

# Studi Aliran Daya dengan Metode Gauss Seidel

Pertemuan 7 (Part 1):  
Analisis Sistem tenaga

# Kuliah 7 AST : Ansinkron

## Perhatikan Alur Kuliah berikut

- Referensi utama Buku Hadi Saadat Chapter 6 bagian Power Flow Analysis dengan Gauss-Seidel dan Newton Raphson
- Absen di OCW
- Download modul pdf dan dibaca secara cermat dan teliti berulang-ulang sampai memahami
- Lihat Video rekaman kuliah, link terdapat di SPADA
- Jika ada yang perlu didiskusikan, kirim pertanyaan di WA, yang bertanya dan menanggapi mendapatkan bonus.
- Pelajari berulang-ulang setiap example yang ada.
- Kerjakan tugas mandiri, perhitungan tangan dan program MATLAB.

# Jenis-jenis Bus

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

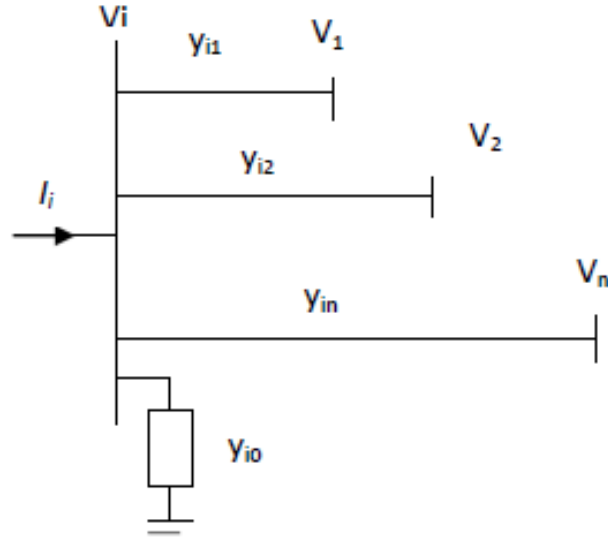
**Load buses** At these buses the active and reactive powers are specified. The magnitude and the phase angle of the bus voltages are unknown. These buses are called P-Q buses.

**Regulated buses** These buses are the *generator buses*. They are also known as *voltage-controlled buses*. At these buses, the real power and voltage magnitude are specified. The phase angles of the voltages and the reactive power are to be determined. The limits on the value of the reactive power are also specified. These buses are called P-V buses.

# Jenis-jenis Bus

Type of Buses	Know or Specified Quantities	Unknown Quantities or Quantities to be determined.
Generation or P-V Bus	$P,  V $	$Q, \delta$
Load or P-Q Bus	$P, Q$	$ V , \delta$
Slack or Reference Bus	$ V , \delta$	$P, Q$

# Power Flow Equation



Note: Transmission lines are represented by their equivalent pi models (impedance in p.u.)

Fig. 1. A typical bus of the power system.

Applying KCL to this bus results in

$$\begin{aligned} I_i &= y_{io}V_i + y_{i1}(V_i - V_1) + y_{i2}(V_i - V_2) + \dots + y_{in}(V_i - V_n) \\ &= (y_{io} + y_{i1} + y_{i2} + \dots + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - \dots - y_{in}V_n \end{aligned} \quad (1)$$

$$I_i = V_i \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j \quad j \neq i \quad (2)$$

The real and reactive power at bus  $i$  is

$$P_i + jQ_i = V_i I_i^* \quad (3)$$

$$I_i = \frac{P_i - jQ_i}{V_i^*} \quad (4)$$

Substituting for  $I_i$  in (2) yields

$$\frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j \quad j \neq i \quad (5)$$

Equation (5) is an algebraic non linear equation which must be solved by iterative techniques

# Gauss-Seidel method

- Equation (5) is solved for  $V_i$  solved iteratively

$$V_i^{(k+1)} = \frac{\frac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} + \sum_{j \neq i} y_{ij} V_j^{(k)}}{\sum y_{ij}} \quad (6)$$

Where  $y_{ij}$  is the actual admittance in p.u.

$P_i^{sch}$  and  $Q_i^{sch}$  are the net real and reactive powers in p.u.

In writing the KCL, current entering bus  $i$  was assumed positive.

Thus for:

Generator buses (where real and reactive powers are injected),  $P_i^{sch}$  and  $Q_i^{sch}$  have positive values.

Load buses (real and reactive powers flow away from the bus),  $P_i^{sch}$  and  $Q_i^{sch}$  have negative values.

Eqn.5 can be solved for  $P_i$  and  $Q_i$

$$P_i^{(k+1)} = R \left\{ V_i^{*(k)} \left[ V_i^{(k)} \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j^{(k)} \right] \right\} \quad j \neq i \quad (7)$$

$$Q_i^{(k+1)} = -Im \left\{ V_i^{*(k)} \left[ V_i^{(k)} \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j^{(k)} \right] \right\} \quad j \neq i \quad (8)$$

The power flow equation is usually expressed in terms of the elements of the bus admittance matrix,  $Y_{bus}$ , shown by upper case letters, are  $Y_{ij} = -y_{ij}$ , and the diagonal elements are  $Y_{ii} = \sum y_{ij}$ . Hence eqn. 6 can be written as

$$V_i^{(k+1)} = \frac{\frac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} - \sum_{j \neq i} Y_{ij} V_j^{(k)}}{Y_{ii}} \quad (9)$$



$$P_i^{(k+1)} = R \left\{ V_i^{*(k)} \left[ V_i^{(k)} Y_{ii} + \sum_{\substack{J=1 \\ J \neq i}}^n Y_{ij} V_j^{(k)} \right] \right\} \quad j \neq i \quad (10)$$

$$Q_i^{(k+1)} = -Im \left\{ V_i^{*(k)} \left[ V_i^{(k)} Y_{ii} + \sum_{\substack{J=1 \\ J \neq i}}^n Y_{ij} V_j^{(k)} \right] \right\} \quad j \neq i \quad (11)$$

### Iterative steps:

- Slack bus: both components of the voltage are specified. 2(n-1) equations to be solved iteratively.
- Flat voltage start: initial voltage of 1.0+j0 for unknown voltages.
- PQ buses:  $P_i$  and  $Q_i$  are known. with flat voltage start, Eqn. 9 is solved for real and imaginary components of Voltage.
- PV buses:  $P_i^{sch}$  and  $[V_i]$  are known. Eqn. 11 is solved for  $Q_i^{k+1}$  which is then substituted in Eqn. 9 to solve for  $V_i^{k+1}$

Iterasi terus menerus dilakukan sampai tingkat akurasi yang diinginkan.

$$|e_i^{(k+1)} - e_i^{(k)}| \leq \epsilon$$

$$|f_i^{(k+1)} - f_i^{(k)}| \leq \epsilon$$

Biasanya, Akurasi/Epsilon = 0.00001 – 0.00005

**Contoh-contoh dari Buku Hadi Saadat Chapter 6  
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6.7. Figure 6.20 shows the one-line diagram of a simple three-bus power system with generation at bus 1. The voltage at bus 1 is  $V_1 = 1.0\angle 0^\circ$  per unit. The scheduled loads on buses 2 and 3 are marked on the diagram. Line impedances are marked in per unit on a 100-MVA base. For the purpose of hand calculations, line resistances and line charging susceptances are neglected.

(a) Using Gauss-Seidel method and initial estimates of  $V_2^{(0)} = 1.0 + j0$  and  $V_3^{(0)} = 1.0 + j0$ , determine  $V_2$  and  $V_3$ . Perform two iterations.

(b) If after several iterations the bus voltages converge to

$$V_2 = 0.90 - j0.10 \text{ pu}$$

$$V_3 = 0.95 - j0.05 \text{ pu}$$

determine the line flows and line losses and the slack bus real and reactive power. Construct a power flow diagram and show the direction of the line flows.

(c) Check the power flow solution using the **lfgauss** and other required programs. (Refer to Example 6.9.) Use a power accuracy of 0.00001 and an acceleration factor of 1.0.