

# A Software Package to Solve Power Flow in Rectangular Coordinates

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## Power Flow -Introduction

The Load flow problem can be described as follows

- 1) Calculate the slack bus power for specified voltage.
- 2) Calculate the voltage angle and reactive power for PV buses for specified voltage magnitude and real power
- 3) Calculate voltage magnitude and angle for PQ buses for specified real and reactive power.

$$P_i = \sum_{j=1}^n e_i (G_{ij} e_j - B_{ij} f_j) + f_i (G_{ij} f_j + B_{ij} e_j) \quad (1a)$$

$$Q_i = \sum_{j=1}^n f_i (G_{ij} e_j - B_{ij} f_j) - e_i (G_{ij} f_j + B_{ij} e_j) \quad (1b)$$

$$|V_i|^2 = e_i^2 + f_i^2 \quad (1c)$$

Equations (1a), (1b) are used to calculate the real and reactive powers for slack bus and PQ buses. Equation (1c) is used to determine the voltage magnitude for PV buses.

## THE PROPOSED METHOD

The load flow can be described in rectangular form as follows

$$P = \bar{e} G e - \bar{e} B f + \bar{f} B e + \bar{f} G f \quad (2a)$$

$$Q = -\bar{e}B_1e - \bar{e}G_1f + \bar{f}G_1e - \bar{f}B_1f \quad (2b)$$

To incorporate PV buses the 'B' and 'G' are modified as  $B_1$  and  $G_1$  using equations (2c, 2d, 2e) and substituted in equation (2b)

$$B_1(i, j) = B(i, j) , G_1(i, j) = G(i, j) \text{ If 'i' is a PQ bus} \quad (2c)$$

$$B_1(i, i) = 1, G_1(i, j) = 0 \text{ If } i \neq j \quad \text{If 'i' is a PV bus} \quad (2d)$$

$$G_1(i, i) = 1 , B_1(i, j) = 0 \text{ if } i \neq j \quad \text{If 'i' is a PV bus} \quad (2d)$$

It can be written in matrices form in a better way

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} \bar{e} & \bar{f} \\ \bar{f} & -\bar{e} \end{bmatrix} \begin{bmatrix} G & -B \\ B & G \end{bmatrix} \begin{bmatrix} e \\ f \end{bmatrix} \quad (3)$$

Taking derivative on both sides

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \Delta \bar{e} & \Delta \bar{f} \\ \Delta \bar{f} & -\Delta \bar{e} \end{bmatrix} \begin{bmatrix} G & -B \\ B & G \end{bmatrix} \begin{bmatrix} e \\ f \end{bmatrix} + \begin{bmatrix} \bar{e} & \bar{f} \\ \bar{f} & -\bar{e} \end{bmatrix} \begin{bmatrix} G & -B \\ B & G \end{bmatrix} \begin{bmatrix} \Delta e \\ \Delta f \end{bmatrix} \quad (4)$$

The right hand side of equation (3) contains two parts the first part due to change in current and the second part due to change in voltage. The change in power due to current change can be assumed negligible. This is a valid assumption

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \approx \begin{bmatrix} \bar{e} & \bar{f} \\ \bar{f} & -\bar{e} \end{bmatrix} \begin{bmatrix} G & -B \\ B & G \end{bmatrix} \begin{bmatrix} \Delta e \\ \Delta f \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} \Delta e \\ \Delta f \end{bmatrix} = [J]^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \quad (6)$$

Where

$$J = \begin{bmatrix} \bar{e} & \bar{f} \\ \bar{f} & -\bar{e} \end{bmatrix} \begin{bmatrix} G & -B \\ B & G \end{bmatrix} \quad (7)$$

$$J^{-1} = \begin{bmatrix} G & -B \\ B & G \end{bmatrix}^{-1} \begin{bmatrix} \vec{e} & \vec{f} \\ \vec{f} & -\vec{e} \end{bmatrix}^{-1} = J_1 \cdot J_2 \quad (8)$$

The first term J1 in is constant throughout the procedure only the second term is varying. Since the second term J2 is containing four diagonal matrices the inverse can be found easily.

$$J_1 = \begin{bmatrix} G & -B \\ B & G \end{bmatrix}^{-1} = \begin{bmatrix} R & X \\ -X & R \end{bmatrix} \quad (9a)$$

where  $R + iB = Z$  impedance matrix of the bus system (9b)

$$J_2 = \frac{1}{K} \begin{bmatrix} -\vec{e}^{-1} & -\vec{f}^{-1} \\ -\vec{f}^{-1} & \vec{e}^{-1} \end{bmatrix} \quad (9c)$$

K is the determinant of matrix J2 it can be calculated from equation(10)

$$K = -\prod_{i=1}^n e_i - \prod_{i=1}^n f_i \quad (10)$$

The above procedure is carried till the convergence level is reached that is

$$(\text{Max } (\Delta e, \Delta f) \leq \epsilon) \quad (11)$$

### **Software to solve power flow in rectangular coordinates.**

This software package contains programs for power flow in rectangular coordinates. It is applied to distribution systems as well as transmission systems.

c6, c14, c30, and c57-data files for the ieee test systems in the format.

tlf6, tlf14, tlf30, and tlf57-programs to solve the transmission power flow.

dlf28, and dlf69 –programs to solve distribution power flow.

For transmission systems the common IEEE format is used and for distribution systems a simple data format is used.

The algorithm can be summarized as follows.

- 1.Read the data

- 2.Build the admittance matrix

- 3.The power flow equations are expressed as quadratic equations as matrix format.

- 4.Run tlf6, tlf14, tlf30, and tlf57-programs to solve the transmission power flow.

- 5.Run dlf28, and dlf69 –programs to solve distribution power flow.