classmate
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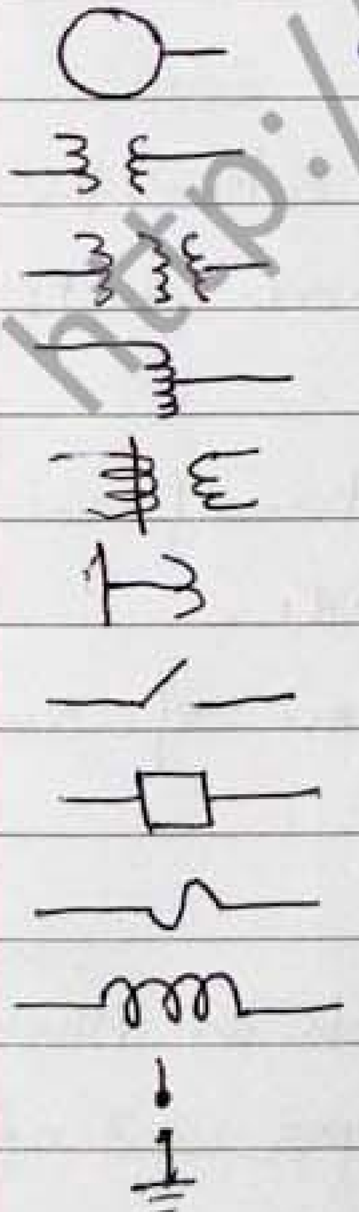
LECTURE-02

Introduction to Single line diagram (SLD)

- Since power systems are extremely complicated electrical N/w which is three phase network. So, it is very difficult to under--stand these Network
- So ~~Single~~ For balanced system, all phase have equal voltage & current displaced at 120° to each other. So, it is possible to make single phase or single line representation of this balanced 3ϕ system.
- Single line diagram (SLD) are concise way of communicating the basic ~~aa~~ arrangement of power system components. SLD use a single line to represent all the three phases.
- It is also called one line diagram. It show the relative electrical interconnection of generator, transformer, transmission and distribution lines, Loads, Circuit breaker etc used in assembling the power system.

Symbols used to represent various components:



- Generator or Motor
- Transformer
- 3-Winding Xmer
- Auto Transformer
- Current Transformer
- Potential Transformer
- Disconnect (Isolator) Switch
- Circuit Breaker
- Fuse
- Reactor
- Lightning Arrestor

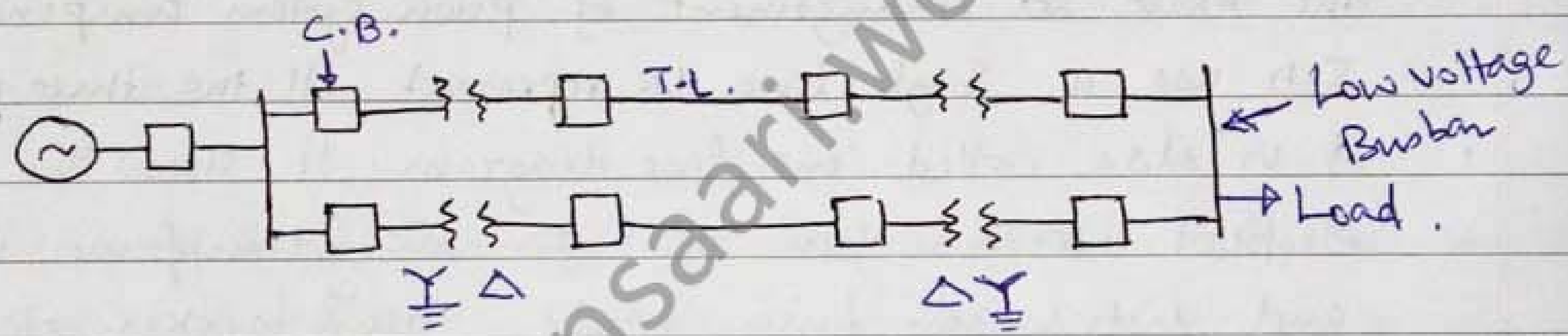
Combining these symbols we make one line diagram.

Bus Bar (Bus) : Node in electrical Circuit
(one bus for each phase)

Buses : Aluminium or Copper bars or pipes and can be several meter long.

Buses in SLD : → short straight line
→ perpendicular to transmission lines and to lines connecting equipment to the Buses.

Example of Single line diagram:



→ In this way we can build a SLD. This is much more Simplified & easy to understand.

PER UNIT SYSTEM

Why Per Unit? (Electrical quantity)

→ Most of the value in power Systems are in KW or MW, KV. So, chances of doing mistakes in Calculation is more. So, Per unit system is advantageous.

→ No need to calculate equivalent impedance of transformer either by refering into primary or secondary side.

→ The value calculated in PU have same base or referance value.

→ So, In power system, electrical quantities such as POWER, VOLTAGE, CURRENT, IMPEDANCE are expressed in per unit of a base or referance value.

$$\text{Per Unit Quantity} = \frac{\text{Actual Quantity}}{\text{Base value}}$$

Two independent Base values are selected

Voltage − V_{base}

Power − S_{base}

$Z_b = \dfrac{V_b^2 \text{(Line to Neutral)}}{S_b}$

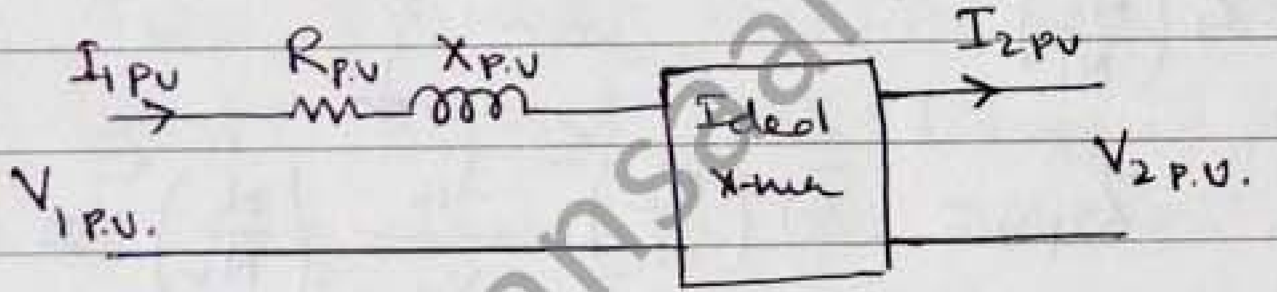
$I_{base} = I_b = \dfrac{S_b}{V_b}$

$$Z_{p.u} = \frac{Z(\Omega) \times S_b}{V_b^2}$$

<u>Conversion for Per Unit system</u>

1. value of S_b is same for the entire system
2. Ratio of V_b on either side of transformer is selected to be same as the ratio of transformer voltage rating

<u>Per Unit system in Transformer</u>



We Neglect the Magnetising comp.

Now, $V_{1PU} = \dfrac{V_1}{V_{1b}} = \dfrac{N_1}{N_2} \times \dfrac{V_2}{V_{1b}}$

Now,

Using conversion 2. $\dfrac{V_{1b}}{V_{2b}} = \dfrac{V_{rated1}}{V_{rated2}} = \dfrac{N_1}{N_2}$

$\therefore V_{1PU} = \dfrac{N_1}{N_2} \times \dfrac{V_2}{\frac{N_1}{N_2} \times V_{2b}} = V_{2PU}$

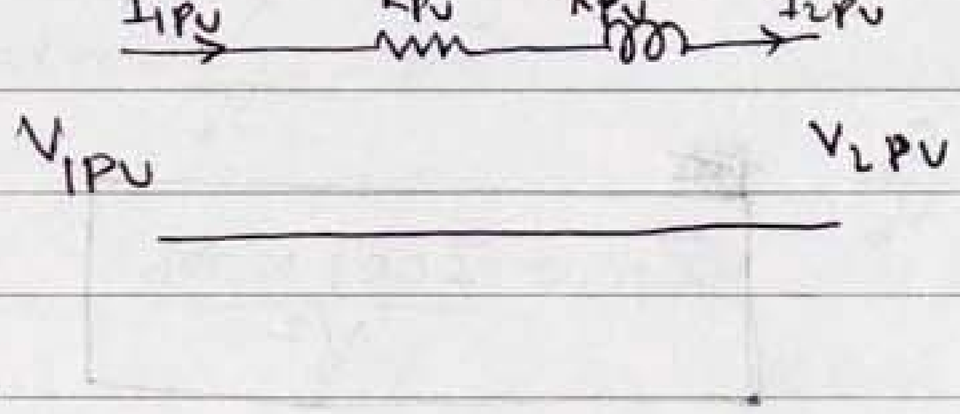
$$V_{1PU} = V_{2PU}$$

→ The voltage at the two side of transformer in perunit are same

$I_{1PU} = \dfrac{N_2}{N_1} \times \dfrac{I_2}{\left(\frac{N_2}{N_1}\right) I_{2b}} = I_{2PU}$

$$I_{1PU} = I_{2PU}$$

Equivalent circuit diagram in P.U



Now,

Transformer Impedance refered to primary side

$$Z_{1pu} = Z_1 \frac{I_{1b}}{V_{1b}}$$

we know, $Z_{2pu} = Z_2 \frac{I_{2b}}{V_{2b}}$

$$Z_2 = Z_1 \left(\frac{N_2}{N_1}\right)^2$$

$$\therefore Z_{2pu} = Z_1 \left(\frac{N_2}{N_1}\right)^2 \frac{I_{1b}}{V_{1b}} \left(\frac{N_1}{N_2}\right)^2 = Z_{1pu}.$$

$$\boxed{Z_{1pu} = Z_{2pu}}$$

Impedance in pu. system are same.
That's why we can easily eliminate all the complication by using PU system.

→ In power system, we are using equipment of different rating. so, it is necessary to convert impedance value at the same rating.

$$\boxed{Z_{pu(new)} = Z_{pu(old)} \left(\frac{V_{b(old)}}{V_{b(new)}}\right)^2 \left(\frac{S_{b new}}{S_{b old}}\right)}$$

In Three Phase system,

$$S_b = \frac{S_{b3\phi}}{3}$$

$$V_{b(L-N)} = \frac{V_{b(L-L)}}{\sqrt{3}}.$$

∴ In three phase, $Z_{p.u} = Z \times \frac{S_{b(3\phi)}}{V^2_{b(L-L)}} = Z \times \frac{S_{b(1\phi)}}{V^2_{b(L-N)}}$

Where $V_b = V_{L-L}$ or V_{L-N}

$S_b = S_{3\phi}$ or $S_{1\phi}$

Numerical.

G_1 : 100 MVA, 11 KV, X = 0.15 P.U.

G_2 = 200 MVA, 13.8 kV X = 0.2 P.U.

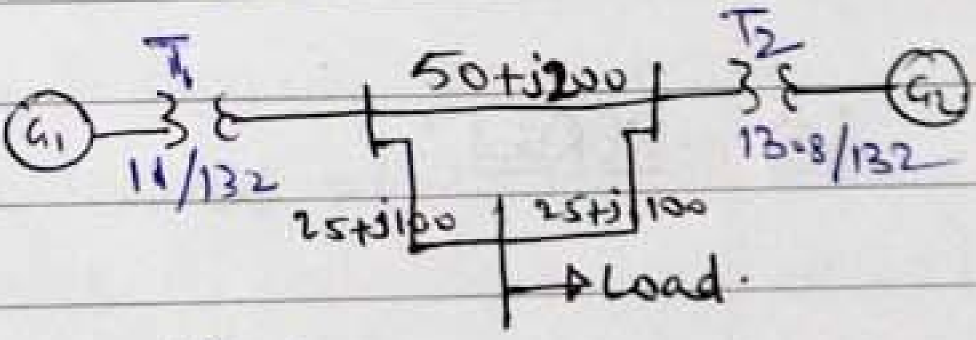
T_1 = 120 MVA, 11/132 kV, X = 0.10 P.U.

T_2 = 250 MVA, 13.8/132 kV X = 0.1 P.U.

Load = 250 MVA, 0.8 p.f lagging, operating at 132 KV.

Show all impedance in perunit on a 100 MVA, 132 kV base in the transmission line circuit.

$X_{G1} = 0.15 \times \frac{100}{100} \times \left(\frac{11}{11}\right)^2 = 0.15$ P.U.



~~$X_{G2} = 0.2 \times \frac{100}{200} \times 13.8$~~

Base kV in the transmission line = 132 kV.

Base kV in the Generator $G_1 = 132 \times \frac{11}{132} = 11$ KV

Base kV in the Generator $G_2 = 132 \times \frac{13.8}{132} = 13.8$ kV.

$X_{G2} = 0.2 \times \frac{100}{200} \left(\frac{13.8}{13.8}\right)^2 = 0.1$ P.U.

$X_{T1} = 0.1 \times \frac{100}{120} \left(\frac{11}{11}\right)^2 = 0.0833$ P.U

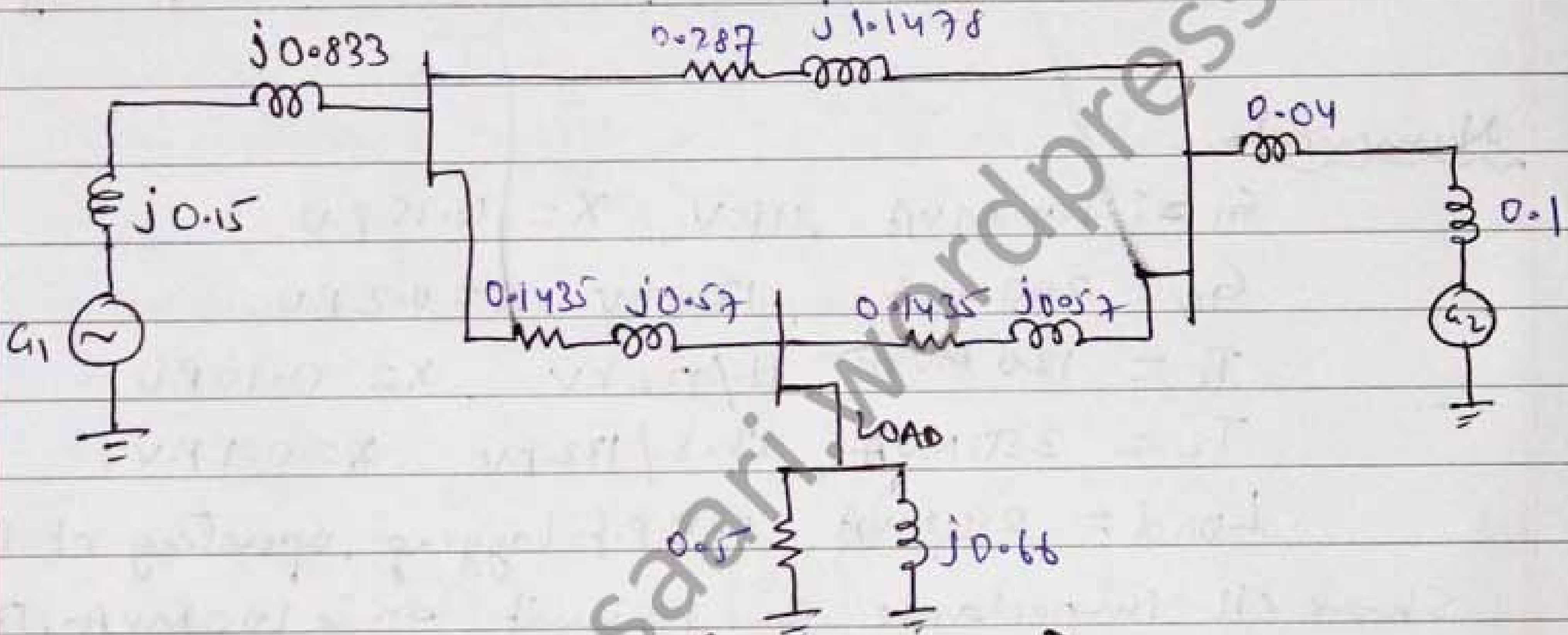
$X_{T2} = 0.1 \times \frac{100}{250} \left(\frac{13.8}{13.8}\right)^2 = 0.04$ P.U

$Z_{Transmission} = (50+j200) \frac{\times 100}{(132)^2} = 0.287 + j1.1478$ P.U.

The Per unit impedance of transmission line connecting the Load bus to the high voltage bus

$$Z = (25 + j100) \times \frac{100}{(132)^2} = 0.1435 + j0.5739 \text{ p.u.}$$

Per unit Circuit Diagram: (Impedance diagram)



(for Parallel Load)

for finding Load in p.u. first we have to make sure whether the Load is connected in Series or Parallel.

(a) SERIES: we have Load = 250MVA (0.8 p.f) lagging.
= 200 + j150

$$Z^*_{Load} = \frac{V_b^2}{S_b} = \frac{(132)^2}{200 + j150} = 55.75 - j41.8176$$

$$Z_{load} = 55.75 + j41.8176 \text{ ohm.}$$

$$Z_{load(p.u.)} = Z_{load} \times \frac{100}{(132)^2} = 0.32 + j0.24 \text{ p.u.}$$

(b) Parallel combination:

$$R_{load} = \frac{(132)^2}{200} = 87.12\,\Omega \quad X_{load} = \frac{(132)^2}{150} = 116.16 \text{ ohm.}$$

$$R_{p.u} = 87.12 \times \frac{100}{132^2} = 0.5 \text{ p.u.} \quad X_{load\,p.u} = 0.66 \text{ p.u.}$$