

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِیْمِ



**King Saud University**

**College of Engineering**

**Electrical Engineering Department**

Course Id : EE 340

Term : 271 (1427/1428)

Midterm Exam (2) : Thursday 17/11/1427 – 07/02/2006

Time Allowed: 1 hour and 30 minutes

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Section # : 1182

Section # : 1180

<input type="checkbox"/>
<input checked="" type="checkbox"/>

**SOLUTION OF THE EXAM**

**MCQ form # 1**

## Instructions:

1. Answer all questions
2. For question # 1 put an [X] in column 1 for the best correct answer only.

### Question #1 (30 Marks) (2- marks per question)

- 1-1. Capacitive reactance of over-head transmission lines decreases with
- |                                     |                             |
|-------------------------------------|-----------------------------|
| <input type="checkbox"/>            | (a) increase of line length |
| <input type="checkbox"/>            | (b) decrease of line length |
| <input type="checkbox"/>            | (c) conductor radius        |
| <input checked="" type="checkbox"/> | (d) a and c                 |
- 1-2. As the spacing between the phase conductors increases, the line capacitance
- |                                     |                             |
|-------------------------------------|-----------------------------|
| <input type="checkbox"/>            | (a) increases               |
| <input checked="" type="checkbox"/> | (b) decreases               |
| <input type="checkbox"/>            | (c) remains the same        |
| <input type="checkbox"/>            | (d) changes with resistance |
- 1-3. When we use bundle conductors the capacitance of a transmission line
- |                                     |                                 |
|-------------------------------------|---------------------------------|
| <input type="checkbox"/>            | (a) decreases                   |
| <input type="checkbox"/>            | (b) increases                   |
| <input checked="" type="checkbox"/> | (c) (b) and (d)                 |
| <input type="checkbox"/>            | (d) changes with bundle spacing |
- 1-4. The shunt reactor compensation is used to
- |                                     |                                 |
|-------------------------------------|---------------------------------|
| <input checked="" type="checkbox"/> | (a) reduce $V_R$ at no load     |
| <input type="checkbox"/>            | (b) reduce $V_R$ at full load   |
| <input type="checkbox"/>            | (c) increase $V_R$ at full load |
| <input type="checkbox"/>            | (d) increase $V_R$ at no load   |
- 1-5. The maximum power flow through a transmission line can be increased by installing
- |                                     |                      |
|-------------------------------------|----------------------|
| <input checked="" type="checkbox"/> | (a) series capacitor |
| <input type="checkbox"/>            | (b) series reactor   |
| <input type="checkbox"/>            | (c) shunt capacitor  |
| <input type="checkbox"/>            | (d) shunt reactor    |
- 1-6. In a long transmission line under no load condition, the receiving end voltage is
- |                                     |  |
|-------------------------------------|--|
| <input type="checkbox"/>            | (a) less than the sending end voltage              |
| <input checked="" type="checkbox"/> | (b) higher than the sending end voltage            |
| <input type="checkbox"/>            | (c) approximately equal to the sending end voltage |
| <input type="checkbox"/>            | (d) constant irrespective of the value of the load |
- 1-7. Ferranti effect means that in a long transmission line
- |                                     |  |
|-------------------------------------|--|
| <input type="checkbox"/>            | (a) the current at receiving end is lower than the current at sending end  |
| <input type="checkbox"/>            | (b) the current at receiving end is higher than the current at sending end |
| <input type="checkbox"/>            | (c) the voltage at receiving end is lower than the voltage at sending end  |
| <input checked="" type="checkbox"/> | (d) the voltage at receiving end is higher than the voltage at sending end |

1-8. To reduce the maximum electric stress on the insulation of a cable having a given conductor size, its insulation thickness must

- (a) increase
- (b) decrease
- (c) not change
- (d) conductor should be made less smooth

1-9. In a power cable, maximum electric stress occurs at

- (a) center of conductor
- (b) center of insulation
- (c) surface of sheath
- (d) surface of conductor

1-10. Maximum power flow in a transmission line is inversely proportional to

- (a) magnitude of A parameter
- (b) magnitude of B parameter
- (c) Angle of C parameter
- (d) non of the above

1-11. The selection of cables is preferred over transmission lines in situation of::

- (a) rainy areas
- (b) dry areas
- (c) densely populated areas.
- (d) (a) and (c)

1-12. Semiconductor insulation screen of an XLPE cable is provided to have

- (a) smooth conductor surface
- (b) good contact between conductor and insulation
- (c) high insulation resistance
- (d) all of the above

1-13. The loss angle of a cable is  $\delta$ . The power factor is

- (a)  $\cos \delta$
- (b)  $\sin \delta$
- (c)  $\tan \delta$
- (d)  $1 - \cos \delta$

1-14. The dielectric material of an insulated cable should have

- (a) good mechanical properties
- (b) high dielectric strength
- (c) low insulation resistance
- (d) a and b.

1-15. Cable ampacity (current carrying capacity) depends on

- (a) conductor cross section
- (b) thermal conductivity of soil around the cable
- (c) conductor material
- (d) all of the above

**Question #2 (20 Marks)**

- 2-1. What is series compensation? Why and where is it used? (4- marks)  
2-2. What is shunt compensation? Why and where is it used? (4- marks)  
2-3. A 320-km long, 500-kV, 60-Hz three-phase line has a series impedance of  $j0.34 \Omega/\text{km}$  and a shunt admittance of  $j4.5 \times 10^{-6} \text{ S/km}$ . The line is assumed lossless. Calculate:  
(a) the characteristic impedance (3-marks)  
(b) the surge impedance (3-marks)  
(c) the propagation constant (3 marks)  
(d) the wavelength of this line. (3 marks)

**Solution :**

2.1 Series capacitor is added in each phase of T.L. to reduce the net series  $X_l$  of the line. It is usually inserted in the middle of long transmission lines. This reduces  $Z$  and hence the element "B" of the (ABCD) constant, which in turn will increase the max power flow in the line.

2.2 Shunt Inductors are added from line to ground of a T.L, It is usually located at the receiving end of a long transmission line. It can also be placed at the middle . Basically it decreases the  $Y$  of the line , therefore decreasing constant "A". This in turn will decrease the voltage regulation of the T.L.

$$2.3 \quad Z_c = \sqrt{\frac{z}{y}} = \sqrt{\frac{.34}{4.5 * 10^{-6}}} = 275 \Omega$$

2.4  $Z_s = \text{Surge Impedance} . \text{ It is the same as } Z_c \text{ because the line is lossless} .$

$$2.5 \quad \gamma = \sqrt{zy} = \sqrt{j0.34 * j4.5 * 10^{-6}} = \alpha + j\beta = \mathbf{j1.2369 * 10^{-3} = j0.00124}$$

$$2.6 \quad \lambda = \frac{2\pi}{\beta} = \frac{2\pi}{1.2369 * 10^{-3}} = 5079.65 \text{ km}$$

Question #3 (25 Marks)

- 3-1. A transmission line has per phase series impedance of  $Z$  ohms and shunt admittance of  $Y$  siemens. Draw a  $\pi$  model for this line and derive it's A, B, C and D parameters (10-marks).
- 3-2. 200-km 230-kV, 60-Hz, three-phase line has a series impedance  $Z = 0.1 + j 0.5 \Omega/\text{km}$  and a shunt admittance  $Y = j4 \times 10^{-6} \text{ S/km}$ . At full load, the line delivers 250 MW at 230 kV and 0.95 lagging pf. Using the  $\pi$  circuit model calculate:
- the sending end voltage (4-mark)
  - the sending end current (4-marks)
  - the sending end power factor and power(4-marks)
  - the line efficiency (1-mark)
  - the percent voltage regulation (2-marks)

**Answers:**

3-1 For the  $\pi$ -model:

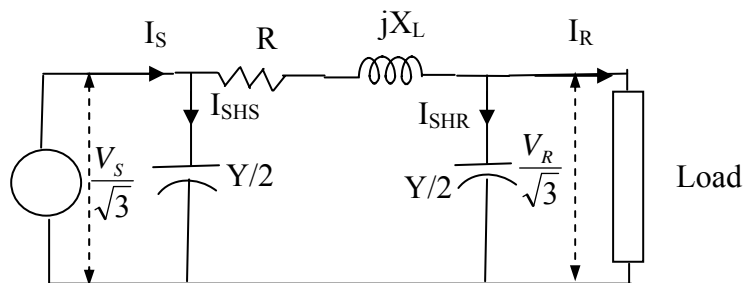


Fig. (5.3): The  $\pi$ -model for Medium Transmission line

Shunt current at the receiving-end is

$$I_{SHR} = \frac{V_R}{\sqrt{3}} Y / 2 \quad (1)$$

Shunt current at the sending-end is

$$I_{SHS} = \frac{V_S}{\sqrt{3}} Y / 2 \quad (2)$$

Moreover,

$$\frac{V_S}{\sqrt{3}} = \frac{V_R}{\sqrt{3}} + Z ( I_R + I_{SHR} ) \quad (3)$$

$$= \frac{V_R}{\sqrt{3}} (1 + ZY/2) + I_R Z \quad (4)$$

However,

$$I_S = I_R + I_{SHR} + I_{SHS} = I_R + \frac{V_R}{\sqrt{3}} Y / 2 + \frac{V_S}{\sqrt{3}} Y / 2 \quad (4)$$

Substituting  $\frac{V_S}{\sqrt{3}}$  from eq. (3) into eq. (4), we get

$$I_S = \frac{V_R}{\sqrt{3}} Y (1+ZY/4) + I_R (1 + ZY/2) \quad (5)$$

Therefore

$$A = (1 + ZY/2)$$

$$B = Z$$

$$C = Y (1+ZY/4)$$

$$D = (1 + ZY/2)$$

3-2

$$z = 0.1 + j 0.5 = 0.51 \angle 78.69^\circ \quad Z = 200 * 0.51 \angle 78.69^\circ = 101.98 \angle 78.69$$

$$y = 4 * 10^{-6} \angle 90^\circ \quad Y = 200 * 4 * 10^{-6} \angle 90^\circ = 800 * 10^{-6} \angle 90$$

$$A = 1 + ZY/2 = 0.96 \angle 0.48$$

$$B = Z = 101.98 \angle 78.69$$

$$C = Y(1+YZ/4) = 0.000784 \angle 90.23^\circ$$

$$V_R = \frac{230 * 10^3}{\sqrt{3}} = 132,790.6 \angle 0^\circ$$

$$I_R = \frac{250 * 10^6}{\sqrt{3} * 230 * 10^3 * 0.95} = 660.58 \angle -18.19^\circ$$

(a) :

$$V_S = A V_R + B I_R$$

$$= 0.96 \angle 0.48 * 132,790.6 \angle 0^\circ + 101.98 \angle 78.69 * 660.58 \angle -18.19^\circ$$

$$= 127479. \angle 0.48 + 67.365.59 \angle 60.50 = 160.647.1 + j59.700.29$$

$$= 171,381.5 \angle 20.39^\circ$$

(b):

$$I_S = C V_R + D I_R$$

$$= 0.000784 \angle 90.23 * 132790.6 \angle 0 + 0.96 \angle 0.48 * 660.58 \angle -18.19$$

$$= 610.18 \angle -8.37^\circ$$

Phase angle difference between  $V_s$  and  $I_s$  is  $|8.37 + 20.39| = 28.76^\circ$

(c):

The sending end power factor =  $\cos(28.76) = 0.8766$

$$P_s = \sqrt{3} * (\sqrt{3} * 610.18 * 171,381) * (0.8766) = 275MW$$

(d):

$$\text{Line efficiency} = \frac{P_r}{P_s} = 250 / 275 = 0.9091 \quad \text{or } 91\%$$

(e):

Voltage Regulation :

$$\frac{\left| \frac{V_s}{A} \right| - |V_R|}{|V_R|} * 100 = \frac{\frac{\sqrt{3}(171381.5)}{0.96} - |230 * 10^3|}{230 * 10^3} * 100 = 34.44\%$$

**Question #4 (25 Marks)**

- 4-1. Compare the following for overhead lines and cables (i.e state the main differences between overhead lines and cables with respect to the mentioned parameter) (3 -marks for each part) :
- (a) capacitance, (b) installation costs  
(c) durability (d) surge impedance loading
- 4-2. A single core cable has an insulation resistance of  $5 \text{ M}\Omega / \text{km}$ . The conductor diameter is 5 cm and the insulation thickness is 2.5 cm. Calculate :
- (a) The resistivity of the insulation material in  $\Omega\text{m}$ , (3-marks)  
(b) the cable capacitance per meter (3-marks)  
(c) total charging current and total kVAR of this cable if the cable is 20 km long and is connected to 75 kV (line to neutral), 60 Hz source. It is given that  $\epsilon_r \approx 3$  for the insulation and  $\epsilon_o = 8.854 \times 10^{-12} \text{ F/m}$  (7-marks)

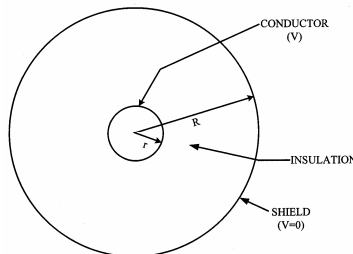
**SOLUTION:**

**4-1 :**

Item	Over Head Lines	Cable
Capacitance	Is less in OH lines	Much more in cables
Installation Costs	Less	More
Durability	Very Long	25-30 years
Surge Impedance Loading	Less in OH	More

**4.2 :**

(a)



$$\Delta R_i = \frac{\rho}{2\pi x l} dx \quad (6.21)$$

$$R_i = \int_r^R \frac{\rho}{2\pi l} \frac{dx}{x} \quad (6.22)$$

or 
$$R_i = \frac{\rho}{2\pi l} \ln\left(\frac{R}{r}\right) \quad (\Omega) \quad (6.23)$$

Equation (6.23) indicates that the insulation resistance is inversely proportional to the length of the insulated cable. On the other hand, an increase in insulation thickness (R-r), increases the insulation resistance and hence breakdown voltage of the insulation but does not give a proportional decrease in voltage stress at the conductor surface. Thus, the increase in insulation thickness does not permit a proportional increase in cable voltage rating.

Where : l cable total length (m),

R outer radius of cable.

r conductor radius

**(a) :  $R_{in} = 5 * 10^6$  ( For each one km ) i.e for each unit length( l= 1000 m) , the ohmic value is  $5M\Omega$**

$$R_i = \frac{\rho}{2\pi l} \ln\left(\frac{R}{r}\right)$$

$$\rho = \frac{R_i * 2\pi l}{\ln\left(\frac{R}{r}\right)} = \frac{5 * 10^6 * 2\pi * 1000}{\ln\left(\frac{5.0}{2.5}\right)} = 4.53 * 10^{10} \Omega m \quad \text{Sam as}$$

$$\rho = \frac{R_i * 2\pi l}{\ln\left(\frac{R}{r}\right)} = \frac{5 * 10^6}{20} * \frac{2\pi * 20 * 1000}{\ln\left(\frac{5.0}{2.5}\right)} = 4.53 * 10^{10} \Omega m$$

$$(b) : c = \frac{2\pi\epsilon_r\epsilon_o}{\ln\frac{R}{r}} = \frac{2\pi * 3 * 8.854 * 10^{-12}}{\ln\frac{5}{2.5}} = 240.7771 * 10^{-12} \text{ F/m}$$

$$\text{Total C} = 240.771 * 10^{-12} * 20 * 1000 = 4.815 * 10^{-6} \text{ F}$$

(c)

$$I_c = \omega CV = 2\pi * 60 * 4.815 * 10^{-6} * 75 * 10^3 = 136.16A$$

$$(d) \quad \text{KVAR} = VI_c = 75 * 10^3 * 136.16 = 10211.96 * 10^3 = 10.212 \text{ MVAR}$$