PROBLEM #1

Consider a Y-connected generator set in which each leg has an open circuit output voltage of 240V and a source impedance of (0.1+j0.8) Ω. The transmission lines connecting the generator set to the loads each have an impedance of (0.4+j3.2) Ω. The load consists of three Y-connected circuits. The loads are Z_A = (59.5+j76) Ω, Z_B = (39.5+j26) Ω, and Z_B = (19.5+j11) Ω.

Use the neutral point of the generator set as the voltage reference.

a) What are the magnitudes of the voltages across and currents in the three loads?

b) What is the magnitude of the voltage at the neutral point of the load?

A ground rod is now placed at the neutral points of both the generator set and the load and the effective impedance through the ground between the two rods is 10 Ω.

c) What are the magnitudes of the voltages across and currents in the three loads?

d) What is the magnitude of the voltage at the neutral point of the load?

e) What is the magnitude of the ground current?

In addition to the ground rods, a fourth wire (the same as the others) is added to the transmission line to serve as a neutral wire.

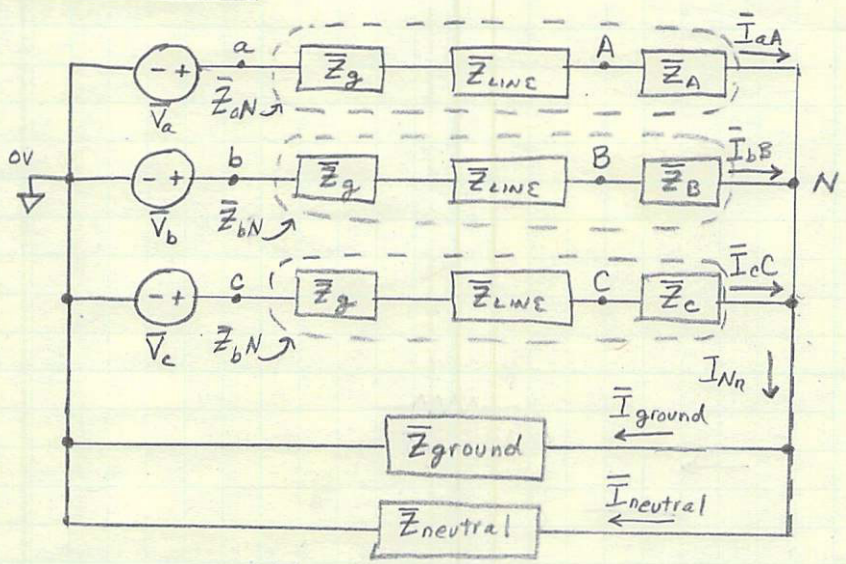
f) What are the magnitudes of the voltages across and currents in the three loads?

g) What is the magnitude of the voltage at the neutral point of the load?

h) What is the magnitude of the ground current?

i) What is the magnitude of the current in the neutral conductor?

GENERAL CIRCUIT



PART	$\bar{Z}_{ground}$	$\bar{Z}_{neutral}$
(a)→(b)	∞	∞
(b)→(e)	10Ω	∞
(f)→(i)	10Ω	$\bar{Z}_{LINE}$

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PROBLEM #1 (CONT'D)

GENERAL SOLUTION

NODAL ANALYSIS AT NODE N

$$\underbrace{\frac{\bar{V}_a}{\bar{Z}_{aN}} + \frac{\bar{V}_b}{\bar{Z}_{bN}} + \frac{\bar{V}_c}{\bar{Z}_{cN}}}_{\bar{I}_0} = V_N \left(\underbrace{\frac{1}{\bar{Z}_{aN}} + \frac{1}{\bar{Z}_{bN}} + \frac{1}{\bar{Z}_{cN}}}_{\frac{1}{\bar{Z}_{abc}}} + \underbrace{\frac{1}{\bar{Z}_{GROUND}} + \frac{1}{\bar{Z}_{neutral}}}_{\frac{1}{\bar{Z}_N}} \right)$$

$$V_N = \bar{I}_0 \frac{1}{\frac{1}{\bar{Z}_{abc}} + \frac{1}{\bar{Z}_n}}$$

NEUTRAL POINT VOLTAGE IN LOAD: $\bar{V}_N = \bar{I}_n (\bar{Z}_{ABC} \,||\, \bar{Z}_n)$; $\bar{Z}_N = \bar{Z}_{GROUND} \,||\, \bar{Z}_{neutral}$

LOAD CURRENT: $\bar{I}_{kK} = \dfrac{\bar{V}_k - \bar{V}_N}{\bar{Z}_{kN}}$

LOAD VOLTAGE: $\bar{V}_{KN} = \bar{I}_{kK} \cdot \bar{Z}_K$

} FOR $k = \{a, b, c\}$ (K IS UPPERCASE k)

GROUND CURRENT: $\bar{I}_{ground} = \dfrac{\bar{V}_N}{\bar{Z}_{ground}}$

NEUTRAL CURRENT: $\bar{I}_{neutral} = \dfrac{\bar{V}_N}{\bar{Z}_{neutral}}$

COMMON INTERMEDIATE RESULTS

	abc	acb
$\bar{V}_a$	$240V \angle 0°$	$240V \angle 0°$
$\bar{V}_b$	$240V \angle -120°$	$240V \angle +120°$
$\bar{V}_c$	$240V \angle +120°$	$240V \angle -120°$

$\bar{Z}_g + \bar{Z}_{LIN} = (0.1 + j0.8)\Omega + (0.4 + j3.2)\Omega = (0.5 + j4.0)\Omega$

$\bar{Z}_{aN} = (\bar{Z}_g + \bar{Z}_{LINE}) + \bar{Z}_A = (0.5 + j4.0)\Omega + (59.5 + j76)\Omega = (60 + j80)\Omega$
$\bar{Z}_{bN} = (\bar{Z}_g + \bar{Z}_{LINE}) + \bar{Z}_B = (0.5 + j4.0)\Omega + (39.5 + j26)\Omega = (40 + j30)\Omega$
$\bar{Z}_{cN} = (\bar{Z}_g + \bar{Z}_{LINE}) + \bar{Z}_c = (0.5 + j4.0)\Omega + (19.5 + j11)\Omega = (20 + j15)\Omega$

$\bar{Z}_{abc} = (\bar{Z}_{aN} \,||\, \bar{Z}_{bN} \,||\, \bar{Z}_{cN}) = (11.13 + j9.068)\Omega = 14.36\Omega \angle 39.17°$

$\bar{I}_0 = \left(\frac{\bar{V}_a}{\bar{Z}_{aN}} + \frac{\bar{V}_b}{\bar{Z}_{bN}} + \frac{\bar{V}_c}{\bar{Z}_{cN}} \right) = \underbrace{6.010A \angle 107.7°}_{abc}$ or $\underbrace{6.877A \angle -172.3°}_{acb}$

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PROBLEM #1 (CONT'D)

A PYTHON SCRIPT WAS WRITTEN TO IMPLEMENT THE GENERAL SOLUTION AND THEN RUN FOR THE THREE CIRCUITS FOR BOTH PHASE SEQUENCES. THE RESULTS FROM THE SCRIPTS ARE PRESENTED BELOW. THE SCRIPT & RUN RESULTS ARE ATTACHED.

		abc		acb		
PART (a)	LOAD	V	I	V	I	
	A	305V	3.16A	305V	3.16A	(#1a)
	B	245V	5.19A	269V	5.70A	
	C	150V	6.71A	130V	5.82A	
PART (b)	V_N	86.3V	—	98.7V	—	(#1b)
PART (c)	LOAD	V	I	V	I	
	A	254V	2.63A	270V	2.80A	(#1c)
	B	245V	5.18A	226V	4.72A	
	C	181V	8.10A	185V	8.28A	
PART (d)	V_N	37.5V	—	42.9V	—	(#1d)
PART (e)	I_{GND}	—	3.75A	—	4.29A	(#1e)
PART (f)	LOAD	V	I	V	I	
	A	246V	2.55A	238V	2.47A	(#1f)
	B	223V	4.71A	238V	5.02A	
	C	206V	9.22A	200V	8.92A	
PART (g)	V_N	14.99V	—	17.15V	—	(#1g)
PART (h)	I_{GND}	—	1.499A	—	1.715A	(#1h)
PART (i)	$I_{NEUTRAL}$	—	4.65A	—	5.32A	(#1i)

FOR REFERENCE

		abc		acb	
SHORT BETWEEN GEN & LOAD NEUTRALS	LOAD	V	I	V	I
	A	232V	2.40A	232V	2.40A
	B	227V	4.80A	227V	4.80A
	C	215V	9.60A	215V	9.60A
	V_N	0V	—	0V	—
	I_{neu}	—	6.01A	—	6.88A

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ROTATION: abc GROUND: open NEUTRAL: open
VloadA = 304.8 @ -9.777 deg  IaA  = 3.158 @ -61.72 deg
VloadB = 245.4 @ -104.1 deg  IbB  = 5.189 @ -137.5 deg
VloadC = 150.1 @ 99.11 deg  IcC  = 6.705 @ 69.68 deg
VloadN = 86.28 @ 146.9 deg  IN   = 1.22e-10 @ 101.9 deg
Ignd   = 6.101e-11 @ 101.9 deg  Ineu = 6.101e-11 @ 101.9 deg

ROTATION: abc GROUND: rod NEUTRAL: open
VloadA = 253.5 @ -8.019 deg  IaA  = 2.626 @ -59.96 deg
VloadB = 244.8 @ -116.1 deg  IbB  = 5.177 @ -149.4 deg
VloadC = 181.4 @ 111.9 deg  IcC  = 8.103 @ 82.46 deg
VloadN = 37.52 @ 123.6 deg  IN   = 3.752 @ 123.6 deg
Ignd   = 3.752 @ 123.6 deg  Ineu = 2.653e-11 @ 78.63 deg

ROTATION: abc GROUND: rod NEUTRAL: line
VloadA = 245.9 @ -1.831 deg  IaA  = 2.547 @ -53.77 deg
VloadB = 222.8 @ -120.1 deg  IbB  = 4.711 @ -153.4 deg
VloadC = 206.4 @ 109.7 deg  IcC  = 9.218 @ 80.32 deg
VloadN = 14.99 @  169 deg  IN   = 5.058 @ 103.2 deg
Ignd   = 1.499 @  169 deg  Ineu = 4.648 @ 86.12 deg

ROTATION: acb GROUND: open NEUTRAL: open
VloadA = 304.8 @ 12.01 deg  IaA  = 3.158 @ -39.93 deg
VloadB = 269.4 @ 97.12 deg  IbB  = 5.697 @ 63.76 deg
VloadC = 130.4 @ -118.6 deg  IcC  = 5.823 @ -148 deg
VloadN = 98.72 @ -133.1 deg  IN   = 1.396e-10 @ -178.1 deg
Ignd   = 6.981e-11 @ -178.1 deg  Ineu = 6.981e-11 @ -178.1 deg

ROTATION: acb GROUND: rod NEUTRAL: open
VloadA = 270.1 @ 2.345 deg  IaA  = 2.799 @ -49.6 deg
VloadB = 226.1 @ 106.2 deg  IbB  = 4.782 @ 72.85 deg
VloadC = 185.4 @ -120.4 deg  IcC  = 8.279 @ -149.8 deg
VloadN = 42.94 @ -156.3 deg  IN   = 4.294 @ -156.3 deg
Ignd   = 4.294 @ -156.3 deg  Ineu = 3.036e-11 @ 158.7 deg

ROTATION: acb GROUND: rod NEUTRAL: line
VloadA = 238.1 @ 2.536 deg  IaA  = 2.467 @ -49.41 deg
VloadB = 237.5 @ 113.4 deg  IbB  = 5.023 @ 80.09 deg
VloadC = 199.8 @ -128.1 deg  IcC  = 8.923 @ -157.6 deg
VloadN = 17.15 @ -111 deg  IN   = 5.788 @ -176.7 deg
Ignd   = 1.715 @ -111 deg  Ineu = 5.319 @ 166.2 deg

ROTATION: abc GROUND: open NEUTRAL: short
VloadA = 231.6 @ -1.187 deg  IaA  =  2.4 @ -53.13 deg
VloadB =  227 @ -123.5 deg  IbB  =  4.8 @ -156.9 deg
VloadC = 214.9 @ 112.6 deg  IcC  =  9.6 @ 83.13 deg
VloadN = 8.499e-12 @ 152.7 deg  IN   = 6.01 @ 107.7 deg
Ignd   = 6.01e-24 @ 107.7 deg  Ineu = 6.01 @ 107.7 deg

ROTATION: acb GROUND: open NEUTRAL: short
VloadA = 231.6 @ -1.187 deg  IaA  =  2.4 @ -53.13 deg
VloadB =  227 @ 116.5 deg  IbB  =  4.8 @ 83.13 deg
VloadC = 214.9 @ -127.4 deg  IcC  =  9.6 @ -156.9 deg
VloadN = 9.725e-12 @ -127.3 deg  IN   = 6.877 @ -172.3 deg
Ignd   = 6.877e-24 @ -172.3 deg  Ineu = 6.877 @ -172.3 deg
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#============================================================
# USERID:..... wbahn
# PROGRAMMER:..... Bahn, William L.
# COURSE:..... EENG-382
# TERM:..... SP14
# PROJECT:..... N/A
# FILENAME:..... HW03.py
# PYTHON VERSION:. 3.3.3
#============================================================

from z import *

def hw03(seq, rod, neutral):

    # Generator Sequence
    Va = PhP(240,0)
    if (seq == "abc"):
        Vb = PhP(240, -120)
        Vc = PhP(240, +120)
    else:
        Vb = PhP(240, +120)
        Vc = PhP(240, -120)

    # Impedances
    Zs = PhR(0.1,0.8)
    ZloadA = PhR(59.5,76)
    ZloadB = PhR(39.5,26)
    ZloadC = PhR(19.5,11)
    Zline = PhR(0.4,3.2)

    Zground = PhR(10,0)
    Zopen = PhR(1e12,1e12)

    # Set ground rod impedance
    Zgnd = Zopen
    if (rod == "rod"):
        Zgnd = Zground

    # Set neutral bond impedance
    Zneu = Zopen
    if (neutral == "line"):
        Zneu = Zline
    if (neutral == "short"):
        Zneu = PhR(1e-12, 1e-12)

    # Total Phase Impedances
    ZA = Zs + Zline + ZloadA
    ZB = Zs + Zline + ZloadB
    ZC = Zs + Zline + ZloadC
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    # Intermediate results
    Io = Va/ZA + Vb/ZB + Vc/ZC
    ZABC = 1/(1/ZA + 1/ZB + 1/ZC)

    ZN = p(Zgnd,Zneu)
    ZABCN = 1/(1/ZABC + 1/ZN)
    VN = Io*ZABCN
    IN = VN/ZN
    Ignd = VN/Zgnd
    Ineu = VN/Zneu
    IaA = (Va-VN)/ZA
    IbB = (Vb-VN)/ZB
    IcC = (Vc-VN)/ZC
    VAN = IaA*ZloadA
    VBN = IbB*ZloadB
    VCN = IcC*ZloadC

    print()
    print("ROTATION: %s GROUND: %s NEUTRAL: %s" % (seq, rod, neutral))
    print("VloadA = %s  IaA  = %s" % (showP(VAN), showP(IaA)))
    print("VloadB = %s  IbB  = %s" % (showP(VBN), showP(IbB)))
    print("VloadC = %s  IcC  = %s" % (showP(VCN), showP(IcC)))
    print("VloadN = %s  IN   = %s" % (showP(VN), showP(IN)))
    print("Ignd   = %s  Ineu = %s" % (showP(Ignd), showP(Ineu)))

hw03("abc", "open", "open")
hw03("abc", "rod", "open")
hw03("abc", "rod", "line")

hw03("acb", "open", "open")
hw03("acb", "rod", "open")
hw03("acb", "rod", "line")

hw03("abc", "open", "short")
hw03("acb", "open", "short")
```