UMP OPEN COURSEWARE

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

CHAPTER 3

BEE3143:POWER SYSTEM ANALYSIS- Power flow solution & Equation

Expected Outcomes

Able to identify type of buses in power system

Able to develop general equation of power flow solution

Type of buses in power system

- The system buses are classified into 3 types:

i) Slack bus

- one bus, known as slack or swing bus
- is taken as reference
- magnitude and phase angle of the voltage is specified
- makes up the difference between scheduled loads and generated power that are caused by the losses in network

ii) Load buses

- active and reactive power are specified
- magnitude and phase angle of the bus voltage are unknown
- these buses are called P-Q buses

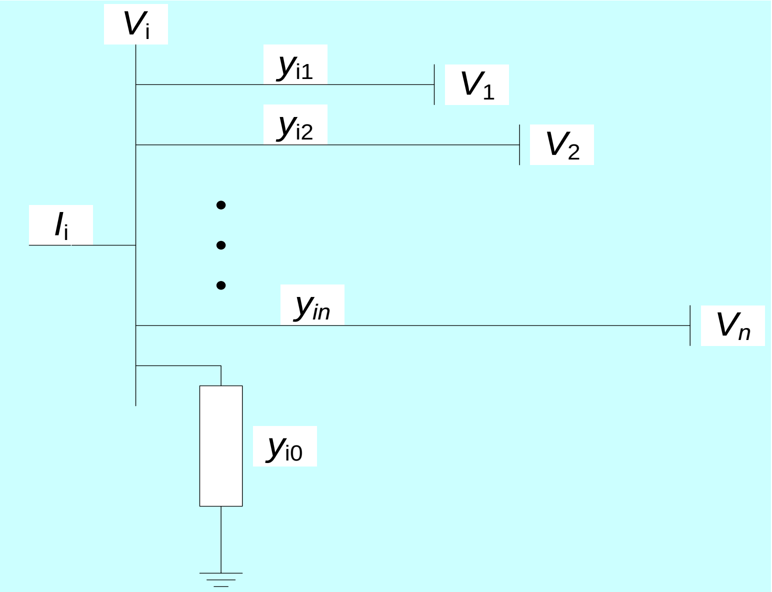
... Type of buses in power system

iii) Regulated buses

- generator buses
- also known as voltage-controlled buses
- real power and voltage magnitude are specified
- phase angle of voltages and reactive power are unknown
- these buses are called P-V buses

	Known	Unknown
Slack bus	**|V|, δ**	**P, Q**
Load buses	**P, Q**	**|V|, δ**
Regulated buses	**P, |V|**	**Q, δ**

Power flow equation



Apply KCL to bus I;

$$I_i = y_{i0}V_i + y_{i1}(V_i - V_1) + y_{i2}(V_i - V_2) + \cdots + y_{in}(V_i - V_n)$$
$$= (y_{i0} + y_{i1} + y_{i2} + \cdots + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - \ldots - y_{in}V_n$$

or

$$I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j \qquad j \neq i \qquad \text{(i)}$$

... Power flow equation

The real and reactive power at bus *i* is

$$P_i + jQ_i = V_i I_i^*$$ or $$I_i = \frac{P_i - jQ_i}{V_i^*}$$ (ii)

Power flow solution

$$\frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j$$

The power flow problem results in a system of nonlinear equations which must be solved by iteration techniques.

... Power flow equation

Basic equation for power-flow analysis is derived from the nodal analysis equation :

$$Y_{bus}V = I$$

For a four-bus p.s.

$$\begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}$$

Y_{ij} are elements of admittance matrix

V_i are bus voltages

I_i are the current injected at each node

For bus 2 in the four-bus p.s.

$$Y_{21}V_1 + Y_{22}V_2 + Y_{23}V_3 + Y_{24}V_4 = I_2$$

... Power flow equation

- The loads on real power system are specified in terms of real and reactive power, not as currents

- Relationship between power and current at bus i can be expressed as:

$$S = VI^* = P + jQ$$

- Current injected at bus 2 can be found as:

$$V_2 I_2^* = P_2 + jQ_2$$

$$I_2^* = \frac{P_2 + jQ_2}{V_2}$$

$$I_2 = \frac{P_2 - jQ_2}{V_2^*}$$

... Power flow equation

$$Y_{21}V_1 + Y_{22}V_2 + Y_{23}V_3 + Y_{24}V_4 = I_2$$

$$I_2 = \frac{P_2 - jQ_2}{V_2^*}$$

Substituting gives:

$$Y_{21}V_1 + Y_{22}V_2 + Y_{23}V_3 + Y_{24}V_4 = \frac{P_2 - jQ_2}{V_2^*}$$

Solving for V_2 gives:

$$V_2 = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^*} - \left(Y_{21}V_1 + Y_{23}V_3 + Y_{24}V_4\right)\right]$$

Similar equations can be created for each load bus in the power system

[1] H. Saadat, *Power System Analysis,* 2nd Edition, McGraw-Hill, 2004


والله أعلم