Benha University
Faculty of Engineering (Shoubra)
Power engineering and sustainable energy Dept.

2019-2020 Final-Term Exam Model Answer
Course Title: Energy Storage & Transmission
Time Allowed: 2 hours
Date: 20-07-2020

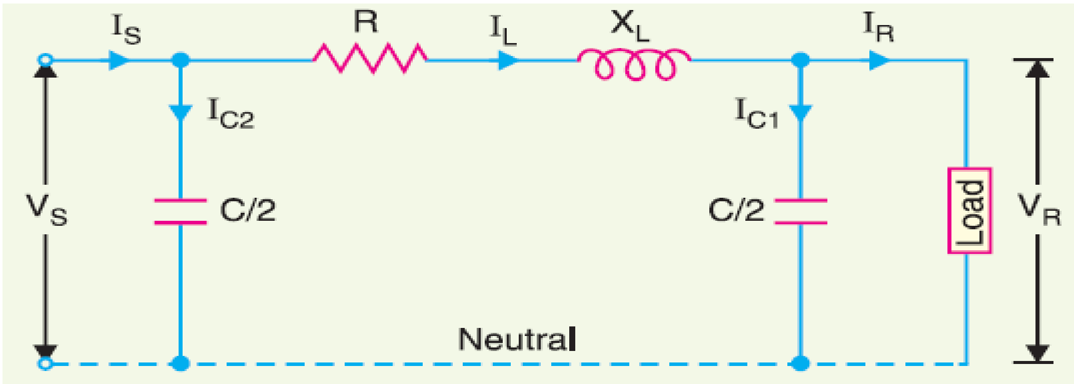
This is a closed book exam. The exam consists of two pages. Attempt all questions

Q.1 Write true or false with correcting the wrong statement ***[20 marks]***

1) Renewable energy resources cannot be used up. √
2) In wind energy, the kinetic energy of wind can turn the blades of a wind turbine. √
3) Renewable resources naturally replaced **less** quickly than they used. X more
4) The underground cabling system cannot be operated above **33 kV**. X 66KV
5) The length of the short transmission line is ranging **between 80: 240 Km**. X less than 80 Km
6) Incandescent lamps and electric heaters are common examples of **inductive** loads. X resistive
7) Medium transmission lines are modeled with lumped shunt admittance. √
8) Gravitational potential depends on the position of **height** in a gravitational field. X mass
9) Energy storage based on lithium-ion battery provides reliable and fast frequency response. √
10) D.C transmission line requires a converter at each end. √
11) The energy of position is known as **kinetic** energy. X potential
12) Electric generators convert chemical energy in fossil fuels. √
13) 9.9 kV is usually not the generating voltage. √
14) Transmission efficiency increases as voltage increases, but the power factor decreases. X increase
15) The homopolar lines have two or more conductors having the same polarity. √
16) As the number of phases increases, as the ripple content in the D.C. output decreases √
17) The commercial loads are composite loads, and induction motors form a high proportion of these loads. X industrial
18) In a short transmission line, the effect of resistance is neglected. X capacitance
19) Corona loss of the transmission line is the most important cause of power losses in the transmission line. √
20) The transmission efficiency is the ratio between power transmitted to power received. X

Q.2 **[10 marks]**

a) Illustrate with equations the nominal (π) transmission line model and also its equivalent circuit.



Let

I_R = load current per phase

R = resistance per phase

X_L = inductive reactance per phase

C = capacitance per phase

$\cos \phi_R$ = receiving end power factor (*lagging*)

V_S = sending end voltage per phase

The *phasor diagram for the circuit is shown in Fig. 10.17. Taking the receiving end voltage as he reference phasor, we have,

$$\vec{V_R} = V_R + j\,0$$

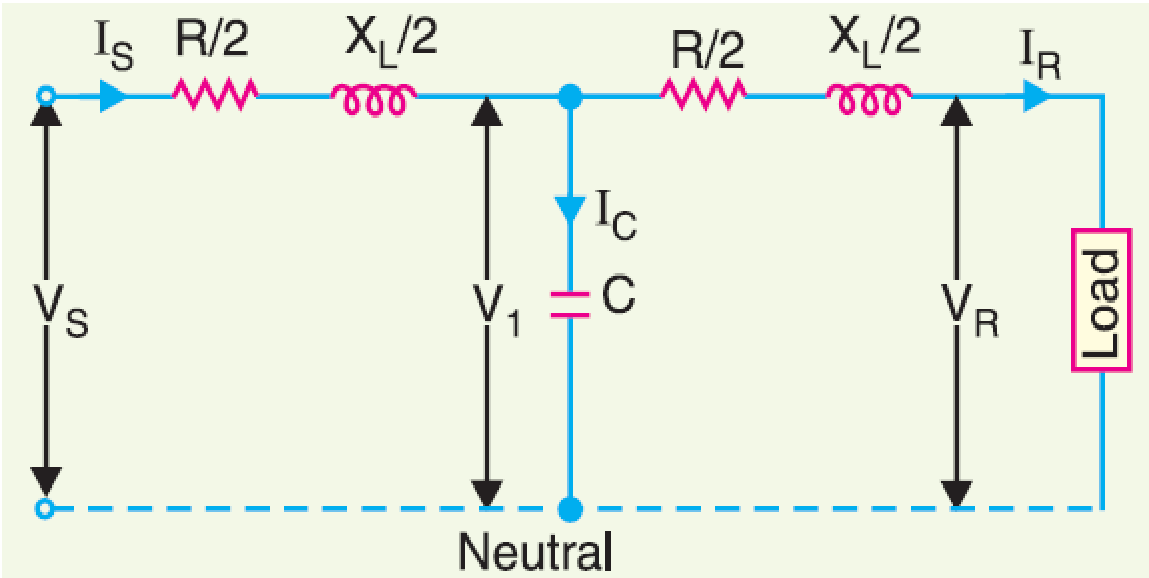
Load current, $\vec{I_R} = I_R(\cos \phi_R - j \sin \phi_R)$

Charging current at load end is

$$\vec{I_{C1}} = j\,\omega\,(C/2)\,\vec{V_R} = j\,\pi\,f\,C\,\vec{V_R}$$

b) A three-phase, 50 Hz, overhead transmission line 100 km long has the following constants: Resistance/km/phase = 0.1 Ω, Inductive reactance/km/phase = 0.2 Ω, Capacitive susceptances/km/phase= 0.04 x 10^{-4} Siemens. Use nominal (T) method to determine, (i) the sending end current, (ii) the sending end voltage, (iii) sending end power factor, (iv) transmission efficiency when supplying a balanced load of 10 MW at 66kV, power factor 0.8 lag.

With our best wishes



Total resistance/phase, $R = 0{\cdot}1 \times 100 = 10\ \Omega$

Total reactance/phase. $X_L = 0{\cdot}2 \times 100 = 20\ \Omega$

Capacitive susceptance, $Y = 0{\cdot}04 \times 10^{-4} \times 100 = 4 \times 10^{-4}$ S

Receiving end voltage/phase, $V_R = 66{,}000/\sqrt{3} = 38105\ V$

Load current, $I_R = \dfrac{10{,}000 \times 10^3}{\sqrt{3} \times 66 \times 10^3 \times 0{\cdot}8} = 109$ A

$\cos\phi_R = 0{\cdot}8\ ; \quad \sin\phi_R = 0{\cdot}6$

Impedance per phase, $\vec{Z} = R + j\,X_L = 10 + j\,20$

(*i*) Taking receiving end voltage as the reference phasor [see Fig. 10.13 (*ii*)], we have,

Receiving end voltage, $\vec{V_R} = V_R + j\,0 = 38{,}105\ V$

Load current, $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R) = 109\,(0{\cdot}8 - j\,0{\cdot}6) = 87{\cdot}2 - j\,65{\cdot}4$

Voltage across C, $\vec{V_1} = \vec{V_R} + \vec{I_R}\,\vec{Z}/2 = 38,105 + (87{\cdot}2 - j\,65{\cdot}4)\,(5 + j\,10)$

$= 38{,}105 + 436 + j\,872 - j\,327 + 654 = 39{,}195 + j\,545$

Charging current, $\vec{I_C} = j\,Y\,\vec{V_1} = j\,4 \times 10^{-4}(39{,}195 + j\,545) = -\,0{\cdot}218 + j\,15{\cdot}6$

Sending end current, $\vec{I_S} = \vec{I_R} + \vec{I_C} = (87{\cdot}2 - j\,65{\cdot}4) + (-\,0{\cdot}218 + j\,15{\cdot}6)$

$= 87{\cdot}0 - j\,49{\cdot}8 = 100 \angle -29°47'$ A

∴ Sending end current = **100 A**

(ii) Sending end voltage, $\vec{V_S} = \vec{V_1} + \vec{I_S}\,\vec{Z}/2 = (39{,}195 + j\,545) + (87{\cdot}0 - j\,49{\cdot}8)\,(5 + j\,10)$

$= 39{,}195 + j\,545 + 434{\cdot}9 + j\,870 - j\,249 + 498$

$= 40128 + j\,1170 = 40145 \angle 1°40'$ V

∴ Line value of sending end voltage

$= 40145 \times \sqrt{3} = 69\,533$ V = **69·533 kV**

(iii) Referring to phasor diagram in Fig. 10.14,

θ_1 = angle between $\vec{V_R}$ and $\vec{V_S}$ = 1°40′

θ_2 = angle between $\vec{V_R}$ and $\vec{I_S}$ = 29° 47′

∴ ϕ_S = angle between $\vec{V_S}$ and $\vec{I_S}$

$= \theta_1 + \theta_2 = 1°40' + 29°47' = 31°27'$

∴ Sending end power factor, $\cos\phi_S = \cos 31°27' =$ **0·853 lag**

(iv) Sending end power $= 3\,V_S I_S \cos\phi_S = 3 \times 40{,}145 \times 100 \times 0{\cdot}853$

$= 10273105$ W $= 10273{\cdot}105$ kW

Power delivered = 10,000 kW

∴ Transmission efficiency $= \dfrac{10{,}000}{10273{\cdot}105} \times 100 =$ **97·34%**

Q.3 ***[10 marks]***

a) Discuss in detail different types of energy storage systems. (LEC 6)

- Mechanical Energy Storage.
- Magnetic Energy Storage.

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- Electrochemical Energy Storage (batteries, flow cells).
- Chemical Energy Storage (hydrogen, methane, gasoline, coal, oil)

b) Compare between types of overhead transmission lines.

- Short line approximation for lines that are less than 80 km long.
- Medium line approximation for lines whose lengths are between 80 km to 240 km.
- Long line model for lines that are longer than 240 km.

The ABCD parameters of the long transmission line can then be written as

$$A = D = \cosh \gamma l$$

$$B = Z_C \sinh \gamma l \ \Omega$$

$$C = \frac{\sinh \gamma l}{Z_C} \text{ mho}$$

☐ the ABCD parameters of the nominal (π) representation

$$A = D = \left(\frac{YZ}{2} + 1\right)$$

$$B = Z \, \Omega$$

$$C = Y\left(\frac{YZ}{4} + 1\right) \text{mho}$$

Then the ABCD parameters of the T-network are

$$A = D = \left(\frac{YZ}{2} + 1\right)$$

$$B = Z\left(\frac{YZ}{4} + 1\right)\Omega$$

$$C = Y \text{ mho}$$

Therefore the ABCD parameters are given by

$$A = D = 1,\ B = Z\,\Omega \text{ and } C = 0$$

c) The daily load on a power system varies, as shown in Table (1). Using the given data compute the average load and the daily load factor.

Table 1. Daily System Load

Interval, hr	0 - 3	3 - 7	7 – 10	10 - 13	13 - 17	17 - 20	20 – 22	22 - 24
Load, MW	2	4	6	8	10	12	14	10

Sum (Dt) =

(3-0)+(7-3)+(10-7)+(13-10)+(17-13)+(20-17)+(22-20)+(22-24)= 24

W = P * Dt=

2(3-0)+4(7-3)+6(10-7)+8(13-10)+10(17-13)+12(20-17)+14(22-20)+10(24-22)= 188

P_{avg}=W/sum Dt = 188/24= 7.833

Load factor = P_{peak} / P_{avg} = 1.8

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