LOAD FLOW ANALYSIS

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LOAD FLOW ANALYSIS:

➢ Load flow studies or Power flow studies is the analysis of a power system in a normal steady state condition.

➢Basically load flow studies comprises of determination of

- Voltage
- Current
- Active Power
- Reactive Power

IMPORTANCE

- Generation supplies demand(load) plus losses.
- Bus voltage magnitude remains close to rated value.
- Generation operates within specified active and reactive power limits.
- Transmission line and transformer are not overloaded.

NEED OF LOAD FLOW STUDY:

- Designing a power system
- Planning a power system
- Expansion of power system
- Providing guidelines for optimum operation of power system
- Providing guidelines for various power system studies

Bus Classifications:-

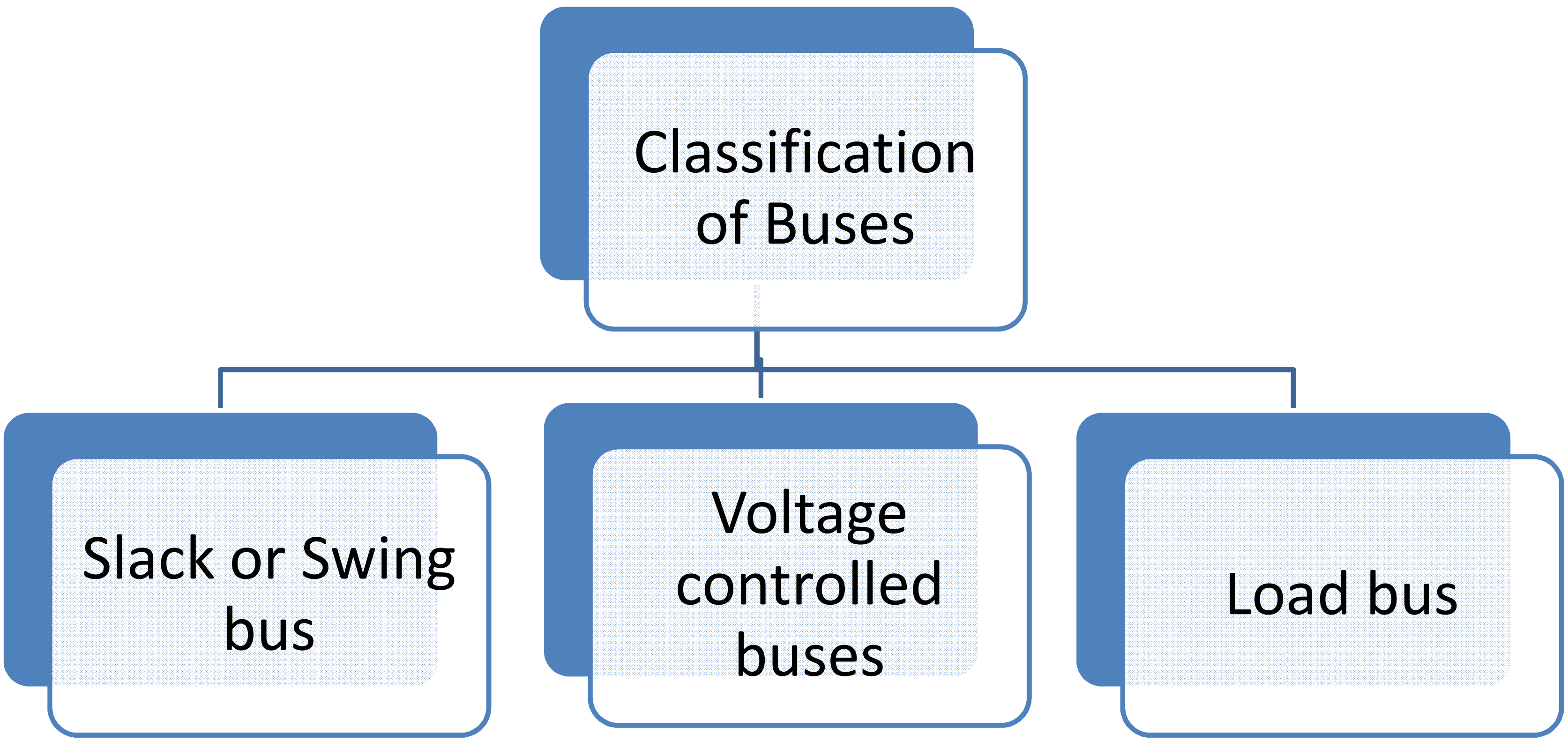
- A bus is a node at which many Transmission lines, Loads and Generators are connected.

- It is not necessary that all of them be connected to every bus.

- Bus is indicated by a vertical line at which number of components are connected.

- In load flow study, two out of four quantities are specified and other two quantities are to be determined by load flow equation.

- Depending upon that bus are classified


Classification of Buses
Slack or Swing bus
Voltage controlled buses
Load bus

Slack Bus

- Voltage magnitude (V) and voltage phase angle ($\boldsymbol{\delta}$) are specified and real (P)and reactive power (Q)are to be obtained.
- Normally there is only one bus of this type in power system.
- One generator bus is selected as the reference bus.
- In slack bus, voltage angle and magnitude is normally considered as 1+j0 pu.
- Real and reactive powers are uncontrolled. Supplies whatever real or reactive power is necessary to make the power flows in the system balance.

Load Bus or PQ bus

- A bus at which active power and reactive power are specified.
- Magnitude (V) and phase angle ($\boldsymbol{\delta}$) of the voltage will be calculated.
- This type of buses are more common , comprising almost 80% of all the buses in given power system.
- Real and Reactive powers supplied to a power system are defined to be positive.
- Powers consumed from the system are defined to be negative.

Generator bus or P-V Bus

- A bus at which magnitude of voltage (V) and active power (P) is defined.
- Reactive power (Q) and phase angle ($\boldsymbol{\delta}$) are to be determined.
- It is also known as P-V bus.
- This bus always connected to generator.

- This type of bus comprises about 10% of all the buses in power system.

- Phase angles will be calculated during iteration.

- Reactive power will be calculated after the solution is found.

Key Points:-

- Voltage on a load bus (P-Q bus) changes as the load varies . P & Q are fixed, while V (magnitude & angle) vary with load conditions.
- Generator (P-V) buses work most efficiently when running at full load. P & V are fixed.
- Slack bus generator varies P & Q that it supplies to balance complex power. V & angle reference are fixed

Bus Classification Table:-

Type of Bus	V (per unit)	δ (degree)	P (MW)	Q (MVar)
Slack bus	specified	specified	unknown	unknown
Load bus (P-Q bus)	unknown	unknown	specified	specified
Regulated bus (P-V bus)	specified	unknown	specified	unknown

Static Method:-

The variables associated with each bus are:

- Voltage magnitude (V)
- Voltage phase angle ($\boldsymbol{\delta}$)
- Active Power (P)
- Reactive Power (Q)

➢ The load flow problem can be solved with the help of load flow equation (static load flow equation).

Basics of Power flow studies:-

To find the power flow solutions via iteration:

1. For the power system create a bus admittance matrix Y_{bus}
2. Make an initial estimate for the voltages at each bus in the system.
3. Iterate to find conditions that satisfy the system's load flow equations.

- Update the voltage estimate for each bus (one at a time), based on the estimates for the voltages & power flows at every other bus and the values of the bus admittance matrix.
- Since the voltage at a given bus depends on the voltages at all of the other buses in the system (which are just estimates), the updated voltage will not be correct

4. Repeat this process to make the voltages at each bus approaching the correct answers to within a set tolerance level.

- The bus admittance matrix given by

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

$I_i = \sum Y_{ik} V_k$ Where i,k= 1,2...n

So, complex power is denoted as

$S_i = V_i I_i^* = P_i + jQ_i$

Where V_i is the per unit voltage at the bus

I_i^* is the complex conjugate of the per unit current injected at the bus

P_i and Q_i are per unit Real and Reactive powers

Therefore, $I_i^* = \dfrac{P_i + jQ_i}{V_i}$

$$\Rightarrow I_i = \frac{P_i - jQ_i}{V_i^*}$$

$$\Rightarrow P_i - jQ_i = V_i^* \sum_{j=1}^{n} Y_{ij} V_j = \sum_{j=1}^{n} Y_{ij} V_j V_i^*$$

$$Y_{ij} = |Y_{ij}| \angle \theta_{ij}, \quad V_i = |V_i| \angle \delta_i$$

The equation is written as

$$P_i - jQ_i = \sum_{j=1}^{n} |Y_{ij}||V_j||V_i| \angle(\theta_{ij} + \delta_j - \delta_i)$$

Real and Reactive power expressed as:

$$P_i = \sum_{j=1}^{n} |Y_{ij}||V_j||V_i| Cos(\theta_{ij} + \delta_j - \delta_i)$$

$$Q_i = -\sum_{j=1}^{n} |Y_{ij}||V_j||V_i| Sin(\theta_{ij} + \delta_j - \delta_i)$$

$$P_i = |V_i| \sum_{k=1}^{n} |V_k| |Y_{ik}| (\delta_i - \delta_k); i = 1,2 \ldots n$$

$$Q_i = -|V_i| \sum_{k=1}^{n} |V_k| |Y_{ik}| Cos(\delta_i - \delta_k) + |V_i|^2 |Y_{ii}|$$

Information from Power flow studies:-

The basic information contained in the load flow output is:

- All bus voltage magnitudes and phase angles w.r.t. Slack bus.
- All bus active and reactive power injections.
- All line sending and receiving end complex power flows.
- Individual line losses can be deduced by subtracting receiving end complex power from sending end complex power.
- Total system losses- deduced by summing complex power at all loads & generators and subtracting the totals.

- The most important information obtained from the load-flow is the **system voltage profile**.
- A power flow program can be set up to provide alerts if the voltage at any given bus exceeds, for instance +/- 5% of the nominal value.
- Such voltage variations may indicate problems.

- If V varies greatly over the system, large reactive flows will result; this in turn, will lead to increased real power losses and in extreme cases, an increased likelihood of voltage collapse.
- When a particular bus has an unacceptable low voltage, the usual practice is to install capacitor banks in order to provide reactive compensation to load.

Thank You