DC Load Flow

BY

SIRAJ MANHAL HAMEED

THE LOAD FLOW PROBLEM

Formulation of classic load flow problem requires considering four variables at each bus i of power system. These variables are

1. Pi (Net active power injection)
2. Qi (Net reactive power injection)
3. Vi (Voltage magnitude)
4. θi (Voltage angle)

The active and reactive power injections are calculated as follows

$$P_i = P_{Gi} - P_{Di}$$

$$Q_i = Q_{Gi} - Q_{Di}$$

in which P_{Gi} and Q_{Gi} are active and reactive power generations at bus i, respectively, whereas P_{Di} and Q_{Di} are active and reactive power demands at this bus, respectively.

Based on the application of Kirchhoff's laws to each bus

$$\mathbf{I} = \mathbf{YV}$$

$$I_i = \frac{(P_i - jQ_i)}{|V_i|} e^{j\theta_i}$$

where

I_i Net injected current at bus i

V Vector of bus voltages

I Vector of injected currents at the buses

Y Bus admittance matrix of the system

DC LOAD FLOW SOLUTION

Direct Current Load Flow (DCLF) gives estimations of lines power flows on AC power systems. DCLF looks only at active power flows and neglects reactive power flows. This method is non-iterative and absolutely convergent but less accurate than AC Load Flow (ACLF) solutions. DCLF is used wherever repetitive and fast load flow estimations are required.

In DCLF, nonlinear model of the AC system is simplified to a linear form through these assumptions

The DC load flow is based on the Fast Decoupled Load Flow introduced by Stott and Alsac in 1974.

Stott and Alsac proposed the new sequential algorithm for solving classic power flow problems. The FDLF algorithm is very fast because it exploits the loose physical connection between active (MW) and reactive (MVAr) power flow in transmission systems.

- Line resistances (active power losses) are negligible i.e. $R << X$.
- Voltage angle differences are assumed to be small i.e. $\sin(\theta) = \theta$ and

$\cos(\theta) = 1$.
- Magnitudes of bus voltages are set to 1.0 per unit (flat voltage profile).
- Tap settings are ignored.

Based on the above assumptions, voltage angles and active power injections are the variables of DCLF. Active power injections are known in advance. Therefore for each bus i in the system,

$$P_i = \sum_{j=1}^{N} |Y_{ij}||V_i||V_j| \cos(\theta_i - \theta_j - \delta_{ij})$$

is converted to

$$P_i = \sum_{j=1}^{N} B_{ij}(\theta_i - \theta_j)$$

in which B_{ij} is the reciprocal of the reactance between bus i and bus j.

B_{ij} is the imaginary part of Y_{ij}.

As a result, active power flow through transmission line i, between buses s and r, can be calculated from

$$P_{Li} = \frac{1}{X_{Li}}(\theta_s - \theta_r)$$

where X_{Li} is the reactance of line i. DC power flow equations in the matrix form and the corresponding matrix relation for flows through branches are represented in

$$\theta = [\mathbf{B}]^{-1}\mathbf{P}$$

$$\mathbf{P_L} = (\mathbf{b} \times \mathbf{A})\theta$$

where

P N * 1 vector of bus active power injections for buses 1, …, N

B N * N admittance matrix with R = 0

h N * 1 vector of bus voltage angles for buses 1, …, N

PL M * 1 vector of branch flows (M is the number of branches)

b M * M matrix (b_{kk} is equal to the susceptance of line k and non-diagonal elements are zero)

A M * N bus-branch incidence matrix

Example A.1: A simple example is used to illustrate the points discussed above. A three bus system is considered. This system is shown in Fig. below, with the details given in Tables A.1 and A.2.

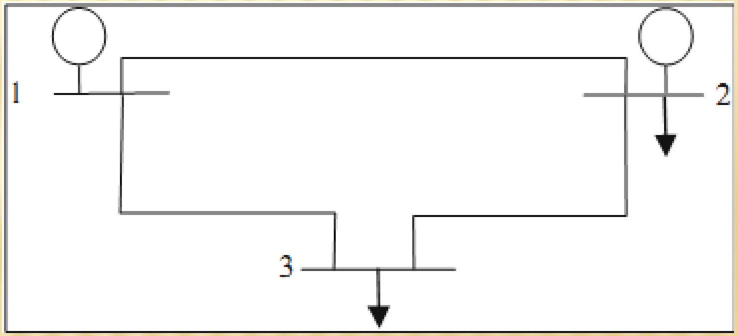

Table A.1 Loads and generations

Bus number	Bus type	P_D (MW)	Q_D (MVAr)	P_G (MW)
1	Slack	0	0	Unknown
2	PV	10	5	63
3	PQ	90	30	0

Table A.2 Branches

Line number	From bus	To bus	X (p.u.)	Rating (MVA)
1	1	2	0.0576	250
2	2	3	0.092	250
3	1	3	0.17	150

With base apparent power equal to 100 MVA, B and P are calculated as follows

$$B = \begin{bmatrix} 23.2435 & -17.3611 & -5.8824 \\ -17.3611 & 28.2307 & -10.8696 \\ -5.8824 & -10.8696 & 16.7519 \end{bmatrix} \quad P = \begin{bmatrix} \text{Unknown} \\ 0.53 \\ -0.9 \end{bmatrix}$$

As bus 1 is considered as slack_1, the first row of P and the first row and column of B are disregarded. θ_2 and θ_3 are then calculated as follows.

$$\begin{bmatrix} \theta_2 \\ \theta_3 \end{bmatrix} = \begin{bmatrix} 28.2307 & -10.8696 \\ -10.8696 & 16.7519 \end{bmatrix}^{-1} \begin{bmatrix} 0.53 \\ -0.9 \end{bmatrix} = \begin{bmatrix} -0.0025 \\ -0.0554 \end{bmatrix} \text{Radian} = \begin{bmatrix} -0.1460^\circ \\ -3.1730^\circ \end{bmatrix}$$

A and **b** are then calculated as

$$\mathbf{A} = \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ 1 & 0 & -1 \end{bmatrix} \quad \mathbf{b} = \begin{bmatrix} 17.3611 & 0 & 0 \\ 0 & 10.8696 & 0 \\ 0 & 0 & 5.8824 \end{bmatrix}$$

Therefore, the transmission flows are calculated as follows

$$\begin{bmatrix} P_{L1} \\ P_{L2} \\ P_{L3} \end{bmatrix} = \text{BaseMVA} \times \mathbf{b} \times \mathbf{A} \times \theta$$

$$= 100 \times \begin{bmatrix} 17.3611 & 0 & 0 \\ 0 & 10.8696 & 0 \\ 0 & 0 & 5.8824 \end{bmatrix} \times \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ 1 & 0 & -1 \end{bmatrix} \times \begin{bmatrix} 0 \\ -0.0025 \\ -0.0554 \end{bmatrix}$$

$$= \begin{bmatrix} 4.4243 \\ 57.4243 \\ 32.5757 \end{bmatrix} \text{MW}$$

THANK YOU

FOR

YOUR LISTINING