# Power Engineering II

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Jacobian expressions

$$J^{11} = \frac{\partial P}{\partial \theta}$$

$$\boxed{J_{ii}^{11} = \frac{\partial P_i}{\partial \theta_i} = -Q_i(\underline{x}) - |V_i|^2 B_{ii}}$$

$$J_{ik}^{11} = \frac{\partial P_i}{\partial \theta_k} = |V_i||V_k|(G_{ik}Sin(\theta_i - \theta_k) - B_{ik}Cos(\theta_i - \theta_k))$$

$$J^{12} = \frac{\partial P}{\partial |V|}$$

$$\boxed{J_{ii}^{12} = \frac{\partial P_i}{\partial |V_i|} = \frac{P_i}{|V_i|} + G_{ii}|V_i|}$$

$$J_{ik}^{12} = \frac{\partial P_i}{\partial |V_k|} = |V_i|(G_{ik}Cos(\theta_i - \theta_k) + B_{ik}Sin(\theta_i - \theta_k))$$

$$J^{21} = \frac{\partial Q}{\partial \theta}$$

$$\boxed{J_{ii}^{21} = \frac{\partial Q_i}{\partial \theta_i} = P_i(x) - G_{ii}|V_i|^2}$$

$$J_{ik}^{21} = \frac{\partial Q_i}{\partial \theta_k} = -|V_i||V_k|(G_{ik}Cos(\theta_i - \theta_k) + B_{ik}Sin(\theta_i - \theta_k))$$

$$J^{22} = \frac{\partial Q}{\partial |V|}$$

$$\boxed{J_{ii}^{22} = \frac{\partial Q_i}{\partial |V_i|} = \frac{Q_i(x)}{|V_i|} - B_{ii}|V_i|}$$

$$J_{ik}^{22} = \frac{\partial Q_i}{\partial |V_k|} = |V_i|(G_{ik}Sin(\theta_i - \theta_k) - B_{ik}Cos(\theta_i - \theta_k))$$

# The Power Flow NR Algorithm

## Basic Steps In the algorithm

1. Specify:

   - All admittance data (Y elements, transformer taps and shunts)
   - $P_d$ , $Q_d$ for all all buses
   - $P_G$ and $|V|$ for all PV buses
   - $|V|$ for swing bus with θ=0

2. Set the iteration count j=0. Input the initial guess for the solution

   - Flat start : $V_k = 1.0\angle 0^0$ for all buses
   - Hot Start: Previously solved power flow solution

3. Calculate the mismatch:

   - If $|\Delta P_k| \le \varepsilon_P$ for all PV and PQ buses and $|\Delta Q_k| \le \varepsilon_Q$ then go to Step 5 else Go to Step 4

4. Find the solution
   - Evaluate the jacobian $J^{(j)}$ at $X^{(j)}$
   - Solve for $\Delta x^j$
     - $\underline{J}^{(j)} \Delta x^{(j)} = -\begin{bmatrix} \Delta P \\ --- \\ \Delta Q \end{bmatrix}$
   - Compute the updated solution vector as $\underline{X}^{(j+1)} = \underline{X}^{(j)} + \Delta \underline{X}^{(j)}$
   - Return to step 3 with j=j+1

5. Stop

# 3 Bus Example

- Check tutorial sample uploaded

# The Decoupled Power Flow Algorithm

Basic Steps In the algorithm

1. Specify:
   - All admittance data (Y elements, transformer taps and shunts)
   - $P_d$ , $Q_d$ for all all buses
   - $P_G$ and $|V|$ for all PV buses
   - $|V|$ for swing bus with θ=0
2. Set the iteration count j=0. Input the initial guess for the solution
   - Flat start : $V_k = 1.0\angle 0^0$ for all buses
   - Hot Start: Previously solved power flow solution
3. Calculate the mismatch:
   - If $|\Delta P_k| \leq \varepsilon_P$ for all PV and PQ buses and $|\Delta Q_k| \leq \varepsilon_Q$ then go to Step 5 else Go to Step 4
4. Find the solution
   - Evaluate the jacobian $J^{(j)}$ and $X^{(j)}$
   - Solve $\Delta X^{(j)}$

Only change

$$\underline{\mathrm{J}11^{(j)}}\ \Delta\underline{\theta}^{(j)} = \underline{-\Delta P}^{(j)}$$

$$\underline{\mathrm{J}22^{(j)}}\ \Delta|\underline{V}|^{(j)} = \underline{-\Delta Q}^{(j)}$$

   - **Compute the updated solution vector** $\underline{X}^{(j+1)} = \underline{X}^{(j)} + \Delta\underline{X}^{(j)}$
   - **Return to step 3 with j=j+1**
5. **Stop**

# The Fast Decoupled Power Flow Algorithm

Define $B'$ as: ( this corresponds to imaginary parts of $Y_{BUS}$ matrix with first row and first column eliminated.
of

$$B' = \begin{bmatrix} B_{22} & B_{23} & \cdots & B_{2N} \\ B_{32} & B_{33} & \cdots & B_{3N} \\ \vdots & \vdots & \vdots\cdots & \vdots \\ B_{N2} & B_{N3} & \cdots & B_{NN} \end{bmatrix}$$

$$[\underline{B'}]\Delta\underline{\theta}^{(j)} = [\underline{V}]^{-1}\,\underline{\Delta P}^{(j)} = \begin{bmatrix} \dfrac{\Delta P_2}{|V_2|} \\ \dfrac{\Delta P_3}{|V_3|} \\ \vdots \\ \dfrac{\Delta P_n}{|V_n|} \end{bmatrix}^{(j)} = \underline{\Delta P}^{\mathrm{mod}ified^{(j)}}$$

# The Fast Decoupled Power Flow Algorithm

We know the voltages at PV buses , but we do not know the reactive powers at these buses, so we have to eliminate the rows corresponding to PV buses. The resulting matrix will be B″

$$[\underline{B}'']\Delta\left|\underline{V}\right|^{(j)} = [\underline{V}]^{-1}\,\underline{\Delta Q}^{(j)} = \begin{bmatrix} \dfrac{\Delta Q_{N_G+1}}{\left|V_{N_G+1}\right|} \\ \dfrac{\Delta Q_{N_G+2}}{\left|V_{N_G+2}\right|} \\ \vdots \\ \dfrac{\Delta Q_N}{\left|V_N\right|} \end{bmatrix} = \underline{\Delta Q}^{\mathrm{mod}\,ified^{(j)}}$$

Where :

$$B'' = \begin{bmatrix} B_{N_G+1,N_G+1} & B_{N_G+1,N_G+2} & \cdots & B_{N_G+1,N} \\ B_{N_G+2,N_G+1} & B_{N_G+2,N_G+2} & \cdots & B_{N_G+2,N} \\ \vdots & \vdots & \vdots\cdots & \vdots \\ B_{N,N_G+1} & B_{N,N_G+2} & \cdots & B_{NN} \end{bmatrix}$$

# The Fast Decoupled Power Flow Algorithm

## Basic Steps In the algorithm

1. Specify:

   - All admittance data (Y elements, transformer taps and shunts)
   - $P_d$ , $Q_d$ for all all buses
   - $P_G$ and $|V|$ for all PV buses
   - $|V|$ for swing bus with θ=0

2. Set the iteration count j=0. Input the initial guess for the solution

   - Flat start : $V_k = 1.0\angle 0^0$ for all buses
   - Hot Start: Previously solved power flow solution

3. Calculate the mismatch:

   - If $|\Delta P_k| \le \varepsilon_P$ for all PV and PQ buses and $|\Delta Q_k| \le \varepsilon_Q$ then go to Step 5 else Go to Step 4

4. Find the solution
   - Evaluate the B' and B'' (remains same in each iteration)
   - Solve ΔX$^{(j)}$

Only change

$$[\underline{B'}]\Delta\underline{\theta}^{(j)} = \begin{bmatrix} \dfrac{\Delta P_2}{|V_2|} \\ \dfrac{\Delta P_3}{|V_3|} \\ \vdots \\ \dfrac{\Delta P_n}{|V_n|} \end{bmatrix}^{(j-1)} = \underline{\Delta P}^{modified^{(j-1)}}$$

$$[\underline{B''}]\Delta|\underline{V}|^{(j)} = \begin{bmatrix} \dfrac{\Delta Q_{N_G+1}}{|V_{N_G+1}|} \\ \dfrac{\Delta Q_{N_G+2}}{|V_{N_G+2}|} \\ \vdots \\ \dfrac{\Delta Q_N}{|V_N|} \end{bmatrix}^{\theta^{(j)},|V|^{(j-1)}} = \underline{\Delta Q}^{modified^{\theta^{(j)},|V|^{(j-1)}}}$$

   - **Compute the updated solution vector**
   - **Return to step 3 with j=j+1**

$$\underline{X}^{(j+1)} = \underline{X}^{(j)} + \Delta\underline{X}^{(j)}$$

5. **Stop**