Calculul circulației de puteri

Construirea matricei Jacobian

Pentru algoritmul Newton-Raphson este necesară formarea unei matrici Jacobian cu ajutorul derivatelor parţiale derivatives ale matricelor de puteri active şi reactive.

$k := 2..N\_bus$

$n := 2..N\_bus$

$$\frac{d}{dV_n} f_{p_k}$$

$$Jac_{k-1,(n+N\_bus)-2} := V_k \cdot \left(\left|Ybus_{k,n}\right|\right) \cdot \cos\left[\left(\arg\left(Ybus_{k,n}\right)\right) + \delta_n - \delta_k\right]$$

$$\frac{d}{dV_k} f_{p_k}$$

$$Jac_{k-1,(k+N\_bus)-2} := \sum_i V_i \cdot \left(\left|Ybus_{k,i}\right|\right) \cdot \cos\left(\arg\left(Ybus_{k,i}\right) + \delta_i - \delta_k\right) \ldots + V_k \cdot \left(\left|Ybus_{k,k}\right|\right) \cdot \cos\left(\arg\left(Ybus_{k,k}\right)\right)$$

$$\frac{d}{dV_n} f_{q_k}$$

$$Jac_{(k+N\_bus)-2,(n+N\_bus)-2} := \left(-V_k\right) \cdot \left(\left|Ybus_{k,n}\right|\right) \cdot \sin\left(\arg\left(Ybus_{k,n}\right) + \delta_n - \delta_k\right)$$

$$\frac{d}{dV_k} f_{q_k}$$

$$Jac_{(k+N\_bus)-2,(k+N\_bus)-2} := \sum_i \left(-V_i\right) \cdot \left(\left|Ybus_{k,i}\right|\right) \cdot \sin\left(\arg\left(Ybus_{k,i}\right) + \delta_i - \delta_k\right) \ldots + -\left[V_k \cdot \left(\left|Ybus_{k,k}\right|\right) \cdot \sin\left(\arg\left(Ybus_{k,k}\right)\right)\right]$$

$$\frac{d}{d\delta_n} f_{p_k}$$

$$Jac_{k-1,n-1} := -\left[V_k \cdot V_n \cdot \left(\left|Ybus_{k,n}\right|\right)\right] \cdot \sin\left(\arg\left(Ybus_{k,n}\right) + \delta_n - \delta_k\right)$$

$$\frac{d}{d\delta_k} f_{p_k}$$

$$Jac_{k-1,k-1} := \sum_i V_k \cdot V_i \cdot \left(\left|Ybus_{k,i}\right|\right) \cdot \sin\left(\arg\left(Ybus_{k,i}\right) + \delta_i - \delta_k\right) \ldots + -\left[\left(V_k\right)^2 \cdot \left|Ybus_{k,k}\right| \cdot \sin\left(\arg\left(Ybus_{k,k}\right)\right)\right]$$

$$\frac{d}{d\delta_n} f_{q_k}$$

$$Jac_{(k+N\_bus)-2,\,n-1} := (-V_k)\cdot V_n\cdot\left(\left|Ybus_{k,n}\right|\right)\cdot\cos\left(\arg\left(Ybus_{k,n}\right) + \delta_n - \delta_k\right)$$

$$\frac{d}{d\delta_k} f_{q_k}$$

$$Jac_{k+N\_bus-2,\,k-1} := \sum_i V_k\cdot V_i\cdot\left|Ybus_{k,i}\right|\cdot\cos\left(\arg\left(Ybus_{k,i}\right) + \delta_i - \delta_k\right) \dots$$
$$+ -\left[\left(V_k\right)^2\cdot\left|Ybus_{k,k}\right|\cdot\cos\left(\arg\left(Ybus_{k,k}\right)\right)\right]$$

$$Jac_{k-1,\,n+N\_bus-2} := if\left(It_n = 1, 0, Jac_{k-1,\,n+N\_bus-2}\right)$$
$$Jac_{k+N\_bus-2,\,n-1} := if\left(It_k = 1, 0, Jac_{k+N\_bus-2,\,n-1}\right)$$
$$Jac_{k+N\_bus-2,\,n+N\_bus-2} := if\left(It_k = 1, 0, Jac_{k+N\_bus-2,\,n+N\_bus-2}\right)$$
$$Jac_{k+N\_bus-2,\,n+N\_bus-2} := if\left(It_n = 1, 0, Jac_{k+N\_bus-2,\,n+N\_bus-2}\right)$$
$$Jac_{k+N\_bus-2,\,k+N\_bus-2} := if\left(It_k = 1, 1, Jac_{k+N\_bus-2,\,k+N\_bus-2}\right)$$

Invert Jacobian matrix.

$$Jinv := Jac^{-1}$$

Solve Load Flow Iteratively

The Iterative solution of the problem is as follows:
Define, using Equation (1.3.5), functions that provide the corrections of voltage and phase angle for the new iteration step.

$$\Delta V(l,V,\delta) := \left[\sum_k \left[Jinv_{l+N\_bus-2,\,k-1}\cdot\left(Pb_k - f_p(k,V,\delta)\right)\right]\right] \ldots$$
$$+ \sum_k \left[Jinv_{l+N\_bus-2,\,k+N\_bus-2}\cdot\left(\mathrm{if}\left(It_k = 1, 0, Qb_k - f_q(k,V,\delta)\right)\right)\right]$$

$$\Delta\delta(l,V,\delta) := \sum_k Jinv_{l-1,\,k-1}\cdot\left(Pb_k - f_p(k,V,\delta)\right) \ldots$$
$$+ \left[\sum_k \left[Jinv_{l-1,\,k+N\_bus-2}\cdot\left(\mathrm{if}\left(It_k = 1, 0, Qb_k - f_q(k,V,\delta)\right)\right)\right]\right]$$

Iterative Solution

Define the maximum iteration number.

$Max\_it := 6$

Define the acceleration coefficient, λ. This coefficient takes values **less than one** and improves the convergence characteristics of the problem. The user may change the value of λ to see its effect on the mismatch at the end of the iterations.

$\lambda := 1$

Define the iteration index.

$Iter := 1 .. Max\_it$

$m := 2 .. N\_bus$

$Num_1 := 0$

Iterations:

$$\begin{pmatrix} Num_{Iter+1} \\ V_m \\ \delta_m \end{pmatrix} := \begin{pmatrix} Num_{Iter} + 1 \\ V_m + \Delta V(m,V,\delta)\cdot\lambda \\ \delta_m + \Delta\delta(m,V,\delta)\cdot\lambda \end{pmatrix}$$

The power mismatch is

$$\varepsilon := \left[\sum_{m} \left[\left(Pb_m - f_p(m,V,\delta)\right)^2 + \mathrm{if}\left[It_m = 1, 0, \left(Qb_m - f_q(m,V,\delta)\right)^2 \right]\right]\right]^{\frac{1}{2}}$$

$\varepsilon = 0.103$

The bus voltage magnitudes and phase angles are

$$V = \begin{pmatrix} 1.04 \\ 0.958 \\ 1.02 \\ 0.914 \\ 0.971 \end{pmatrix}$$

$$\frac{\delta}{deg} = \begin{pmatrix} 0 \\ -6.307 \\ -3.575 \\ -11.144 \\ -6.193 \end{pmatrix}$$

The real and reactive power of the slack bus are respectively

$Ps := f_p(1,V,\delta) + Bus_{1,3}$

$Qs := f_q(1,V,\delta) + Bus_{1,4}$

$Ps = 2.349$

$Qs = 1$

Calculation of Line Losses

The line losses for the second line are calculated as follows:

Define line number as in the array **Series**.

$m := 2$

$i := Is_m$

$j := Js_m$

$$ys := \frac{1}{Series_{m,3}}$$

$ysh := Series_{m,4}$

PASE – Laborator 2

Power flow from sending to receiving terminal:

$$Pij := -\left(V_i \cdot V_j \cdot |ys| \cdot \cos\left(\arg(ys) + \delta_j - \delta_i\right)\right) + \left(V_i\right)^2 \cdot |ys| \cdot \cos(\arg(ys)) \ldots + \left(V_i\right)^2 \cdot |ysh| \cdot \cos(\arg(ysh))$$

Power flow from receiving to sending terminal:

$$Pji := -\left(V_j \cdot V_i \cdot |ys| \cdot \cos\left(\arg(ys) + \delta_i - \delta_j\right)\right) + \left(V_j\right)^2 \cdot |ys| \cdot \cos(\arg(ys)) \ldots + \left(V_j\right)^2 \cdot |ysh| \cdot \cos(\arg(ysh))$$

The real power losses in the second line are

$$Ploss := Pij + Pji$$

$$Ploss = 0.03$$

Reactive power flow from sending to receiving terminal:

$$Qij := V_i \cdot V_j \cdot |ys| \cdot \sin\left(\arg(ys) + \delta_j - \delta_i\right) - \left(V_i\right)^2 \cdot |ys| \cdot \sin(\arg(ys)) \ldots + -\left[\left(V_i\right)^2 \cdot |ysh| \cdot \sin(\arg(ysh))\right]$$

Reactive power flow from receiving to sending terminal:

$$Qji := V_j \cdot V_i \cdot |ys| \cdot \sin\left(\arg(ys) + \delta_i - \delta_j\right) - \left(V_j\right)^2 \cdot |ys| \cdot \sin(\arg(ys)) \ldots + -\left[\left(V_j\right)^2 \cdot |ysh| \cdot \sin(\arg(ysh))\right]$$

The reactive power losses in the second line are

$$Qloss := Qij + Qji$$

$$Qloss = 0.095$$