Rensselaer

ECSE 2110: Electrical Energy Systems
Midterm Exam 2 (25% of overall grade)

Time: 8:30 am to 10:05 am eastern

Date: July 19th, 2022

Total points: 100

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Z=4+36j
Y=0.000272j
A=0.995104+0.000544j
B=4+36j
C=-0.000000073984+0.000271334144j
D=0.995104+0.000544j
[Vs]  [A B][Vr]
[Is ]=[C D][Ir]
delivers:
200M<cos^-1(.8)=160M+j120M
Vr=220k/sqrt3=127.0170592k
Ir=S*/(3Vr*)=419.8911-314.9183j
Vs=(.995+.000544j)(127k)+(4+36j)(419-314j)
=139411.8079+13925.50374j

Is=(-7.3984x10^-8+2.71x10-4)(127k)+
        (.995+.000544j)(419-314j)
=417.997-278.684j
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Name:________________________________

RIN #:________________________________

General Instructions

1. It is student's responsibility to make sure that all pages of the exam are intact. If any page is missing, then please inform the instructor for replacement.
2. Please put your name and RIN on the front sheet and any additional sheet you may attach. Also include the question number on the additional sheets.
3. Please return the exam at the end of exam session. Please make sure to return all pages.
4. If you have any questions during the exam, please raise your hand.
5. This exam is an closed-book, closed-notes exam. Laptop/tablet cannot be used. **No internet connection** is allowed.
6. You are allowed to use your calculator.
7. You are **not allowed** to use your phone or other electronics during the exam.
8. **Please show all your work clearly**.

Please use separate blank sheets of paper to answer questions. Not enough space here.

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Short Answer Questions (40 points)

Question 1. (10 points) Why capacitance is neglected in short transmission line models?

Answer:

In short line, the voltage of the transmission as well as the length of the transmission line is not large enough to make the effect of capacitance significant. Hence neglected.

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V

Please use separate blank sheets of paper to answer questions. Not enough space here.

Question 2. (10 points) Explain the phenomenon of corona in high voltage transmission lines.

Answer:

Corona is a partial discharge phenomenon that can occur in high voltage transmission lines. This is associated with a partial discharge activity, a visual bluish glow around the conductors. This partial discharge activity happens due to a very high electric field stress on the surrounding air.

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V

Please use separate blank sheets of paper to answer questions. Not enough space here.

Problem 3. (**10 points)** Describe about the Skin effect in AC transmission.

Answer:

The magnetic flux linkage inside of an AV transmission conductor is not uniform across the cross section. It is highest at the center of the conductor and decreases towards the surface of the conductor. As a result, the inductive reactance is highest at the center and lowest at the surface of the conductor. This encourages, AC current to concentrate towards the surface or skin of the conductor called the skin effect.

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[Vs] [A B][Vr]
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Ir=S*/(3Vr*)=419.8911

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Problem 4. (**10 points)** Describe about the velocity of traveling waves in lossless as well as lossy transmission lines.

Answer:

In the ideal (lossless) power transmission lines, the traveling waves propagate at the velocity of light given by 1/sqrt(LC). In the case of lossy transmission lines these waves propagate at velocity lightly less than that of light.

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Long Answer Questions (60 points)

Problem 5. (20 points)

A solid cylindrical aluminum conductor 25 km long has an area of 336,400 circular mils. Obtain the conductor resistance at (a) 20°C and (b) 50°C. The resistivity of aluminum at 20°C is 2.8×10^{-8} Ω-m.

Solution:

(a)

$$d = \sqrt{336400} = 580 \text{ mil} = (580)(10^{-3})(2.54) = 1.4732 \text{ cm}$$

$$A = \frac{\pi d^2}{4} = 1.704564 \text{ cm}^2$$

$$R_1 = \rho \frac{\ell}{A} = 2.8 \times 10^{-8} \frac{25 \times 10^3}{1.704564 \times 10^{-4}} = 4.106 \ \Omega$$

(b)

$$R_2 = R_1 \left(\frac{228 + 50}{228 + 20} \right) = 4.106 \left(\frac{278}{248} \right) = 4.6 \ \Omega$$

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Problem 6. (20 points) A 230kV, 3-phase transmission line has a per phase series impedance of z = 0.05 + j0.45 ohm/km and a per phase shunt admittance of y = j3.4X10^{-6} siemens/km. The line is 80 km long. Using the nominal pi model (assuming a medium line), determine the ABCD parameters of the line. Also find the sending end voltage and current when the line delivers 200MVA, 0.8 lagging power factor at 220kV.

Solution:

The line impedance and shunt admittance are

$$Z = (0.05 + j0.45)(80) = 4 + j36\ \Omega$$

$$Y = (j3.4 \times 10^{-6})(80) = j0.272 \times 10^{-3} \text{ siemens}$$

The ABCD constants of the nominal π model are

$$A = (1 + \frac{ZY}{2}) = (1 + \frac{(4 + j36)(j0.272 \times 10^{-3})}{2}) = 0.9951 + j0.000544$$
$$B = Z = 4 + j36$$
$$C = Y(1 + \frac{ZY}{4}) = j0.0002713$$

The receiving end voltage per phase is

$$V_R = \frac{220\angle 0^\circ}{\sqrt{3}} = 127\angle 0^\circ \ \ \text{kV}$$

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Vs=(.995+.000544j)(127k)+(4+36j)(419-314j)
=139411.8079+13925.50374j
Vs line to line=sqrt3 Vs=241468+24119j
Is=(-7.3984x10^-8+2.71x10-4)(127k)+
(.995+.000544j)(419-314j)
=417.997-278.684j

Please use separate blank sheets of paper to answer questions. Not enough space here.

(a) The complex power at the receiving end is

$$S_{R(3\phi)} = 200\angle\cos^{-1}0.8 = 200\angle 36.87^\circ = 160 + j120 \ \ \text{MVA}$$

The current per phase is given by

$$I_R = \frac{S^*_{R(3\phi)}}{3V^*_R} = \frac{200000\angle -36.87^\circ}{3\times 127\angle 0^\circ} = 524.864\angle -36.87^\circ \ \ \text{A}$$

The sending end voltage is

$$V_S = AV_R + BI_R = 0.9951 + j0.000544)(127\angle 0^\circ) + (4 + j36)$$
$$(524.864\times 10^{-3}\angle{-36.87^\circ}) = 140.1051\angle 5.704^\circ \ \ \text{kV}$$

The sending end line-to-line voltage magnitude is

$$|V_{S(L-L)}| = \sqrt{3}\,|V_S| = 242.67 \ \ \text{kV}$$

The sending end current is

$$I_S = CV_R + DI_R = (j0.0002713)(127000\angle 0^\circ) + (0.9951 + j0.000544)$$
$$(524.864\angle{-36.87^\circ}) = 502.38\angle{-33.69^\circ} \ \ \text{A}$$

Please use separate blank sheets of paper to answer questions. Not enough space here.

Problem 7. (20 points)

A 69-kV, three-phase short transmission line is 16 km long. The line has a per phase series impedance of $0.125 + j0.4375\ \Omega$ per km. Determine the sending end voltage, voltage regulation, the sending end power, and the transmission efficiency when the line delivers

(a) 70 MVA, 0.8 lagging power factor at 64 kV.
(b) 120 MW, unity power factor at 64 kV.

Z=2+7j
A,B,C,D=1,Z,0,1
a)
70M<cos^-1(.8)=56M+j42M
Vr=64k/sqrt3=36950
Ir=S*/(3Vr*)=505.18-378.886j
[Vs] [A B][Vr]
[Is]=[C D][Ir]
Vs=1*36950+(2+7j)(505-378j)
=40612.983+2778.498j
Vs3ph=Vs sqrt3=70343.75+4812.5j
Is=0+1*Ir=505.18-378.886j
Vreg=100%*(70.34-64)/64=10.169%
Ss3ph=3VsIs*=(40612+2778j)(505+378j)
=58392578+50374023j
Efficiency=100%*56M/58.3M=95.9026%
.9590259893
b)
120M+0j, same Vr
Ir=S*/(3Vr*)=1082.53
Vs=1Vr+ZIr=36950+(2+7j)(1082.53)
=39115.48+7577.72j
Vs3ph=sqrt3 Vs=67750+13125j
Is=0Vr+1Ir=1082.53
Ss=3VsIs*=127031250+24609375j
Vreg=100%*(69.009k-64k)/64k=7.8275%
Efficiency=100%*120M/127.03M=94.4649%

Solution:

The line impedance is

$$Z = (0.125 + j0.4375)(16) = 2 + j7\ \Omega$$

The receiving end voltage per phase is

$$V_R = \frac{64\angle 0^\circ}{\sqrt{3}} = 36.9504\angle 0^\circ \quad \text{kV}$$

(a) The complex power at the receiving end is

$$S_{R(3\phi)} = 70\angle \cos^{-1} 0.8 = 70\angle 36.87^\circ = 56 + j42 \text{ MVA}$$

The current per phase is given by

$$I_R = \frac{S^*_{R(3\phi)}}{3V^*_R} = \frac{70000\angle -36.87^\circ}{3 \times 36.9504\angle 0^\circ} = 631.477\angle -36.87^\circ \quad \text{A}$$

Please use separate blank sheets of paper to answer questions. Not enough space here.

The sending end voltage is

$$V_S = V_R + ZI_R = 36.9504\angle 0^\circ + (2 + j7)(631.477\angle -36.87^\circ)(10^{-3})$$
$$= 40.708\angle 3.9137^\circ \quad \text{kV}$$

The sending end line-to-line voltage magnitude is

$$|V_{S(L-L)}| = \sqrt{3}\,|V_S| = 70.508 \quad \text{kV}$$

The sending end power is

$$S_{S(3\phi)} = 3V_S I_S^* = 3 \times 40.708\angle 3.9137 \times 631.477\angle 36.87^\circ \times 10^{-3}$$
$$= 58.393 \text{ MW} + j50.374 \text{ Mvar}$$
$$= 77.1185\angle 40.7837^\circ \quad \text{MVA}$$

Voltage regulation is

$$\text{Percent } VR = \frac{70.508 - 64}{64} \times 100 = 10.169\%$$

Transmission line efficiency is

$$\eta = \frac{P_{R(3\phi)}}{P_{S(3\phi)}} = \frac{56}{58.393} \times 100 = 95.90\%$$

(b) The complex power at the receiving end is

$$S_{R(3\phi)} = 120\angle 0^\circ = 120 + j0 \quad \text{MVA}$$

The current per phase is given by

$$I_R = \frac{S^*_{R(3\phi)}}{3V_R^*} = \frac{120000\angle 0^\circ}{3 \times 36.9504\angle 0^\circ} = 1082.53\angle 0^\circ \quad \text{A}$$

The sending end voltage is

$$V_S = V_R + ZI_R = 36.9504\angle 0^\circ + (2 + j7)(1082.53\angle 0^\circ)(10^{-3})$$
$$= 39.8427\angle 10.9639^\circ \quad \text{kV}$$

The sending end line-to-line voltage magnitude is

$$|V_{S(L-L)}| = \sqrt{3}\,|V_S| = 69.0096 \quad \text{kV}$$

The sending end power is

$$S_{S(3\phi)} = 3V_S I_S^* = 3 \times 39.8427\angle 10.9639 \times 1082.53\angle 0^\circ \times 10^{-3}$$
$$= 127.031 \text{ MW} + j24.609 \text{ Mvar}$$
$$= 129.393\angle 10.9639^\circ \quad \text{MVA}$$

Voltage regulation is

$$\text{Percent } VR = \frac{69.0096 - 64}{64} \times 100 = 7.8275\%$$

Transmission line efficiency is

$$\eta = \frac{P_{R(3\phi)}}{P_{S(3\phi)}} = \frac{120}{127.031} \times 100 = 94.465\%$$

60MVA 69.3kV synchronus generator has synchronus reactance of 15ohm/phase and negligable resistance
a) .8pf lag at rated voltage to bus bar. Determine mag of generated emf per phase and power angle delta.

Vph=69.3kV/sqrt3=40kV
60MVA^cos^1(.8)j=48MW+j36MVAR=60MVA<36.869deg
I=S*/3V*=60MVA<-36/(3 40kV)=400-300j=500<-36 A
EMF=V+IZ=40kV+(500<-36A)(15johm)=44902.67V<7.6789

b) if gen EMF is 36kV/phase, what is max 3ph power can deliver before synchronus loss
Pmax=3|E||V|/X=3*36kV*40kV/15ohm=288MW

c) gen delivers 48MW to bus bar at rated voltage with field current adjusted for generated EMF of 46kV/phase. Det the armature current and PF, lag or lead.
48MW=3*46kV*40kV/15 sin(d)
d=7.4947 deg
EMF=V+IZ=V+jXI
(EMF-V)/jX=I=(46k<7.4947-40k)/15j=547.47<-43.06
PF=cos(43.06)=.7306 lag