CHAPTER II

REPRESENTATION OF A POWER SYSTEM

2.1. The One-Line Diagram.

A balanced three phase system is generally solved by considering only one of its phases. A diagram can, therefore, be drawn to show the phase, and it is called a one-line diagram. The diagram is indicated by a single line and standard symbols of the transmission line and associated apparatus of an electric system. If the impedances of the equivalent circuits of lines, transformers, capacitors and rotating machines are shown on the one-line diagram. The diagram is an impedance diagram.

The variables and characteristic values used in power system analysis are generally expressed in "per unit" values. The use of per unit value greatly simplifies the work on a system with transformers, moreover, the impedance of a piece of apparatus is usually specified in per unit on the base of the nameplate ratings.

2.2. Generators and Loads.

Generators are any synchronous machines. Motors are considered as generators that generate negative power. In this investigation, a generator and its internal impedance is treated as a current source and a shunt admittance. According to Norton's theorem a voltage source E_g behind an impedance Z_g is represented by a current source of $Y_g E_g$ and a shunt admittance Y_g where $Y_g = \frac{1}{Z_g}$.

In short circuit studies, a subtransient impedance is used for the internal impedance of a generator; and a transient impedance, for that of a synchronous motor.

A load is represented by a equivalent admittance connecting from busbars to ground. If a load S_1 is connected to busbar A, whose voltage magnitude is V_A , then the load equivalent admittance is

$$Y_1 = \frac{S_1^*}{|V_A|^2} \qquad (2.1)$$

The representations of d generator and of a load is shown in Fig. 1.

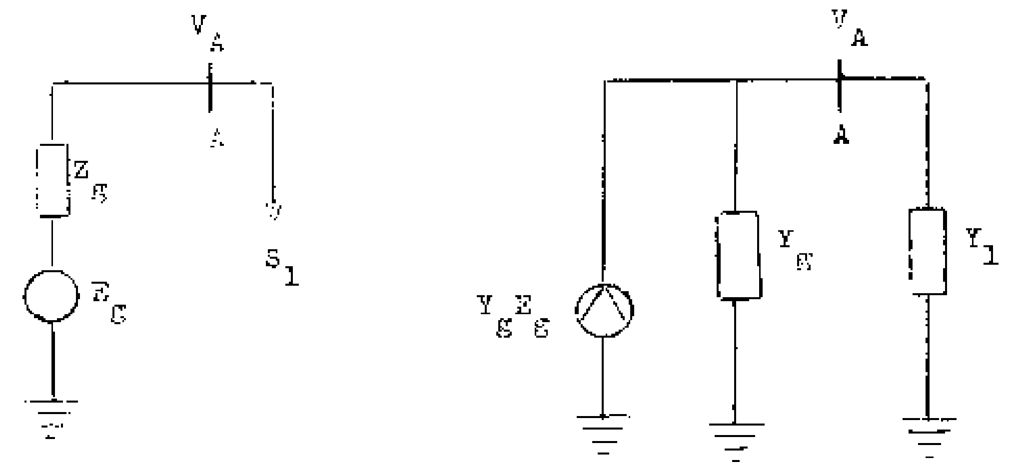

Fig. 1. Representations of a generator and of a load

2.3. Transformers.

A two-winding transformer with a nominal turns ratio is represented by its equivalent impedance on either of its sides connected between two busbars. The small magnetizing impedance is neglected. The equivalent representation of a transformer with nominal turn-ratio is shown in Fig. 2 (a).

If a transformer is tapped at one side, the voltage base on the tapped side will change. The equivalent impedance on the tapped side will be changed, and so will the current in the transformer. In order to compensate this effect so that the system can be handled on the original voltage base the equivalent network of the transformer is reformed.

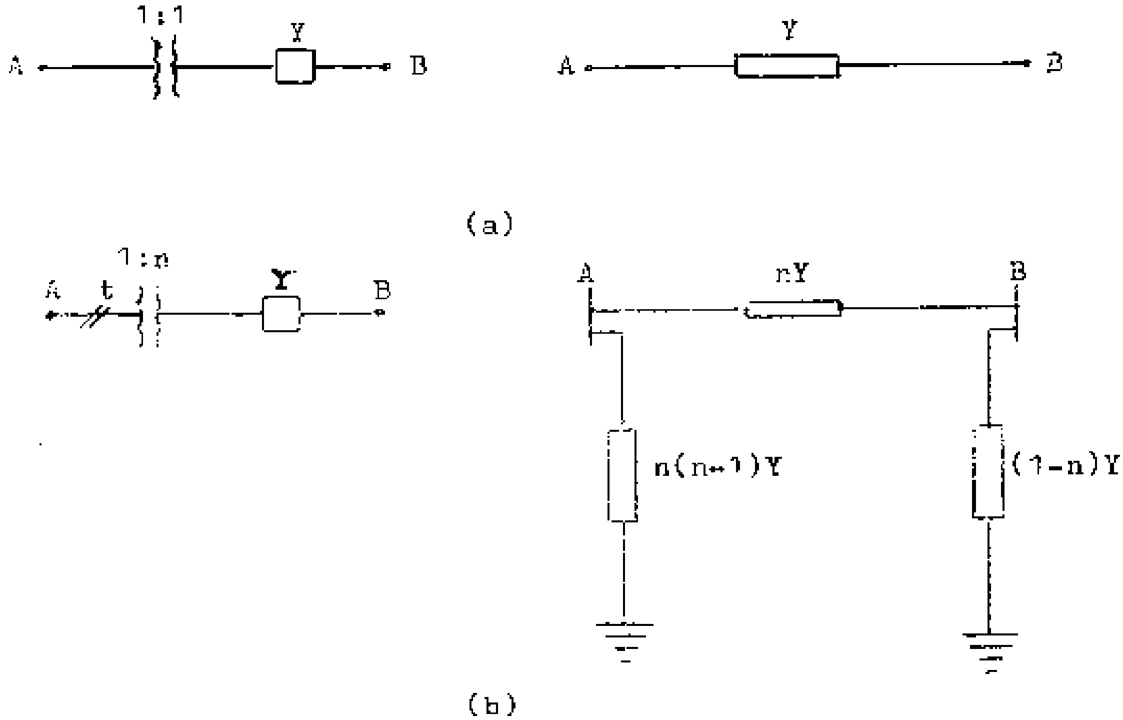

Fig. 2 Representation of a transformer

(a) with nominal turn-ratio.

(b) with off-nominal turn-ratio.

In the untapped transformer, the current, in per unit value, flows in either side is equal to I where

$$I = (V_A - V_B)\ Y \qquad (2.2)$$

If side A of the transformer is tapped for t%, the off-nominal turn-ratio which appears on side B is n where

$$n = 100/(100 + t) \qquad (2.3)$$

The current on side A, then, is

$$I_A = (V_A - V_B/n)n^2 Y \qquad (2.4)$$

and that on side B is

$$I_B = (V_B - nV_A)Y \qquad (2.5)$$

Equations (2.4) and (2.5) may be so rearranged that the admittance coefficients are grouped as self-and mutual values. Then

$$I_A = n(n - 1)Y\ V_A + nY(V_A - V_B) \qquad (2.6)$$

$$I_B = (1 - n)Y\ V_B + nY(V_B - V_A) \qquad (2.7)$$

A π - network, as shown in Fig. 2(b), can be used as the new representation of the transformer.

A three winding transformer includes a tertiary winding on a core. It is classically represented by a T-network. If the tertiary winding is opened circuited or if it supplies a comparatively small load, as it usually does, the transformer equivalent representations, both with and without tap setting, are the same as those of a two winding transformer. In case of being a T-network, tap setting effects cannot be represented, and it is treated as a circuit with three branches and with its ficitious node as one more busbar.

2.4. Generalized Representation of a Branch.

For the sake of programming, a transmission line, a transformer, a branch of the T-network of a three winding transformer, or a shunt line is referred to as a branch. The generalized representation of a branch is then assumed to be as shown in Fig. 3.

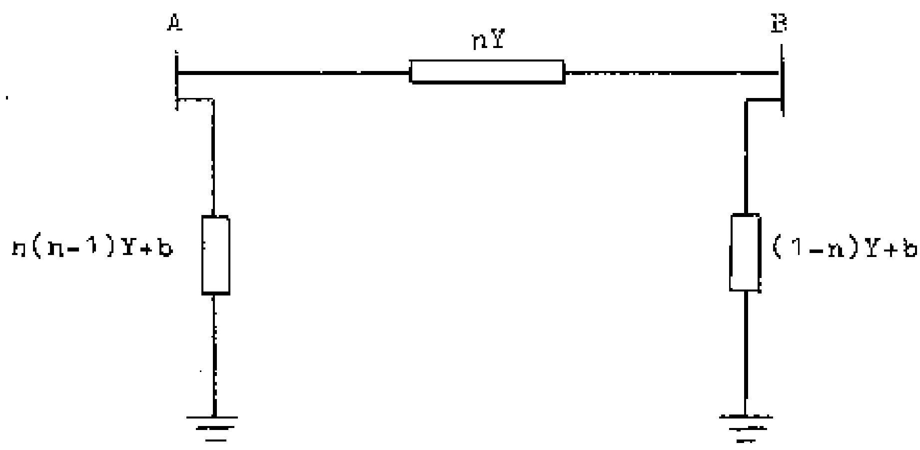

Fig. 3 A generalized representation of a branch

For a transmission line, $n = 1$ as $t = 0$, and $b = b$

For a untapped transformer, $n = 1$ as $t = 0$, and $b = 0$

For a tapped transformer, $0 < n \neq 1$ as $t \neq 0$, and $b = 0$

For a branch of a T-network of a three-winding transformer $n = 1$ as $t = 0$, and $b = 0$

For a shunt line at busbar A, $B = A$, $n = 1$ as $t = 0$, and $b = 0$

2.5. Representation of a Unbalanced System.

The phase sequence component techniques are usually used to attack problems in an unbalanced system. A phase 'a' of the system is represented by three networks called a positive (phase) sequence network, a negative (phase) sequence network, and a zero (phase) sequence network.

A positive sequence network is composed of the positive sequence components of the system elements; a negative network, the negative sequence components; and a zero network, the zero sequence components.

The sequence component representations of various system elements, especially of generators and transformers of different types of winding connections and groundings, can be looked in any standard texts in power system analysis.

A balanced system may be considered as an unbalanced system in which the negative sequence and zero sequence components of all system elements are zero. A positive sequence network, therefore, can represent a balanced system.

Tap settings of transformers can be treated in a negative network as well, but in a zero sequence network they have comparatively small effects and so are not represented in it.