Syllabus:

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11. Iterative Methods Gauss-Seidal Method.
12. Newton Raphson Method.

References

1- power system analysis John J.Grainger , William D. Stevenson , JR.
2- power system analysis Hadi Saadat .
3- power system analysis and Design J. Duncan Glover

1- Introduction of Power System

Electric energy is the most popular form of energy. Because it can be transported easly at high efficiency and reasonable cost.

The first electric network in the united states was established in 1882 at the Peral Street station in New York city by Thomas Edison. The station supplied dc power for lighting the lower Manhattan area. The power was genrerated by dc generators and distributed by underground cables. In the same year the first water-wheel driven generator was installed in Appleton, Wisconsin. Within a few years many companies were established producing energy for lighting all operated under Edison's pantents. Because of the excessive power loss, I^2R at low voltage Edison's companies could deliver energy only a short distance from their stations.

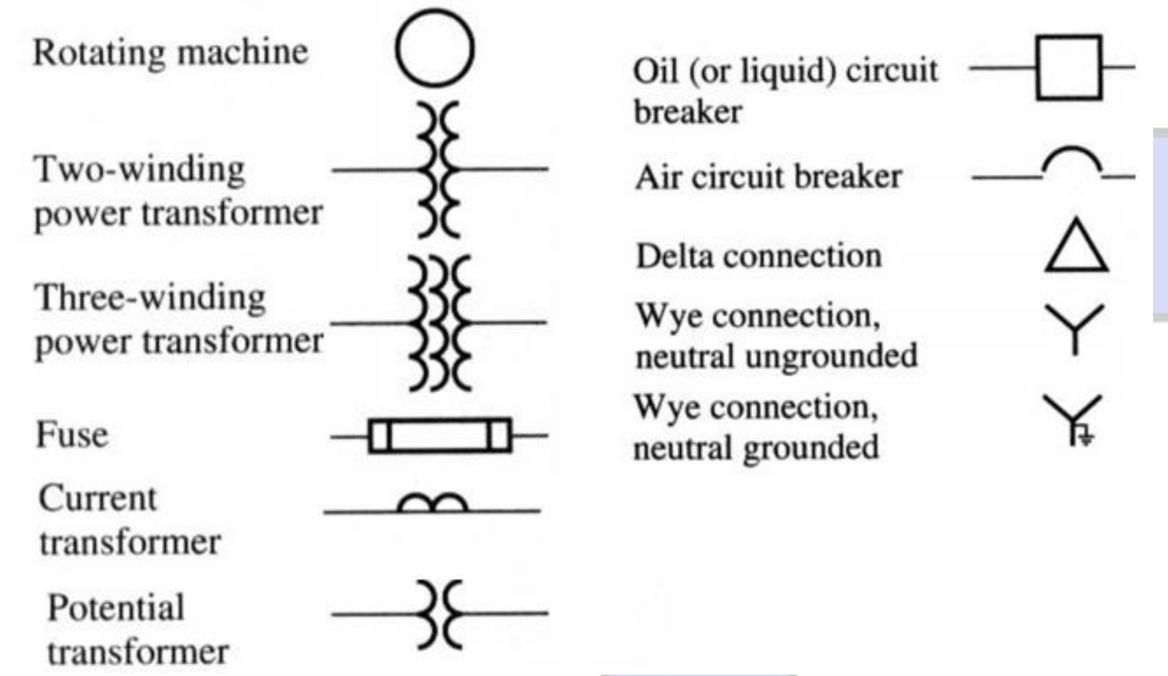
With the invention of transformer (William Stanley 1885) to raise the level of ac voltage for transmission and distribution and the invention of the induction motor (Nikola Tesla 1888) to replace the dc motor, the advatages of ac system becom apparent, and made the ac sysrem prevalent. Another advantage of the ac system is that due to lack of commutators in the genratore, more power can be produced conveniently at higher voltage.

An interconnected power system consists of generation units, transmission lines and distribution network. The function of an integrated power system is to generate electrical power from different sources of energy, transmit the generated power to the load centers and distribute it to the end consumers. Different types of generators and loads are an integral part of the power system network. Source of generation may be thermal, hydel, nuclear, wind or solar and the load may be inductive, capacitive and resistive type, depending upon the nature of utilization of electrical power. In a power system load demand keeps changing all the time; therefore, proper power balance between load and generation have to be maintained continuously by the power system operators. Therefore, proper planning is required to operate an interconnected power system to ensure uninterrupted quality power supply to the consumers.

2-Power System Representation

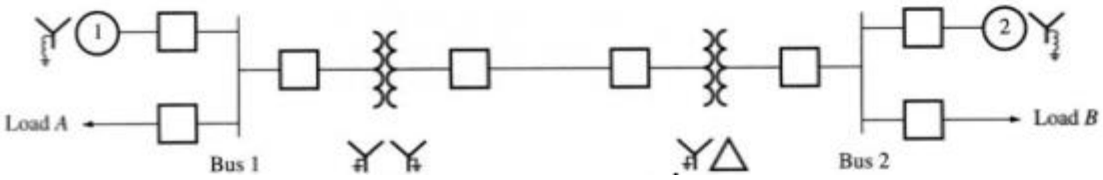
Almost all modern power systems are three-phase systems with the phases of equal amplitude and shifted by 120˚. Since phases are similar, it is customary to sketch power system is similar it is customary to sketch power system in a simple form with a single line representing all three phases of the real system.

Combined with a standard set of symbols for electrical components, such one-line diagrams provide compact way to represent information.



2-1 One-Line (Single-Line) Diagrams:

As example a power system containing two synchronous machines, two loads, two busses, two transformers, and a transmission line to connect busses together.



All devices are protected by oil circuit breakers (OCBs). We notice that the diagram indicates the type of connection for each machine and transformer, and also the points in the system connected to the ground.

The ground connections are important since they affect the current flowing in nonsymmetrical faults. These connection can be direct or through a resistor or inductor (they help reducing the fault current that flows in unsymmetrical faults, while having no impact on the steady-state operation of the system since the current through them will be zero).

Machine ratings, impedances, and/or consumed (or supplied) powers are usually included in the diagrams.

3-PER UNIT SYSTEM

Because of the large amount of power transmitted (KW or MW and KVA or MVA). These quantities as well as ampere and voltages are often expressed as a percent or per unit of a reference or base value specified for each.

3-1 Advantages of Per Unit System

1. While performing calculations, referring quantities from one side of the transformer to the other side serious errors may be committed. This can be avoided by using per unit system.
2. Voltages, currents and impedances expressed in per unit do not change when they are referred from one side of transformer to the other side. This is a great advantage'.
3. Per unit impedances of electrical equipment of similar type usually lie within a narrow range, when the equipment ratings are used as base values.
4. Transformer connections do not affect the per unit values.
5. Manufacturers usually specify the impedances of machines and transformers in per unit or percent of name plate ratings.

In power systems there are four base quantities required to define a per unit system. These are: power S_b, voltage V_b, current I_b, and impedance Z_b. In single phase systems, the relationships among these quantities are:

$$S_b = V_b I_b$$

$$V_b = I_b Z_b$$

It is necessary to specify two base values (usually power and voltage). The other two bases value (current and impedance) are computed from the above equations. as follows.

$$I_b = \frac{S_b}{V_b}$$

$$Z_b = \frac{V_b \ in \ V_{LN}}{I_b \ in \ Amp} = \frac{(V_b \ in \ KV_{LN})^2 \times 1000}{S_b(KVA_{1\phi})} = \frac{\left(KV_{b(LN)}\right)^2}{MVA_{b(1\phi)}}$$

The formulas above relate the various quantities in a single phase system and 3-ph system where the current is line current, voltage is voltage to neutral and S is S per phase.

But normally we select a three-phase power base (S_b or MVA_b) and a line-to-line voltage base (V_b or kV_b). From these two the other bases can be computed using circuit laws thus:

$$I_{b-Line} = \frac{S_{b-3\phi}}{3}\frac{\sqrt{3}}{V_{b-LL}} = \frac{S_{b-3\phi}\ (KVA)}{\sqrt{3}V_{b-LL}(KV)}$$

$$Z_b = \frac{(V_{b-LN})^2}{S_{b-1\phi}} = \frac{(V_{b-LL})^2}{S_{b-3\phi}} = \frac{(KV_b)^2}{MVA_b}$$

In general for any quantity:

$$\text{quantity per unit} = \frac{\text{actual quantity}}{\text{base value of quantity}}$$

The specified power base is applicable to all parts of the power system. The voltage base varies across a transformer and so do the current base and impedance base. The pu electrical quantities are calculated as follows:

$$S_{pu} = \frac{S}{S_b} = \frac{P + jQ}{S_b} = \frac{P + jQ}{S_b} = P_{pu} + jQ_{pu} \qquad pu$$

$$V_{pu} = \frac{V}{V_b} \qquad pu$$

$$I_{pu} = \frac{I}{I_b} \qquad pu$$

$$Z_{pu} = \frac{Z}{Z_b} \qquad pu$$

$$Z_{pu} = Z_{ohm}\frac{MVA_b}{(KV_b)^2}$$

It’s clear that the base voltage change as the voltage level of the system is changed by transformers, but the voltage and impedance expressed in pu remain unaffected on both sides of transformers.

Different parts of a system may have different base values under such conditions the conversion of pu impedance from one base to another is perform as:

$$Z_{pu2(new)} = Z_{pu1(old)} \times \frac{MVA_{b2(new)}}{MVA_{b1(old)}} \times \left(\frac{KV_{b1(old)}}{KV_{b2(new)}}\right)^2$$

Note

It can be seen by inspection of any power system diagram that:

a. Several voltage levels exist in a system

b. It is common practice to refer to plant MVA in terms of per unit or percentage values

c. Transmission line and cable constants are given in ohms/km.