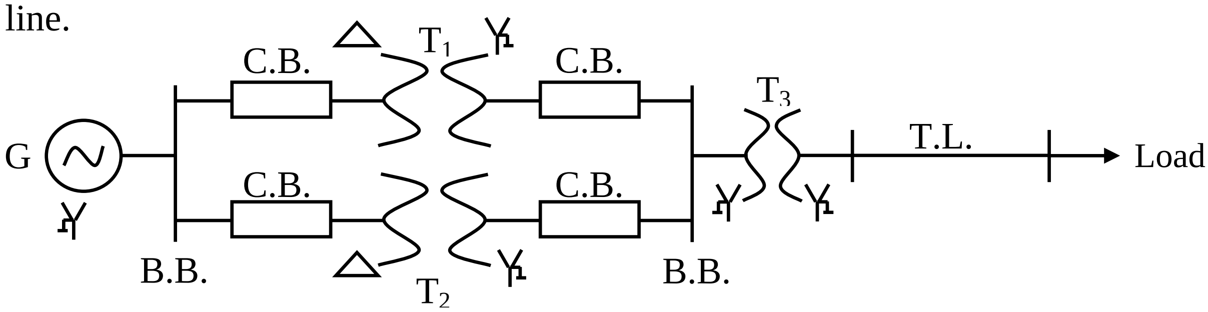
# ***Chapter One***
# ***Power System Representation***

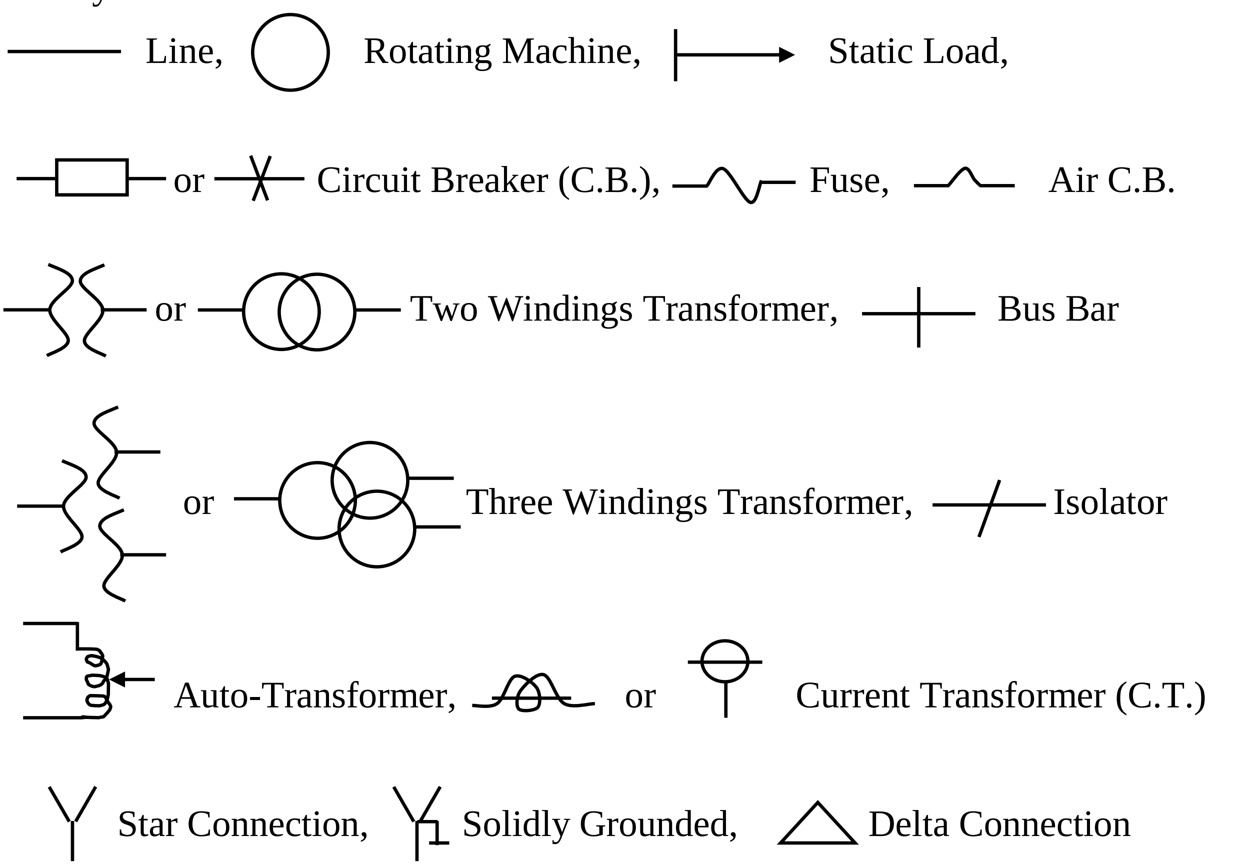
## 1-1 One – Line Diagram:-

A very useful simple way of graphically representing a network is schematic or line diagram or in which 3-ph circuit are represented by simple line.




One Line Diagram of a Simple Power System

* Symbols:



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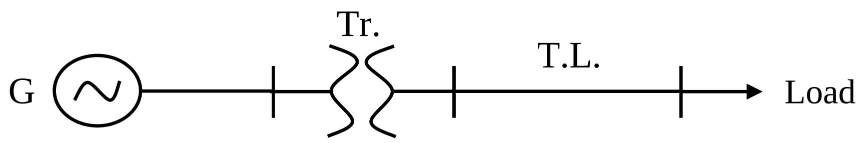
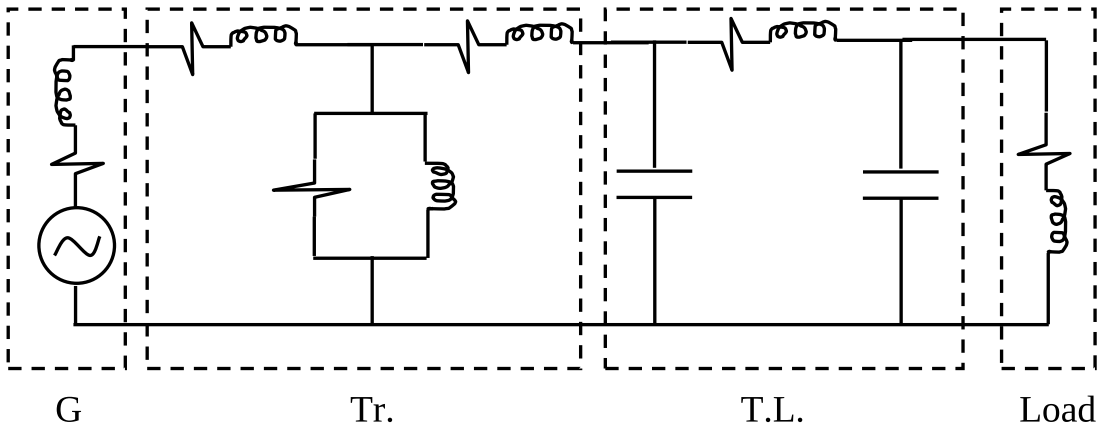
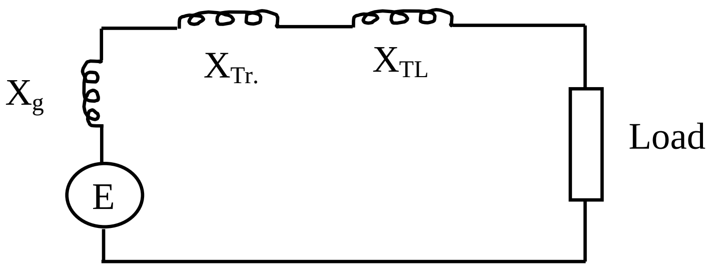
## 1-2 Impedance and Reactance Diagrams:-




One Line Diagram




Impedance Diagram




Reactance Diagram

## 1-3 Per Unit System:-

The analysis of power networks instead of using actual values of quantities, it is usually to express them as fractions of reference quantity such as rated or full load values. These fractions are called per unit (p.u.) and p.u. value of any quantity is defined as:

$$value\ p.u. = \frac{the\ actual\ value\ (in\ any\ unit)}{the\ base\ or\ reference\ value\ in\ the\ same\ unit}$$



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***Notes:***

Some authorities express the p.u. value as a percentage %

$X_{p.u.} = \frac{X\%}{100}$ (for example 0.02 in p.u. or 2%)

$$Base\ Current\ I_b(A) = \frac{S_b\ (kVA)}{V_b\ (kV)}$$

Where: $S_b$= base kVA per phase, $V_b$= base phase voltage

$$I_b(A) = \frac{S_{3ph}\ (kVA)/3}{V_{Lb}\ (kV)/\sqrt{3}} = \frac{S_{3ph}\ (kVA)}{\sqrt{3}\,V_{Lb}\ (kV)}$$

$$Base\ Impedance\ Z_b(\Omega) = \frac{V_b}{I_b} = \frac{V_b^2(kV)}{S_b(MVA)} = \frac{V_b^2(kV)}{S_b(kVA)} * 1000$$

$$= \frac{V_{Lb}^2(kV)}{S_{3ph}(MVA)}$$

## 1-4 Changing the Base of p.u. Quantities:-

$$p.u.Impedance = \frac{Actual\ Impedance}{Base\ Impedance}$$

Sometimes the p.u. impedance of element of a system is expressed in a base differ than the selected base for other parts of the system in which the element is located. Since all the impedances must be selected in one phase, then it's necessary to change the base

$$p.u.Impedance\ of\ cct\ element = \frac{Actual\ Impedance * base\ kVA}{(base\ voltage)^2 * 1000}$$

$$Z_{p.u.} \propto base\ kVA \propto \frac{1}{base\ voltage}$$

Then, change to a new base:

$$(Z_{p.u.})new = (Z_{p.u.})given * \frac{(kVA_b)new}{(kVA_b)given} * \frac{(V_b^2)given}{(V_b^2)new}$$

## 1-5 P.U. Impedance of Transformers:-

*1) Two-Winding Transformers*

Let $Z_1$ = H.T. impedance, $Z_2$ = L.T. impedance, $V_1$ = H.T. voltage, $V_2$ = L.T. voltage, S = kVA of transformer

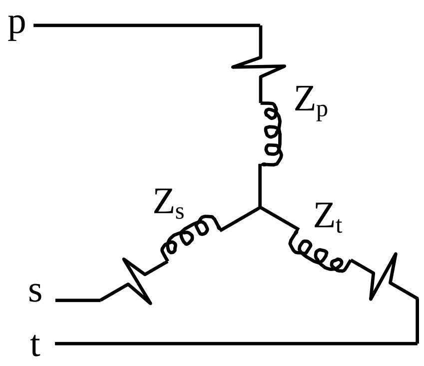
$$Z_2 = Z_1 * \left(\frac{V_2}{V_1}\right)^2 \rightarrow Z_{2p.u.} = \frac{Z_2}{Z_{2base}} \rightarrow$$

$$Z_{2p.u.} = Z_1 * \left(\frac{V_2}{V_1}\right)^2 * \frac{kVA}{(V_2)^2 * 1000} = \frac{Z_1}{\frac{(V_1)^2 * 1000}{kVA}} = \frac{Z_1}{Z_{1base}} = Z_{1p.u.}$$

$$\therefore Z_{2p.u.} = Z_{1p.u.}$$

*2) Three-Winding Transformers*

All three winding transformer may have different kVA ratings. The impedance of each winding may be given in p.u. or percent based on the rating of it or tests may be made to determine the impedances.




A standard short-circuit (s.c.) test may be made to determine the three impedances as follows:-

$Z_{ps}$ = leakage impedance measured in primary with secondary short circuit and tertiary open circuit

$Z_{pt}$ = leakage impedance measured in primary with tertiary short circuit and secondary open circuit

$Z_{st}$ = leakage impedance measured in secondary with tertiary short circuit and primary open circuit

$$Z_{ps} = Z_p + Z_s, Z_{pt} = Z_p + Z_t, Z_{st} = Z_s + Z_t$$

$$Z_p = \frac{1}{2}\left[Z_{ps} + Z_{pt} - Z_{st}\right], Z_s = \frac{1}{2}\left[Z_{ps} + Z_{st} - Z_{pt}\right],$$

$$Z_t = \frac{1}{2}\left[Z_{pt} + Z_{st} - Z_{ps}\right]$$



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