IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

Computer aided power system analysis

AC- DC Load Flow (Contd.)

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Case - i)

Specified quantities: α, P_{dr}, γ, V_{di}

To calculate
- Q_{dr} ✓
- P_{di} ✓
- Q_{di} ✓
- 6 other quantities

Steps

1. $P_{dr} = V_{dr} I_d = V_{dr} \dfrac{V_{dr} - V_{di}}{R_{dc}}$

$\Rightarrow P_{dr} R_{dc} = V_{dr}^2 - V_{dr} V_{di}$

$\Rightarrow V_{dr}^2 - V_{dr} V_{di} - P_{dr} R_{dc} = 0$

$\Rightarrow$ V_{dr} can be calculated.

2. Calculate $I_d = \dfrac{V_{dr} - V_{di}}{R_{dc}}$

3. $V_{dor} = \dfrac{V_{dr} + \frac{3}{\pi} X_{cr} N_r I_d}{\cos\alpha}$ | as $V_{dr} = V_{dor}\cos\alpha - \frac{3}{\pi} X_{cr} N_r I_d$

$\Rightarrow V_{dor}$ is known (calculated)

4. $V_{dr} = V_{dor}\cos\phi_r \Rightarrow \cos\phi_r = \dfrac{V_{dr}}{V_{dor}}$ → known

5. $Q_{dr} = P_{dr}\tan\phi_r$ → calculated.

6. $V_{dor} = \dfrac{3\sqrt{2}}{\pi} N_r a_r E_{tr}$ → a_r is calculated.

7. $P_{di} = V_{di} I_d$ → P_{di} is calculated

8. $V_{doi} = \dfrac{V_{di} + \frac{3}{\pi} X_{ci} N_i I_d}{\cos\gamma}$ ✓ ✓ ✓ $\longrightarrow$ V_{doi} is calculated

9. $\cos\phi_i = \dfrac{V_{di}}{V_{doi}}$ $\longrightarrow$ $\cos\phi_i$ is calculated

10. $Q_{di} = P_{di} \tan\phi_i$ $\longrightarrow$ Q_{di} is calculated.

11. $V_{doi} = \dfrac{3\sqrt{2}}{\pi} N_i a_i E_{ti}$ $\longrightarrow$ a_i is calculated

Therefore, P_{dr}, Q_{dr}, P_{di}, Q_{di} are known. Utilising these values, we carry out one iteration of AC load flow and therefore, updated values of E_{tr} and E_{ti} are obtained.

Case - ii) α, γ, P_{di}, V_{dr} are specified.

Steps

i) $P_{di} = V_{di} I_d = V_{di} \dfrac{V_{dr} - V_{di}}{R_{dc}}$

$\Rightarrow R_{dc} P_{di} = V_{di} V_{dr} - V_{di}^2 \Rightarrow V_{di}^2 - V_{di} V_{dr} + R_{dc} P_{di} = 0$

$\Downarrow$ V_{di} is calculated

ii) $I_d = \dfrac{V_{dr} - V_{di}}{R_{dc}} \rightarrow I_d$ is calculated

Schematic (overall) algorithm for AC-DC load flow

i) Assume flat start for the AC system.

ii) Solve the DC equations to calculate P_{dr}, Q_{dr}, P_{di}, Q_{di}

iii) Run one iteration of AC load flow

iv) Go to step (ii) till convergence is achieved.

Example of AC-DC load flow in 5 bus system

- One bipolar HVDC link is connected between bus 4 and 5 (rectifier at bus 4 and inverter at bus 5)
- Base voltage of the AC system is 132 kV

$$R_d = 10.0\ \Omega;$$

$$N_r = N_i = 2;\ \frac{3}{\pi}X_{cr} = \frac{3}{\pi}X_{ci} = 6.0\ \Omega.$$

Example of AC-DC load **flow** in 5 bus system

Combination-1

$$\alpha = 5^o,\ P_{dr} = 100 \text{ MW};\ \gamma = 18^o,\ V_{di} = 250 \text{ kV}$$

$$V_{dr} = 253.938 \text{ kV};\ i_d = 393.8 \text{ Amp.};\ Q_{dr} = 16.276 \text{ MVAR};$$

$$P_{di} = 98.45 \text{ MW};\ Q_{di} = 35.024 \text{ MVAR}$$

$$P_4 = -1.15 - 1.0 = -2.15 \text{ p.u.},\ Q_4 = -0.6 - 0.16276 = -0.76276 \text{ p.u.}$$

$$P_5 = -0.85 + 0.9845 = 0.1345 \text{ p.u.}$$

$$Q_5 = -0.4 - 0.35024 = -0.75024 \text{ p.u.}$$

Example of AC-DC load flow in 5 bus system

Bus no.	Without generator Q limit			
	$\|V\|$ (p.u)	θ (deg)	P_{inj} (p.u)	Q_{inj} (p.u)
1	1.0	0	0.68984	0.46301
2	1.0	-0.63995	0.5	-0.17235
3	1.0	-4.91128	1.0	1.54134
4	0.82813	-17.48682	-2.15	-0.76277
5	0.91332	-3.89028	0.13449	-0.75025
	Total iteration = 5			

$$a_r = 0.8714 \qquad a_i = 0.8149.$$