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ELECTRICAL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

POWER SYSTEMS

1 CHAPTER

Performance of Transmission Lines, Line Parameters and Corona

Q.1 (a) A 220 kV, 20 km long, 3-phase transmission line has the following *ABCD* parameters: $A = D = 0.96\angle 3°$, $B = 55\angle 65°$ Ω/phase, $C = 0.5 \times 10^{-4}\angle 90°$ S/phase. Determine the charging current per phase.

(b) Find the surge impedance loading for 240 kV line

(i) If line is single circuit overhead line.

(ii) If line is double circuit overhead line.

Solution:

(a) Given,

$$V_L = 220 \text{ kV}$$

$$V_{ph} = \frac{220}{\sqrt{3}} \text{ kV}$$

$$\because \quad X_C = \frac{1}{Y} = \frac{1}{0.5\times10^{-4}\angle 90°}\ \Omega$$

Charging current/phase,

$$I_C = \frac{Vph}{X_C} \Rightarrow I_C = \frac{220\times10^3}{\sqrt{3}\left[\frac{1}{0.5\times10^{-4}}\angle -90°\right]}$$

$$= \frac{220\times10^3\times0.5\times10^{-4}}{\sqrt{3}}\angle 90° = 6.35\angle 90° \text{ A}$$

(b) (i)

$$\text{SIL for a line} = \frac{|V|^2}{Z_s}$$

For single circuit overhead line,

$$Z_s = 400\ \Omega$$

Hence,

$$\text{SIL} = \frac{(240)^2\times10^6}{400} = 144 \text{ MW}$$

(ii) For double circuit overhead line,

$$Z_s = 200\ \Omega$$

Hence,

$$\text{SIL} = \frac{(240)^2\times10^6}{200} = 288 \text{ MW}$$

Note: In SIL $= \frac{|V|^2}{Z_s}$, *V* is line to line voltage.

Q.2 For a 220 kV line, $A = D = 0.94\angle 10°$, $B = 130\angle 73°$ Ω/ph, $C = 0.001\angle 90°$ S/ph. Determine the voltage regulation of the line if the sending end voltage of the line for a given load delivered at nominal voltage 240 kV?

Solution:

Given, Sending end voltage $= V_s = 240$ kV

Full-load receiving end voltage $= (V_R)_{FL} = 220$ kV

$$V_{s(\text{per phase})} = \frac{240}{\sqrt{3}}\text{ kV}$$

As we know, $V_{s(\text{per phase})} = AV_{R(\text{perphase})} + BI_R$

At no-load, $I_R = 0$

No-load receiving end voltage (per phase)

$$= (V_R)_{NL\,(\text{per phase})} = \frac{V_{s(\text{per phase})}}{A} = \frac{240}{\sqrt{3}\times 0.94} = \frac{255.32}{\sqrt{3}}\text{ kV}$$

No-load receiving end voltage (line to line) $= (V_R)_{NL} = 255.32$ kV

$$\%\text{ voltage regulation} = \frac{(V_R)_{NL}-(V_R)_{FL}}{(V_R)_{FL}}\times 100 = \frac{255.32-220}{220}\times 100 \approx 16\%$$

Q.3 Find the length of a 3-phase, 50 Hz, lossless power transmission line if at no load condition, line has sending end and receiving end voltages of 400 kV and 420 kV respectively.
(Assuming the velocity of traveling wave to be the velocity of light).

Solution:

$\because$ $V_s = AV_R + BI_R$

At no load, $I_R = 0$,

Hence, $V_s = AV_R$

$$400 = A\times 420$$

$$A = \frac{400}{420} = 0.9524$$

$$A = 1+\frac{YZ}{2} = 1+\frac{(r+j\omega L)(g+j\omega C)}{2}$$

For lossless line $r = 0$, $g = 0$

Then, $$A = 1-\frac{(\omega C)(\omega L)}{2}$$

$$\beta l = \sqrt{\omega L\,\omega C}$$

$$A = 0.9524 = 1-\frac{\beta^2 l^2}{2}$$

$$\beta l = 0.3085$$

$$\beta = \frac{0.3085}{l}$$

$\because$ $$\frac{V}{f} = \frac{2\pi}{\beta}$$

$$\frac{3\times 10^5}{50} = \frac{2\pi}{\left(\frac{0.3085}{l}\right)}$$

$$l = 294.59\text{ km}$$

Q.4 A transmission line has an electrical line length 9°. What is the length in km if it is a 50 Hz system? If frequency is 60 Hz, what is the length in km?

Solution:

$\because$ v = Velocity of propagation $= 3\times 10^8$ m/sec

Electrical line length $= \beta$

2 CHAPTER

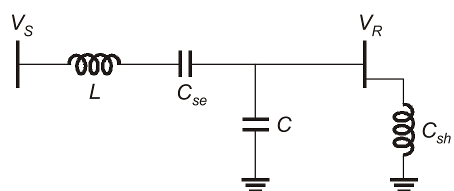
Compensation Techniques, Voltage Profile, Control & Load Freqeuncy Control

Q.1 A lossless line have SIL of 2450 MW is provided with a uniformly distributed series capacitive compensation of 30% and shunt capacitive compensation of 20%. Find the SIL of compensated transmission line.

Solution:

Given, Surge impedance loading = SIL = 2450 MW

With both C_{se} and C_{sh} compensation,



$$(\text{SIL})_{\text{compensated}} = (\text{SIL})_{\text{Uncompensated}}\sqrt{\frac{1+K_{sh}}{1-K_{se}}}$$

Given, $K_{sh} = 0.2$ ($\because$ 20% shunt compensation)

$K_{se} = 0.3$ ($\because$ 30% series compensation)

$$(\text{SIL})_{\text{compensated}} = 2450\sqrt{\frac{1+0.2}{1-0.3}} = 3207.8 \text{ MW} \approx 3208 \text{ MW}$$

Q.2 A shunt reactor at receiving end of a transmission line is operated at 96% of its rated voltage and 104% of its rated frequency. Find the reactive power consumed by it (as compared to rated capacity)

Solution:

Let us consider rated voltage V_0 and rated frequency f_0.

Reactive power: $$Q_0 = \frac{V_0^2}{\omega_0 L} = \frac{V_0^2}{2\pi f_0 L}$$

At 96% of rated voltage $V \to 0.96\, V_0$

and 104% of rated frequency $f \to 1.04\, f_0$

$$Q' = \frac{V'^2}{\omega' L} = \frac{V'^2}{2\pi f' L} = \frac{(0.96V_0)^2}{2\pi(1.04 f_0 L)^2} = 0.886\, Q_0$$

$$\%\text{change} = \frac{Q' - Q_0}{Q_0}\times 100 = \frac{0.886Q_0 - Q_0}{Q_0}\times 100$$

$$= -\frac{11.4Q_0}{Q_0}\times 100 = -11.4\%$$

$\therefore$ Reactive power consumed by it is 11.4% low.

Q.3 A 3-phase 11 kV generator fed power to a constant power unity power factor load of 100 MW through a 3-phase transmission line. The line-to-line voltage is maintained constant at 11 kV. The per unit positive sequence impedance of the line based on 100 MVA and 11 kV is *j*0.2. The line to line voltage at load terminals is measured to be less than 11 kV. Determine the total reactive power to be injected at the terminals of the load to increase the line-to-line voltage at the load terminals to 11 kV.

Solution:

Given, $|V_s| = |V_R| = 11 \text{ kV}$

p.u impedance of the line = j0.2 p.u.

Impedance of the line = p.u. impedance × Base impedance

$$x = j0.2 \times \frac{11^2}{100} = j0.242\Omega$$

Let, Active power at receiving end = P_R

Given, $P_R = 100$ MW

$$P_R = \frac{|V_s||V_R|}{x}\sin\delta \quad \Rightarrow \quad 100 = \frac{11\times 11}{0.242}\sin\delta \quad \Rightarrow \quad \delta = 11.54°$$

Reactive power at receiving end,

$$Q_R = \frac{|V_s||V_R|}{x}\cos\delta - \frac{|V_R|^2}{x} = \frac{11\times 11}{0.242}\cos 11.54 - \frac{11^2}{0.242} = -10.1 \text{ MVAR}$$

Since, Power factor = 1

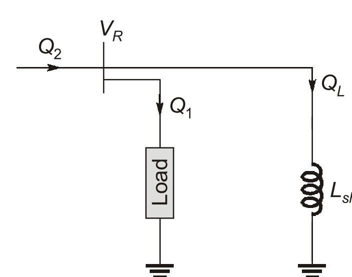
Load reactive power should be zero.

Therefore, reactive power to be injected at terminals

$$= -Q_R = -(-10.1) = 10.1 \text{ MVAR}$$

Q.4 A 3-phase, 132 kV, 50 Hz transmission line has connected to a load of 80 MW at power factor 0.87 lagging. Find the reactive power absorbed by the shunt reactor which is already connected to the system. Due to absorbed reactive power the power factor is reduce to 0.6 lagging. Also find the value of shunt inductance per phase.

Solution:



Given,

Load, $P = 80$ MW

Without L_{sh},

p.f. $= \cos\phi_1 = 0.87$

$\phi_1 = 29.54°$

With L_{sh},

p.f. $= \cos\phi_2 = 0.6$

$\phi_2 = 53.13°$

Q_L is reactive power absorbed by L_{sh}

$$Q_L = Q_2 - Q_1 = P[\tan\phi_2 - \tan\phi_1] \quad \text{...(i)}$$

$$(Q_L)_{ph} = \frac{Q_L}{3} = \frac{V_{ph}^2}{2\pi f L_{sh}} \Rightarrow L_{sh} = \frac{3V_{ph}^2}{2\pi f Q_L} \quad \text{...(ii)}$$

From equation (i), $Q_L = 80\,[\tan 53.13° - \tan 29.54°]$

$= 61.33$ MVAR

From equation (ii),

$$L_{sh} = \frac{3\left(\frac{132}{\sqrt{3}}\right)^2 \times 10^6}{2\pi \times 50 \times 61.33 \times 10^6} = 0.904 \text{ H/phase}$$