Per Unit System

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Outline of Presentation

- ❖Introduction
- ❖Change of base quantities
- ❖Calculation of base quantities for Transformers
- ❖ Advantages of Per Unit Computations
- ❖ Previous years GATE Questions

Introduction

❖The various components of a power system like Alternators, Transformers, Induction Motors etc., have their voltage, power, current and impedance ratings in KV, KVA, KA and KΩ respectively

❖It will be convenient for analysis of power system networks if the voltage, power, current and impedance ratings of components of power system are expressed with reference to a common value called base value

❖For analysis purpose, a base value is chosen for voltage, power, current and impedance

Introduction (contd…)

❖ Hence, All the Voltage, Power, Current and Impedance ratings of the components are expressed as a percentage or per unit of the base value

❖Per unit value of any quantity is defined as the ratio of actual value to the chosen base value in the same unit.

$$i.e\ Perunit\ value = \frac{Actual\ value\ in\ any\ unit}{Base\ value\ in\ the\ same\ unit}$$

Introduction (contd…)

- Per unit Impedance

$$Z_{p.u} = \frac{Z}{Z_b} = Z \times \frac{(MVA)_b}{(kV)_b^2} = Z \times \frac{(KVA)_b}{(kV)_b^2} \cdot \frac{1}{1000} \quad \ldots (1)$$

Where,

Actual Impedance	=	Z in ohms
Base Impedance	=	Z_b in ohms
Base Mega Volt Amps	=	$(MVA)_b$
Line to line base Kilo Volts	=	$(kV)_b$

This Formula is applicable for both Single & Three-Phase Systems

Change of base Quantities

❖ Normally, the impedances are specified on the rating of the equipment. Hence, there is a need to change the p.u values from the base of the equipment rating (old value) to that of the chosen system base (new value)

❖When MVA base is changed from $(MVA)_{b,old}$ to $(MVA)_{b,new}$ and KV base is changed from $(KV)_{b,old}$ to $(KV)_{b,new}$ the per unit impedance from the above equation is

$$Z(p.u)_{new} = Z(p.u)_{old} \times \frac{(MVA)_{b,new}}{(MVA)_{b,old}} \times \frac{(kV)^2_{b,old}}{(kV)^2_{b,new}}$$

❖Similarly we can also write … (2)

$$X(p.u)_{new} = X(p.u)_{old} \times \frac{(MVA)_{b,new}}{(MVA)_{b,old}} \times \frac{(kV)^2_{b,old}}{(kV)^2_{b,new}}$$

… (3)

Calculation of base quantities for Transformers

❖ The various sections of power system works at different voltage levels and the voltage conversion is achieved by means of Transformers

❖For a Transformer, primary side of Base KV of power system should be converted to secondary side of Base KV as per the Transformation Ration of the Transformer

❖ Base KV on L.T side of T/F = Base KV on H.T side of T/F $\times \frac{L.T\ voltage\ \ rating}{H.T\ voltage\ \ rating}$

Advantages of Per Unit Computations

❖Manufacturers usually specify the Impedance of a device or machine in per unit on the name pates

❖ The various components of power system and their interconnections are usually represented by single line diagram

❖ In a single line diagram, the components are represented by standard symbols and their interconnections are shown by single line with the representations in per unit quantities

Previous years GATE Questions

Q.No.1 :

If a 250MVA,11/400 KV, Three –Phase power Transformer has leakage reactance of 0.05 pu on the base of 250 MVA and the primary voltage of 11KV,then the actual leakage reactance of the Transformer refereed to the secondary side of 400KV is

Sol:

$$Z = Z_{pu} * \left({KV_b^2}/{MVA_b} \right)$$

$$Z = 0.05 * \left({400^2}/{250} \right) = 32$$

Q.No.2 :

The Direct axis reactance of a synchronous generator is given as 0.4 pu based on the generators name plate rating of 10 KV,75MVA. The base for calculation is 11KV,100MVA. What is the pu value of Generator on the new base?

Sol:

$$X(p.u)_{new} = X(p.u)_{old} \times \frac{(MVA)_{b,new}}{(MVA)_{b,old}} \times \frac{(kV)^2_{b,old}}{(kV)^2_{b,new}}$$

$$X_{pu(New)} = 0.4 * \frac{100}{75} * \left(\frac{10}{11}\right)^2 = 0.44$$

Previous years GATE Questions

Q.No.3 :

For the following power system network shown in the figure, the specifications of the component are as follows:

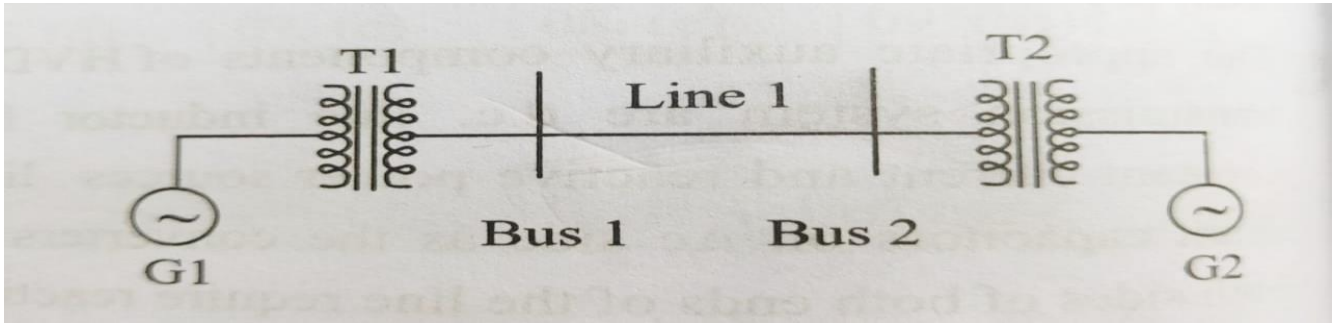
G1: 25 KV, 100 MVA, X=9%

G2: 25 KV, 100 MVA, X=9%

T1: 25 / 220 kV, 90 MVA, X=12%

T2: 220 KV/25 kV, 90 MVA, X=12%

Transmission Line 1: 220 KV, X=150 ohms



Choose 25 KV as the base voltage at the generator G1 and 200 MVA as the MVA base.

Sol)Refer eqn 2

$$X_{G1} = j0.09 * \left(\frac{200}{100}\right) * \left(\frac{25}{25}\right)^2 = j0.18\ p.u.$$

$$X_{T1} = j0.12 * \left(\frac{200}{90}\right) * \left(\frac{25}{25}\right)^2 = j0.27\ p.u.$$

$$X_1 = X_\Omega * \frac{MVA_{base}}{(kV_b)^2}$$

$$X_1 = j150 * \frac{200}{(220)^2} = j0.62\ p.u.$$

$$X_{T2} = X_{T1} = j0.27\ p.u.$$

$$X_{G2} = j0.09 * \left(\frac{200}{100}\right) * \left(\frac{25}{25}\right)^2 = j0.18\ p.u.$$