1),L1=1,NOHAR)
      IF(IOPT(9) .NE. 0)WRITE (*,1002)NBEXT(M),(GI(M,L1),L1=1,NOHAR)
      DO 40 L1 = 1,NOHAR
      IF(NPHSEQ(L1) .EQ. 0)GO TO 40
      AR = GR(M,L1) * 2.0 / PI
      AI = GI(M,L1) * 2.0 / PI
      CALL ROTATE(AR,AI,-PSHIFT(L1))
      GR(M,L1) = AR
      GI(M,L1) = AI
   40 CONTINUE
      IF(IOPT(9) .NE. 0)WRITE (*,1000)NBEXT(M),(GR(M,L1),L1=1,NOHAR)
      IF(IOPT(9) .NE. 0)WRITE (*,1002)NBEXT(M),(GI(M,L1),L1=1,NOHAR)
      RETURN
 1000 FORMAT(/1X,'SERIES',I5,8E15.6)
 1002 FORMAT(1X,'SERIES',I5,8E15.6)
      END
C
      SUBROUTINE SUMMARY
      COMPLEX VK1,VK2,VV1,VV2,AMPS,ZLIN,SK1K2,T
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
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1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
 CHARACTER * 2 SUBNAME
 CHARACTER * 12 BUSNAME, BTEMPN
 CHARACTER * 80 TITLE, COMMENT
 COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
 COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
9HPEAK, ACCEL
 COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
 COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
 COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
 CALL PGHEAD(11)
 KBUS = 0
 DO 1 J = 1,MBHUSE
 IF(KBUS .EQ. NB)GO TO 19
 K1 = NBINT(J)
 IF(K1 .EQ. 0)GO TO 1
 KBUS = KBUS + 1
 WRITE (*,1010)
 VRMS = 0.0
 DO 4 LHAR = 1,NOHAR
 K1POS = 2 * K1 + 2 * (LHAR - 1) * NB
 VRMS = VRMS + X(K1POS) * X(K1POS)
 4 CONTINUE
 VRMS = SQRT(VRMS)
 DO 2 K = 1,NLINES
 KFROM = LINES(1,K)
 KTC = LINES(2,K)
 IF(KFROM .NE. K1 .AND. KTO .NE. K1)GO TO 2
 K2 = KTO
 IF(K1 .EQ. KTO)K2 = KFROM
 P = 0.0
 Q = 0.0
 DO 5 LHAR = 1,NOHAR
 KHAR = NHVECT(LHAR)
 KSEQ = NPHSEQ(LHAR)
 IF(KSHAR(K) .LT. 0 .AND. LHAR .EQ. 1)GO TO 2
 RR = R1(K)
 XX = X1(K)
 GG = 0.0
 BB = B1(K)
 T = CMPONE
 K1POS = 2 * K1 + 2 * (LHAR - 1) * NB
 VOLTK1 = X(K1POS)
 ANGK1 = X(K1POS - 1) / VOLTK1
 VK1 = VOLTK1 * CMPLX(COS(ANGK1),SIN(ANGK1))
 VV1 = VK1
 VV2 = CMPZERO
 IF(K2 .EQ. 0)GO TO 3
 K2POS = 2 * K2 + 2 * (LHAR - 1) * NB
 VOLTK2 = X(K2POS)
 ANGK2 = X(K2POS - 1) / VOLTK2
 VK2 = VOLTK2 * CMPLX(COS(ANGK2),SIN(ANGK2))
 VV2 = VK2
 IF(KTRTYPE(K) .NE. 0)GO TO 52
 VV2 = VK2
 IF(KSEQ .NE. 0)GO TO 51
 RR = RO(K)
 XX = XO(K)
 BB = BO(K)
 51 CALL ZLINE(RR,XX,GG,BB,KHAR)
 GO TO 6
 3 IF(KSEQ .EQ. 0 .AND. IABS(KSHAR(K)) .NE. 1)GO TO 5
 IF(XX .GE. 0.0)XX = XX * FLOAT(KHAR)
 IF(XX .LT. 0.0)XX = XX / FLOAT(KHAR)
 GO TO 6
 52 CALL ZTRAN(RR,XX,KHAR)
 IF(KSEQ .EQ. 0)GO TO 55
 T = CMPLX(TAP(K),0.0)
 IF(KTRTYPE(K) .EQ. 6 .OR. KTRTYPE(K) .EQ. 7)T = T *
1CMPLX(COS30,-FLOAT(KSEQ) * SIN30)
 IF(KTRTYPE(K) .EQ. 8 .OR. KTRTYPE(K) .EQ. 9)T = T *
1CMPLX(COS30, FLOAT(KSEQ) * SIN30)
 IF(K1 .EQ. KFROM)VV1 = VK1 / T
 IF(K2 .EQ. KFROM)VV2 = VK2 / T
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```
      GO TO 6
   55 IF(KTRTYPE(K) .EQ. 1)GO TO 6
      IF(KTRTYPE(K) .NE. 6 .AND. KTRTYPE(K) .NE. 8)GO TO 5
      IF(K1 .EQ. KFROM .AND. KTRTYPE(K) .NE. 6)GO TO 5
      IF(K1 .EQ. KTO .AND. KTRTYPE(K) .NE. 8)GO TO 5
      VV2    = CMPZERO
      K2     = 0
    6 ZLIN   = CMPLX(RR,XX)
      AMPS   = (VV1 - VV2) / ZLIN + VV1 * CMPLX(GG,BB)
      SK1K2 = VV1 * CONJG(AMPS)
      P      = P + DBLE(SK1K2)
      Q      = Q + AIMAG(SK1K2)
      HMAG(LHAR) = CABS(AMPS)
      IF(K1 .EQ. KFROM .AND. KSEQ .NE. 0)HMAG(LHAR) = HMAG(LHAR) /
     1CABS(T)
      HANG(LHAR) = 0.0
      IF(HMAG(LHAR) .GT. EP9)HANG(LHAR) = ATAN2(AIMAG(AMPS),
     1DBLE(AMPS))
    5 CONTINUE
      CALL HARSTAT
      VA = VRMS * HRMS
      D  = 0.0
      D2 = VA * VA - P * P - Q * Q
      IF(D2 .GT. EP9)D = SQRT(D2)
      IF(K2.NE.0)WRITE(*,1000)J,BUSNAME(K1),NBEXT(K2),BUSNAME(K2),HFUND,
     1HRMS,HPEAK,HDF,P,Q,D,VA
      IF(K2 .EQ. 0)WRITE (*,1002)J,BUSNAME(K1),HFUND,HRMS,HPEAK,HDF,
     1P,Q,D,VA
    2 CONTINUE
      IF(ABS(SRCBL(K1)) .LT. EP6)GO TO 8
      P = 0.0
      Q = 0.0
      DO 10 LHAR = 1,NOHAR
      KHAR     = NHVECT(LHAR)
      K1POS    = 2 * K1 + 2 * (LHAR - 1) * NB
      VOLTK1 = X(K1POS)
      ANGK1   = X(K1POS - 1) / VOLTK1
      VK1      = VOLTK1 * CMPLX(COS(ANGK1),SIN(ANGK1))
      QSHUNT = VOLTK1 * VOLTK1 * SRCBL(K1)
      IF(QSHUNT .GT. 0.0)QSHUNT = QSHUNT / FLOAT(KHAR)
      IF(QSHUNT .LT. 0.0)QSHUNT = QSHUNT * FLOAT(KHAR)
      AMPS     = CMPLX(0.0,-QSHUNT) / CONJG(VK1)
      HMAG(LHAR) = CABS(AMPS)
      HANG(LHAR) = 0.0
      IF(HMAG(LHAR) .GT. EP9)HANG(LHAR) = ATAN2(AIMAG(AMPS),
     1DBLE(AMPS))
      Q = Q + QSHUNT
   10 CONTINUE
      CALL HARSTAT
      VA = VRMS * HRMS
      D  = 0.0
      D2 = VA * VA - P * P - Q * Q
      IF(D2 .GT. EP9)D = SQRT(D2)
      WRITE (*,1004)J,BUSNAME(K1),HFUND,HRMS,HPEAK,HDF,P,Q,D,VA
    8 IF(NBTYPE(K1) .EQ. 0)GO TO 1
      P = 0.0
      Q = 0.0
      DO 11 LHAR = 1,NOHAR
      K1POS   = 2 * K1 + 2 * (LHAR - 1) * NB
      VOLTK1 = X(K1POS)
      ANGK1   = X(K1POS - 1) / VOLTK1
      VK1      = VOLTK1 * CMPLX(COS(ANGK1),SIN(ANGK1))
      AMPS     = CMPLX(GR(K1,LHAR),GI(K1,LHAR))
      SK1K2 = VK1 * CONJG(AMPS)
      P        = P + DBLE(SK1K2)
      Q        = Q + AIMAG(SK1K2)
      HMAG(LHAR) = CABS(AMPS)
      HANG(LHAR) = 0.0
      IF(HMAG(LHAR) .GT. EP9)HANG(LHAR) = ATAN2(AIMAG(AMPS),
     1DBLE(AMPS))
   11 CONTINUE
      CALL HARSTAT
      VA = VRMS * HRMS
      D  = 0.0
      D2 = VA * VA - P * P - Q * Q
      IF(D2 .GT. EP9)D = SQRT(D2)
      WRITE (*,1006)J,BUSNAME(K1),HFUND,HRMS,HPEAK,HDF,P,Q,D,VA
    1 CONTINUE
   19 CALL PGHEAD(12)
      KBUS = 0
      DO 20 J = 1,MBHUSE
      IF(KBUS .EQ. NB)RETURN
      K1 = NBINT(J)
      IF(K1 .EQ. 0)GO TO 20
      KBUS   = KBUS + 1
      DO 21 LHAR = 1,NOHAR
      K1POS = 2 * K1 + 2 * (LHAR - 1) * NB
      HMAG(LHAR) = X(K1POS)
      HANG(LHAR) = X(K1POS - 1) / X(K1POS)
   21 CONTINUE
```

```
      CALL HARSTAT
      WRITE (*,1008)J,BUSNAME(K1),HFUND,HRMS,HPEAK,HDF
   20 CONTINUE
      RETURN
 1000 FORMAT(1X,I4,2X,A12,2X,I4,2X,A12,2PF10.2,3F10.2,4X,4F10.2)
 1002 FORMAT(1X,I4,2X,A12,2X,'NEUT',2X,'Z SHUNT',5X,2PF10.2,3F10.2,
     14X,4F10.2)
 1004 FORMAT(1X,I4,2X,A12,2X,'NEUT',2X,'Q SHUNT',5X,2PF10.2,3F10.2,
     14X,4F10.2)
 1006 FORMAT(1X,I4,2X,A12,2X,'NEUT',2X,'NONLIN DEV.',1X,2PF10.2,
     13F10.2,4X,4F10.2)
 1008 FORMAT(1X,I4,2X,A12,2PF10.2,3F14.2)
 1010 FORMAT(1X,122(1H-))
      END
C

      SUBROUTINE YBUILD
      COMPLEX YLINE, YFS, YTS, YFT, YTF, ZZ, T
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      DO 1 L    = 1,NOHAR
      KHAR      = NHVECT(L)
      KSEQ      = NPHSEQ(L)
      DO 5 L1 = 1,NLINES
      IF(KSHAR(L1) .LT. 0 .AND. L .EQ. 1) GO TO 5
      LFROM     = LINES(1,L1)
      LTO       = LINES(2,L1)
      GG        = 0.0
      IF(KSEQ .EQ. 0) GO TO 10
      RR = R1(L1)
      XX = X1(L1)
      BB = B1(L1)
      IF(KTRTYPE(L1) .NE. 0 .OR. KSHAR(L1) .NE. 0) GO TO 30
      CALL ZLINE(RR,XX,GG,BB,KHAR)
      T    = CMPONE
      GO TO 32
   30 IF(KTRTYPE(L1) .NE. 0) GO TO 31
      IF(XX .GT. 0.0) XX = XX * FLOAT(KHAR)
      IF(XX .LT. 0.0) XX = XX / FLOAT(KHAR)
      T = CMPONE
      GO TO 32
   31 CALL ZTRAN(RR,XX,KHAR)
      T = CMPLX(TAP(L1),0.0)
      IF(KTRTYPE(L1) .EQ. 6 .OR. KTRTYPE(L1) .EQ. 7)T = T *
     1CMPLX(COS30,-FLOAT(KSEQ) * SIN30)
      IF(KTRTYPE(L1) .EQ. 8 .OR. KTRTYPE(L1) .EQ. 9)T = T *
     1CMPLX(COS30,FLOAT(KSEQ) * SIN30)
   32 YLINE = CMPONE / CMPLX(RR,XX)
      YFS   = YLINE / T / CONJG(T) + CMPLX(GG,BB)
      YTS   = YLINE + CMPLX(GG,BB)
      YFT   = YLINE / CONJG(T)
      YTF   = YLINE / T
      GO TO 20
   10 IF(KTRTYPE(L1) .NE. 0 .OR. KSHAR(L1) .NE. 0)GO TO 16
      RR = RO(L1)
      XX = XO(L1)
      BB = BO(L1)
      ZZ = CMPLX(RR,XX)
      F  = CABS(ZZ)
      IF(F .GT. EP6)GO TO 17
      ISDUM1 = 0
      ISDUM2 = 0
      IF(LFROM .NE. 0)ISDUM1 = NBEXT(LFROM)
      IF(LTO .NE. 0)ISDUM2 = NBEXT(LTO)
      CALL ERROR(45)
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      GO TO 5
   17 CALL ZLINE(RR,XX,GG,BB,KHAR)
      GO TO 18
   16 RR = R1(L1)
      XX = X1(L1)
      BB = B1(L1)
      IF(KTRTYPE(L1) .NE. 0)GO TO 12
      IF(IABS(KSHAR(L1)) .GT. 1)GO TO 5
      IF(XX .GT. 0.0)XX = XX * FLOAT(KHAR)
      IF(XX .LT. 0.0)XX = XX / FLOAT(KHAR)
   18 YLINE = CMPONE / CMPLX(RR,XX)
      YFS   = YLINE + CMPLX(GG,BB)
      YTS   = YLINE + CMPLX(GG,BB)
      YFT   = YLINE
      YTF   = YLINE
      GO TO 20
   12 CALL ZTRAN(RR,XX,KHAR)
      YLINE = CMPONE / CMPLX(RR,XX)
      IF(KTRTYPE(L1) .NE. 1)GO TO 13
      T = CMPLX(TAP(L1),0.0)
      YFS = YLINE / T / CONJG(T)
      YTS = YLINE
      YFT = YLINE /CONJG(T)
      YTF = YLINE / T
      GO TO 20
   13 IF(KTRTYPE(L1) .NE. 6)GO TO 14
      YFS = YLINE
      YTS = CMPZERO
      YFT = CMPZERO
      YTF = CMPZERO
      GO TO 20
   14 IF(KTRTYPE(L1) .NE. 8)GO TO 5
      YFS = CMPZERO
      YTS = YLINE
      YFT = CMPZERO
      YTF = CMPZERO
   20 IF(LFROM .NE. 0)YBUS(LFROM,LFROM,L) = YBUS(LFROM,LFROM,L) + YFS
      IF(LTO .NE. 0)YBUS(LTO,LTO,L) = YBUS(LTO,LTO,L) + YTS
      IF(LFROM .EQ. 0 .OR. LTO .EQ. 0)GO TO 5
      YBUS(LFROM,LTO,L) = YBUS(LFROM,LTO,L) - YFT
      YBUS(LTO,LFROM,L) = YBUS(LTO,LFROM,L) - YTF
    5 CONTINUE
      DO 15 L1 = 1,NB
      IF(KSHTYPE(L1) .EQ. 0)GO TO 15
      IF(KSEQ .EQ. 0 .AND. KSHTYPE(L1) .GT. 1)GO TO 15
      BB = -SRCBL(L1)
      IF(BB .GT. 0.0)BB = BB * FLOAT(KHAR)
      IF(BB .LT. 0.0)BB = BB / FLOAT(KHAR)
      YBUS(L1,L1,L) = YBUS(L1,L1,L) + CMPLX(0.0,BB)
   15 CONTINUE
    1 CONTINUE
      RETURN
      END
C
      SUBROUTINE ZLINE(R,XREACT,G,B,KHAR)
      COMPLEX C1,C2,GAMMA,ZO,CEXP1,CEXP2,ZPI,YPI
      COMPLEX YBUS, CMPZERO, CMPONE
      LOGICAL PATHBTS, CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
      CHARACTER * 2 SUBNAME
      CHARACTER * 12 BUSNAME, BTEMPN
      CHARACTER * 80 TITLE, COMMENT
      COMMON /COMP/ YBUS(20,20,9), CMPZERO, CMPONE
      COMMON /REAL/ AJAC(366,366), GR(20,9), GI(20,9), FFMAG(2,9),
     1FFANG(2,9), PL(20), QL(20), S(20), PG(20), QG(20), V(20),
     2SRCBL(20), RCONV(20), FCONV(20), ECONV(20), DELAY(20), RTRCON(20),
     3XTRCON(20), COM(20), R1(50), X1(50), G1(50), B1(50), GO(50),
     4BO(50), RO(50), XO(50), TAP(50), PSHIFT(9), GRTEMPO(9),
     5GITEMPO(9), HMAG(9), HANG(9), X(366), Y(366), DELTAX(366),
     6DELTAY(366), TOLE, COMTOLE, F2TOLE, DEPART, PI, R30, R60, R90,
     7R120, R360, DR, AK1, AK2, AK3, P1, P2, EDUM1, EDUM2, EDUM3,
     8SIN30, COS30, EP3, EP4, EP6, EP9, ER, HFUND, HRMS, HDF,
     9HPEAK, ACCEL
      COMMON /CHAR/ BUSNAME(20), SUBNAME(6), BTEMPN
      COMMON /INIG/ LINES(2,50), KTRTYPE(50), KSHAR(50),
     1NBTYPE(20), NBSUBT(20), NBEXT(20), KRENUM(20), KTRCON(20),
     2KSHTYPE(20), NBSHFT(20), NHVECT(9), NPHSEQ(9), NBINT(100),
     3MHVECT(49), IOPT(14), NOERR, NOERMAX, MAXNB, MAXLINE,
     4MAXHAR, MBHUSE, NB, NLIN, NNLIN, NNL1, NNL2, NLINES, NPVLIN,
     5NPQLIN, NOHAR, NHIGH, ITERCOM, MAXAJAC, MAXHMP, NTYPES, NSUBS,
     6MXFITER, MXHITER, NTRMAX, ISDUM1, ISDUM2, NSHMAX
      COMMON /LOGI/ PATHBTS(20), CODE3, CODE4, CODE5, CODE6, CODE7,
     1TRUE, FALSE, TERMINAL, CSWING, CONV, ZOURCE, GPATH
C
      IF(XREACT .GE. 0.0)XREACT = XREACT * FLOAT(KHAR)
      IF(XREACT .LT. 0.0)XREACT = XREACT / FLOAT(KHAR)
      IF(B .GE. 0.0)B = B * FLOAT(KHAR)
      IF(B .LT. 0.0)B = B / FLOAT(KHAR)
      B = B / 2.0
      RETURN
```

```
      END
C

      SUBROUTINE ZTRAN(R,X,K)
      IF(X .GE. 0.0)X = X * FLOAT(K)
      IF(X .LT. 0.0)X = X / FLOAT(K)
      RETURN
      END
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ประวัติผู้เขียน

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