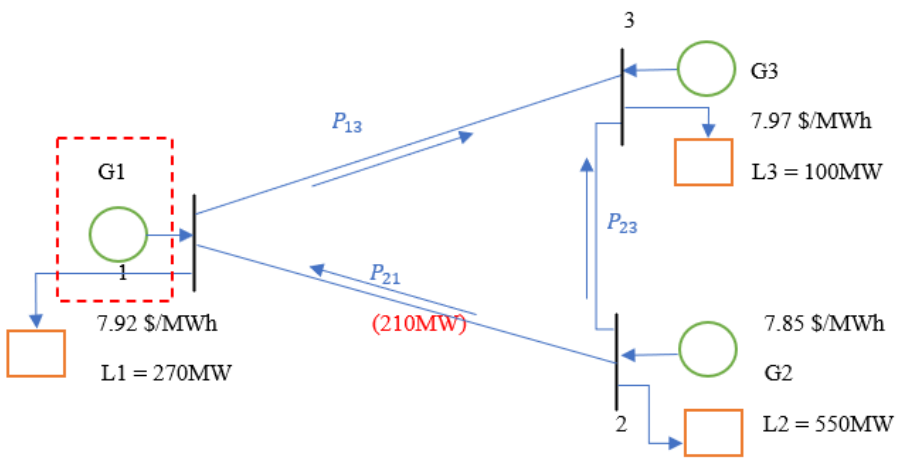
1. DC Optimal Power Flow

The section – 1 consists of 3 modules. Module 1 which is DC Optimal Power Flow and its mathematical model; module – 1a which is the Excel program Input and Output; module – 1b which is a guide leaflet for 1a; module – 1c is the excel file which can be downloaded and used for experimentation and other purposes.

Introduction -

DC Optimal Power Flow – 3 Bus configuration



A 3-bus network is presented above. Note that there are three generators over bus 1, 2 and 3. The marginal cost of generator 1, 2 and 3 is $7.92/MWh (when it is built), $7.85/MWh and $7.97/MWh, respectively. The physical transmission limit of transmission line P12 is 210MW. The demand load at bus 1 is 270 MW, bus 2 is 550 MW and bus 3 is 100 MW, and the total demand load is 850 MW.

We consider two cases for this particular problem. In the first case, only two generators are being used by the whole network, i.e., G_3 and G_2. The total demand is met by these two generators only. In the second case, we add a generator at node 1. Now, the total demand can be met by all the three generators. We will see in the following modules how adding a generator to node 1 in this network is beneficial in various ways.

Mathematical formulation for DCOPF model –

MC_i = marginal cost of bus *i*
G_i = generation at bus *i*
θ_i = phase angle for bus *i*
P_{ij} = Power-flow in line *i-j*
P_{load_i} = demand load at bus *i*

Objective Function: minimize ($MC_1 \times G_1$ + $MC_2 \times G_2$)

Decision variables are G_1, G_2, G_3 and $\theta_1, \theta_2, \theta_{3,}$ and $P_{12},\ P_{13}, P_{23}$

Subject to following constraints:

Nodal power balance constraints:

$100 \times [B_x]\underline{\theta} = \underline{P_{gen}} - \underline{P_{load}}$

Where, $\underline{\theta}$ is in radians and $[B_x]$ is in per unit.

We multiply $[B_x]\underline{\theta}$ or simply the values in $[B_x]$ matrix by 100 to keep the values of $\underline{P_{gen}} - \underline{P_{load}}$ in MW which means we convert the power from per unit to MW with an MVA system base of 100 MVA.

Where, $[B_x]$ = $\begin{pmatrix} (1/x_{12}+1/x_{13}) & -1/x_{12} & -1/x_{13} \\ -1/x_{12} & (1/x_{12}+1/x_{23}) & -1/x_{23} \\ -1/x_{13} & -1/x_{23} & (1/x_{13}+1/x_{23}) \end{pmatrix}$

$[B_x]$ is the susceptance matrix with x_{ij} components and,

$\theta_i = \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix} \qquad \underline{P_{load}} = \begin{bmatrix} P_{load\,1} \\ P_{load\,2} \\ P_{load\,3} \end{bmatrix} \qquad \underline{P_{gen}} = \begin{bmatrix} G_1 \\ G_2 \\ G_3 \end{bmatrix}$

B_{ij} is the susceptance of the branch i to j given by:

B_{ij} = $(-1/x_{ij}\ )$;

B_{ii} = $(1/x_{ij} + 1/x_{ik})$ i.e., the sum of reactance of the lines joining at the bus.

x_{ij} = reactance between line *i* and *j*

Reactance for line 1-2, 1-3 and 2-3 is 0.1 PU, 0.125 PU and 0.2 PU, respectively.

Power-flow in each branch:

$P_{ij} = 100 * B_{ij}(\theta_i - \theta_j) = 100 * (\theta_i - \theta_j)/(-x_{ij})$

Transmission limit constraints:

$100 * (\theta_i - \theta_j)/x_{ij} \leq P_{ijmax}$

$100 * (\theta_j - \theta_i)/x_{ij} \leq P_{ijmax}$

Note that there will be additional non-negativity constraints on some variables such as $0 \leq G_1, G_2, G_3$. Also the transmission losses are assumed negligible, and the line resistances are negligible compared to line reactance.