

***Distribution System Modeling and Analysis 4th
edition Kersting Solutions Manual***

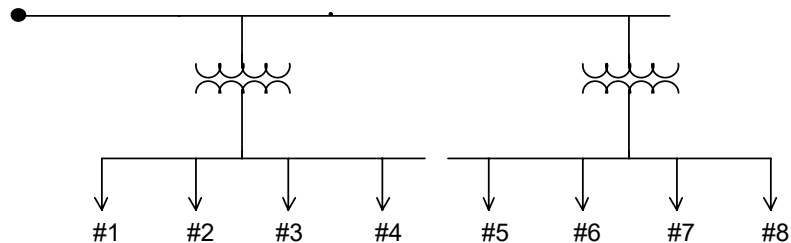
SKU: 9781498772136-SOLUTIONS

**Problem
2.1**

	A	B	C	D	E	F	G	H
1	Four Customers Connected to a 25 kVA Transformer							
2								
3	Time	Cust #1	Cust #2	Cust #3	Cust #4	Total	Totals	
4		kW	kW	kW	kW		Sorted Descending	
5	17:00	8.81	4.96	11.04	1.44	26.25	26.7	
6	17:15	2.12	3.16	7.04	1.62	13.94	26.25	
7	17:30	9.48	7.08	7.68	2.46	26.7	23.8	
8	17:45	7.16	5.08	6.08	0.84	19.16	20.12	
9	18:00	6.04	3.12	4.32	1.12	14.6	19.68	
10	18:15	9.88	6.56	5.12	2.24	23.8	19.24	
11	18:30	4.68	6.88	6.56	1.12	19.24	19.16	
12	18:45	5.12	3.84	8.48	2.24	19.68	18.08	
13	19:00	10.44	4.44	4.12	1.12	20.12	16.88	
14	19:15	3.72	8.52	3.68	0.96	16.88	16.26	
15	19:30	8.72	4.52	0.32	2.56	16.12	16.12	
16	19:45	10.84	2.92	3.04	1.28	18.08	15.29	
17	20:00	6.96	2.08	2.72	1.92	13.68	14.6	
18	20:15	6.62	1.48	3.24	1.12	12.46	13.94	
19	20:30	7.04	2.33	4.16	1.76	15.29	13.68	
20	20:45	6.69	1.89	4.96	2.72	16.26	12.46	
21	21:00	1.88	1.64	4.32	2.41	10.25	10.25	

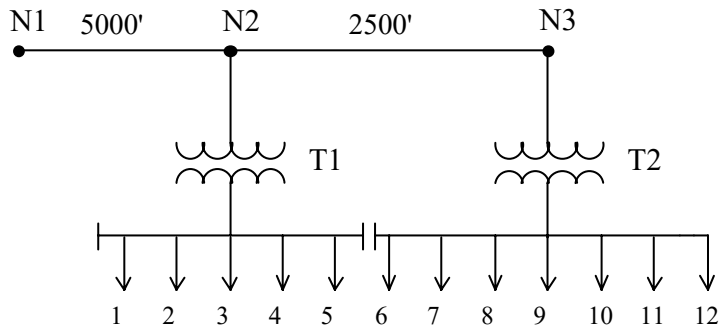
**Problem
2.2**

Tap



	A	B	C	D	E	F	G
1	Problem 2.2						
2							
3	1 For each transformer determine:						
4						Trf	Trf
5						#1	#2
6	a. 30 minute maximum kVA demand					105	128
7	b. Non-coincident maximum kVA demand					130.00	170.00
8	c. Load factor					0.595238	0.686523
9	d. Diversity factor					1.2381	1.3281
10	e. Suggested transformer rating (50, 75, 100, 167)					75	100
11	f. Utilization factor					1.4	1.2800
12	g. Energy (kWh) during the 4 hour period					225	316.3500
13							
14	2 Maximum diversified 30-minute kVA demand at the Tap						195

**Problem
2.3**



Problem 2.3.1-2.3.9 **Answers for 2.3.5, 2.3.6, and 2.3.9 are kW demands**

Problem 2.3		Cust #1	Cust #2	Cust #3	Cust #4	Cust #5	Cust #6	Cust #7	Cust #8	Cust #9	Cust #10	Cust #11	Cust #12
1. Maximum 15 minute kW demand		3.81	5.81	4.93	11.26	6.37	1.56	1.56	13.48	1.80	8.97	8.99	12.23
2. Average 15 minute kW demand		2.45	1.61	3.59	9.26	1.56	0.82	5.15	0.69	3.34	5.42	9.06	2.05
3. Total KWH usage in the time period		10.42	6.85	15.26	39.36	6.65	3.47	21.89	2.92	14.20	23.05	38.49	8.71
4. Load factor		0.6437	0.2774	0.7284	0.8225	0.2456	0.5230	3.3017	0.0510	1.8565	0.6045	1.0073	0.1676
		Trf #1	Trf #2										
5. Maximum diversified demand		22.71	41.56										
6. Maximum non-coincident demand		32.18	48.59										
7. Utilization factor		0.9084	1.1083										
8. Diversity factor		1.4170	1.1692										
9. Maximum Diversified demand at N1		57.89											

Problem 2.3.j

$$V_{N1} := 2500 \cdot e^{j \cdot 0 \text{deg}} \quad \text{pf} := .95 \quad \text{kVA}_{T1} := 25 \quad \text{kVA}_{T2} := 37.5 \quad \text{kV}_{hi} := 2.4 \quad V_{low} := 240$$

$$z_{line} := 0.306 + 0.6272j \quad z_{pu_{T1}} := 0.018 \cdot e^{j \cdot 40 \text{deg}} \quad z_{pu_{T2}} := 0.02 \cdot e^{j \cdot 50 \text{deg}}$$

$$D_{N1N2} := 5000 \quad D_{N2N3} := 2500$$

$$Z_{baseT1} := \frac{\text{kV}_{hi}^2 \cdot 1000}{\text{kVA}_{T1}} \quad Z_{baseT1} = 230.4000$$

$$Z_{T1} := z_{pu_{T1}} \cdot Z_{baseT1} \quad Z_{T1} = 3.1769 + 2.6658j$$

$$Z_{baseT2} := \frac{\text{kV}_{hi}^2 \cdot 1000}{\text{kVA}_{T2}} \quad Z_{baseT2} = 153.6000$$

$$Z_{T2} := z_{pu_{T2}} \cdot Z_{baseT2} \quad Z_{T2} = 1.9746 + 2.3533j$$

$$z_{N1N2} := z_{line} \cdot \frac{D_{N1N2}}{5280} \quad z_{N1N2} = 0.2898 + 0.5939j$$

$$z_{N2N3} := z_{line} \cdot \frac{D_{N2N3}}{5280} \quad z_{N2N3} = 0.1449 + 0.2970j$$

Note: The voltage drops will be computed for a "worst case" situation. For each segment or transformer the maximum kVA demand on that segment or transformer will be used to compute the voltage drop to the remote end. This remote end voltage will then be assumed to be the voltage at that node when the maximum diversified demand downstream occurs.

$$kVADemand_{N1} := \frac{57.89}{pf} \cdot e^{j \cdot \text{acos}(pf)} \quad |kVADemand_{N1}| = 60.9368 \quad \frac{\arg(kVADemand_{N1})}{\text{deg}} = 18.1949$$

$$I_{N1N2} := \frac{\overline{kVADemand_{N1}}}{\frac{V_{N1}}{1000}} \quad |I_{N1N2}| = 24.3747 \quad \frac{\arg(I_{N1N2})}{\text{deg}} = -18.1949$$

$$V_{N2} := V_{N1} - Z_{N1N2} \cdot I_{N1N2} \quad |V_{N2}| = 2488.7963 \quad \frac{\arg(V_{N2})}{\text{deg}} = -0.2658$$

$$kVADemand_{T1} := \frac{22.71}{pf} \cdot e^{j \cdot \text{acos}(pf)} \quad |kVADemand_{T1}| = 23.9053 \quad \frac{\arg(kVADemand_{T1})}{\text{deg}} = 18.1949$$

$$I_{T1} := \frac{\overline{kVADemand_{T1}}}{\frac{V_{N2}}{1000}} \quad |I_{T1}| = 9.6052 \quad \frac{\arg(I_{T1})}{\text{deg}} = -17.9290$$

$$V_{T1} := V_{N2} - I_{T1} \cdot Z_{T1} \quad |V_{T1}| = 2451.9975 \quad \frac{\arg(V_{T1})}{\text{deg}} = -0.6196$$

$$V_{\text{low}T1} := V_{T1} \cdot \left(\frac{V_{\text{low}}}{kV_{hi} \cdot 1000} \right) \quad |V_{\text{low}T1}| = 245.1998$$

$$kVADemand_{N2} := \frac{41.56}{pf} \cdot e^{j \cdot \text{acos}(pf)} \quad |kVADemand_{N2}| = 43.7474 \quad \frac{\arg(kVADemand_{N2})}{\text{deg}} = 18.1949$$

$$I_{N2N3} := \frac{\overline{kVADemand_{N2}}}{\frac{V_{N1}}{1000}} \quad |I_{N2N3}| = 17.4989 \quad \frac{\arg(I_{N2N3})}{\text{deg}} = -18.1949$$

$$V_{N3} := V_{N2} - Z_{N2N3} \cdot I_{N2N3} \quad |V_{N3}| = 2484.7879 \quad \frac{\arg(V_{N3})}{\text{deg}} = -0.3619$$

$$V_{T2} := V_{N3} - I_{N2N3} \cdot Z_{T2} \quad |V_{T2}| = 2439.4506 \quad \frac{\arg(V_{T2})}{\text{deg}} = -1.0341$$

$$V_{\text{low}T2} := V_{T2} \cdot \left(\frac{V_{\text{low}}}{kV_{hi} \cdot 1000} \right) \quad |V_{\text{low}T2}| = 243.9451$$

Problem 2.4

$$V_{N1} := 2500 \cdot e^{j \cdot 0\text{deg}} \quad pf := .95 \quad kVA_{T1} := 25 \quad kVA_{T2} := 37.5 \quad kV_{hi} := 2.4 \quad V_{\text{low}} := 240$$

$$z_{\text{line}} := 0.306 + 0.6272j \quad z_{pu_{T1}} := 0.018 \cdot e^{j \cdot 40\text{deg}} \quad z_{pu_{T2}} := 0.02 \cdot e^{j \cdot 50\text{deg}}$$

$$D_{N1N2} := 5000$$

$$D_{N2N3} := 2500$$

$$Z_{baseT1} := \frac{kV_{hi}^2 \cdot 1000}{kVA_{T1}}$$

$$Z_{baseT1} = 230.4000$$

$$Z_{T1} := zpu_{T1} \cdot Z_{baseT1}$$

$$Z_{T1} = 3.1769 + 2.6658j$$

$$Z_{baseT2} := \frac{kV_{hi}^2 \cdot 1000}{kVA_{T2}}$$

$$Z_{baseT2} = 153.6000$$

$$Z_{T2} := zpu_{T2} \cdot Z_{baseT2}$$

$$Z_{T2} = 1.9746 + 2.3533j$$

$$z_{N1N2} := z_{line} \cdot \frac{D_{N1N2}}{5280}$$

$$z_{N1N2} = 0.2898 + 0.5939j$$

$$z_{N2N3} := z_{line} \cdot \frac{D_{N2N3}}{5280}$$

$$z_{N2N3} = 0.1449 + 0.2970j$$

$$kW_{Demand_{N1}} := 72.43$$

$$pf := 0.95$$

$$kVA_{T1} := 25$$

$$kVA_{T2} := 37.5$$

$$kVADemand_{N1} := \frac{kW_{Demand_{N1}}}{pf} \cdot e^{j \cdot \arccos(pf)}$$

$$|kVADemand_{N1}| = 76.2421$$

$$\frac{\arg(kVADemand_{N1})}{deg} = 18.1949$$

$$kVA_{total} := kVA_{T1} + kVA_{T2}$$

$$AF := \frac{kW_{Demand_{N1}}}{kVA_{total}}$$

$$AF = 1.1589$$

$$kW_{Demand_{T1}} := AF \cdot kVA_{T1}$$

$$kW_{Demand_{T1}} = 28.9720$$

$$kW_{Demand_{T2}} := AF \cdot kVA_{T2}$$

$$kW_{Demand_{T2}} = 43.4580$$

$$kVADemand_{T1} := \frac{kW_{Demand_{T1}}}{pf} \cdot e^{j \cdot (\arccos(pf))}$$

$$|kVADemand_{T1}| = 30.4968$$

$$\frac{\arg(kVADemand_{T1})}{deg} = 18.1949$$

$$kVADemand_{T2} := \frac{kW_{Demand_{T2}}}{pf} \cdot e^{j \cdot (\arccos(pf))}$$

$$|kVADemand_{T2}| = 45.7453$$

$$\frac{\arg(kVADemand_{T2})}{deg} = 18.1949$$

Note: For all segment and transformer currents, for the constant current model the allocated kVA will be used along with the Node N1 voltage to compute the currents.

$$I_{N1N2} := \frac{kVADemand_{N1}}{\frac{V_{N1}}{1000}}$$

$$|I_{N1N2}| = 30.4968$$

$$\frac{\arg(I_{N1N2})}{deg} = -18.1949$$

$$V_{N2} := V_{N1} - Z_{N1N2} \cdot I_{N1N2} \quad |V_{N2}| = 2485.9908 \quad \frac{\arg(V_{N2})}{\deg} = -0.3330$$

$$I_{T1} := \frac{\overline{\text{kVADemand}_{T1}}}{\frac{V_{N1}}{1000}} \quad |I_{T1}| = 12.1987 \quad \frac{\arg(I_{T1})}{\deg} = -18.1949$$

$$V_{T1} := V_{N2} - I_{T1} \cdot Z_{T1} \quad |V_{T1}| = 2439.2044 \quad \frac{\arg(V_{T1})}{\deg} = -0.7808$$

$$V_{\text{low}T1} := V_{T1} \cdot \left(\frac{V_{\text{low}}}{\text{kV}_{\text{hi}} \cdot 1000} \right) \quad |V_{\text{low}T1}| = 243.9204 \quad \frac{\arg(V_{\text{low}T1})}{\deg} = -0.7808$$

$$\text{kVADemand}_{N2} := \text{kVADemand}_{T2} \quad |\text{kVADemand}_{N2}| = 45.7453 \quad \frac{\arg(\text{kVADemand}_{N2})}{\deg} = 18.1949$$

$$I_{N2N3} := \frac{\overline{\text{kVADemand}_{N2}}}{\frac{V_{N1}}{1000}} \quad |I_{N2N3}| = 18.2981 \quad \frac{\arg(I_{N2N3})}{\deg} = -18.1949$$

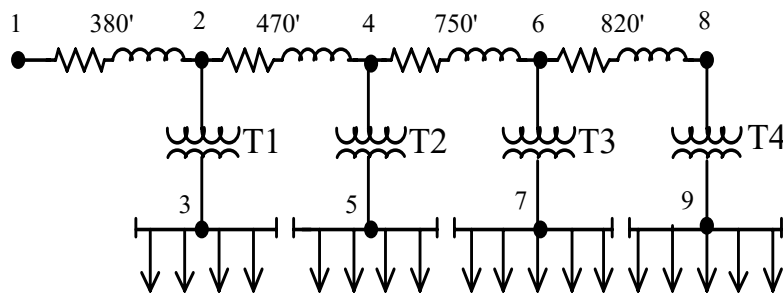
$$V_{N3} := V_{N2} - Z_{N2N3} \cdot I_{N2N3} \quad |V_{N3}| = 2481.8046 \quad \frac{\arg(V_{N3})}{\deg} = -0.4336$$

$$V_{T2} := V_{N3} - I_{N2N3} \cdot Z_{T2} \quad |V_{T2}| = 2434.4435 \quad \frac{\arg(V_{T2})}{\deg} = -1.1394$$

$$V_{\text{low}T2} := V_{T2} \cdot \left(\frac{V_{\text{low}}}{\text{kV}_{\text{hi}} \cdot 1000} \right) \quad |V_{\text{low}T2}| = 243.4443$$

Problem

2.5



$$\text{CustMaxDem} := 15.5 + 7.5j$$

$$V_{N1} := 2600 \cdot e^{j \cdot 0 \deg} \quad \text{pf} := .95$$

$$z_{\text{line}} := 0.4421 + 0.3213j$$

$$\text{kVA}_{T1} := 37.5 \quad \text{kVA}_{T2} := \text{kVA}_{T1} \quad \text{kVA}_{T3} := 50 \quad \text{kVA}_{T4} := \text{kVA}_{T3}$$

$$z_{\text{pu}T1} := 0.01 + 0.03j \quad z_{\text{pu}T2} := z_{\text{pu}T1} \quad z_{\text{pu}T3} := 0.015 + 0.035j \quad z_{\text{pu}T4} := z_{\text{pu}T3}$$

$$\text{kV}_{\text{hi}} := 2.4 \quad V_{\text{low}} := 240$$

$$\text{DF}_4 := 2.1 \quad \text{DF}_5 := 2.2 \quad \text{DF}_{10} := 2.65 \quad \text{DF}_{14} := 2.78 \quad \text{DF}_{18} := 2.86$$

Problem 2.5.a

$$\text{kVADemand}_{T1} := \frac{4 \cdot \text{CustMaxDem}}{\text{DF}_4}$$

$$\text{kVADemand}_{T1} = 29.5238 + 14.2857j$$

$$\text{kVADemand}_{T2} := \frac{4 \cdot \text{CustMaxDem}}{\text{DF}_4}$$

$$\text{kVADemand}_{T2} = 29.5238 + 14.2857j$$

$$\text{kVADemand}_{T3} := \frac{5 \cdot \text{CustMaxDem}}{\text{DF}_5}$$

$$\text{kVADemand}_{T3} = 35.2273 + 17.0455j$$

$$\text{kVADemand}_{T4} := \frac{5 \cdot \text{CustMaxDem}}{\text{DF}_5}$$

$$\text{kVADemand}_{T4} = 35.2273 + 17.0455j$$

Problem 2.5.b

$$\text{kVADemand}_{N1N2} := \frac{18 \cdot \text{CustMaxDem}}{\text{DF}_{18}}$$

$$\text{kVADemand}_{N1N2} = 97.5524 + 47.2028j$$

$$\text{kVADemand}_{N2N4} := \frac{14 \cdot \text{CustMaxDem}}{\text{DF}_{14}}$$

$$\text{kVADemand}_{N2N4} = 78.0576 + 37.7698j$$

$$\text{kVADemand}_{N4N6} := \frac{10 \cdot \text{CustMaxDem}}{\text{DF}_{10}}$$

$$\text{kVADemand}_{N4N6} = 58.4906 + 28.3019j$$

$$\text{kVADemand}_{N6N8} := \frac{5 \cdot \text{CustMaxDem}}{\text{DF}_5}$$

$$\text{kVADemand}_{N6N8} = 35.2273 + 17.0455j$$

Problem 2.5.c

$$D_{N1N2} := 380$$

$$D_{N2N4} := 470$$

$$D_{N4N6} := 750$$

$$D_{N6N8} := 820$$

$$z_{N1N2} := z_{\text{line}} \cdot \frac{D_{N1N2}}{1000}$$

$$z_{N1N2} = 0.1680 + 0.1221j$$

$$z_{N2N4} := z_{\text{line}} \cdot \frac{D_{N2N4}}{1000}$$

$$z_{N2N4} = 0.2078 + 0.1510j$$

$$z_{N4N6} := z_{\text{line}} \cdot \frac{D_{N4N6}}{1000}$$

$$z_{N4N6} = 0.3316 + 0.2410j$$

$$z_{N6N8} := z_{\text{line}} \cdot \frac{D_{N6N8}}{1000}$$

$$z_{N6N8} = 0.3625 + 0.2635j$$

$$Z_{\text{base}T1} := \frac{kV_{hi}^2 \cdot 1000}{kVA_{T1}}$$

$$Z_{\text{base}T1} = 153.6000$$

$$Z_{\text{base}T3} := \frac{kV_{hi}^2 \cdot 1000}{kVA_{T3}}$$

$$Z_{\text{base}T3} = 115.2000$$

$$Z_{T1} := z_{puT1} \cdot Z_{\text{base}T1}$$

$$Z_{T1} = 1.5360 + 4.6080j$$

$$Z_{T3} := z_{puT3} \cdot Z_{\text{base}T3}$$

$$Z_{T3} = 1.7280 + 4.0320j$$

$$Z_{\text{base}T2} := \frac{kV_{hi}^2 \cdot 1000}{kVA_{T2}}$$

$$Z_{\text{base}T2} = 153.6000$$

$$Z_{\text{base}T4} := \frac{kV_{hi}^2 \cdot 1000}{kVA_{T4}}$$

$$Z_{\text{base}T4} = 115.2000$$

$$Z_{T2} := z_{puT2} \cdot Z_{\text{base}T2}$$

$$Z_{T2} = 1.5360 + 4.6080j$$

$$Z_{T4} := z_{puT4} \cdot Z_{\text{base}T4}$$

$$Z_{T4} = 1.7280 + 4.0320j$$

$$I_{N1N2} := \frac{\text{kVADemand}_{N1N2}}{\frac{V_{N1}}{1000}}$$

$$|I_{N1N2}| = 41.6817$$

$$\frac{\arg(I_{N1N2})}{\text{deg}} = -25.8210$$

$V_{N2} := V_{N1} - Z_{N1N2} \cdot I_{N1N2}$	$ V_{N2} = 2591.4805$	$\frac{\arg(V_{N2})}{\deg} = -0.0338$
$I_{T1} := \frac{\overline{\text{kVADemand}_{T1}}}{\frac{V_{N2}}{1000}}$	$ I_{T1} = 12.6563$	$\frac{\arg(I_{T1})}{\deg} = -25.7871$
$V_{T1} := V_{N2} - I_{T1} \cdot Z_{T1}$	$ V_{T1} = 2549.0127$	$\frac{\arg(V_{T1})}{\deg} = -1.0247$
$V_{N3} := V_{T1} \cdot \left(\frac{V_{\text{low}}}{\text{kV}_{\text{hi}} \cdot 1000} \right)$	$ V_{N3} = 254.9013$	$\frac{\arg(V_{N3})}{\deg} = -1.0247$
$I_{N2N4} := \frac{\overline{\text{kVADemand}_{N2N4}}}{\frac{V_{N2}}{1000}}$	$ I_{N2N4} = 33.4617$	$\frac{\arg(I_{N2N4})}{\deg} = -25.8548$
$V_{N4} := V_{N2} - Z_{N2N4} \cdot I_{N2N4}$	$ V_{N4} = 2583.0213$	$\frac{\arg(V_{N4})}{\deg} = -0.0676$
$I_{T2} := \frac{\overline{\text{kVADemand}_{T2}}}{\frac{V_{N4}}{1000}}$	$ I_{T2} = 12.6977$	$\frac{\arg(I_{T2})}{\deg} = -25.7534$
$V_{T2} := V_{N4} - I_{T2} \cdot Z_{T2}$	$ V_{T2} = 2540.4700$	$\frac{\arg(V_{T2})}{\deg} = -1.0662$
$V_{N5} := V_{T2} \cdot \left(\frac{V_{\text{low}}}{\text{kV}_{\text{hi}} \cdot 1000} \right)$	$ V_{N5} = 254.0470$	$\frac{\arg(V_{N5})}{\deg} = -1.0662$
$I_{N4N6} := \frac{\overline{\text{kVADemand}_{N4N6}}}{\frac{V_{N4}}{1000}}$	$ I_{N4N6} = 25.1558$	$\frac{\arg(I_{N4N6})}{\deg} = -25.8886$
$V_{N6} := V_{N4} - Z_{N4N6} \cdot I_{N4N6}$	$ V_{N6} = 2572.8734$	$\frac{\arg(V_{N6})}{\deg} = -0.1082$
$I_{T3} := \frac{\overline{\text{kVADemand}_{T3}}}{\frac{V_{N6}}{1000}}$	$ I_{T3} = 15.2104$	$\frac{\arg(I_{T3})}{\deg} = -25.7128$
$V_{T3} := V_{N6} - I_{T3} \cdot Z_{T3}$	$ V_{T3} = 2523.0500$	$\frac{\arg(V_{T3})}{\deg} = -1.1062$

$$V_{N7} := V_{T3} \cdot \left(\frac{V_{low}}{kV_{hi} \cdot 1000} \right)$$

$$|V_{N7}| = 252.3050$$

$$\frac{\arg(V_{N7})}{\deg} = -1.1062$$

$$I_{N6N8} := \frac{\overline{kVADemand_{N6N8}}}{\frac{V_{N6}}{1000}}$$

$$|I_{N6N8}| = 15.2104$$

$$\frac{\arg(I_{N6N8})}{\deg} = -25.9292$$

$$V_{N8} := V_{N6} - Z_{N6N8} \cdot I_{N6N8}$$

$$|V_{N8}| = 2566.1646$$

$$\frac{\arg(V_{N8})}{\deg} = -0.1351$$

$$I_{T4} := I_{N6N8}$$

$$|I_{T4}| = 15.2104$$

$$\frac{\arg(I_{T4})}{\deg} = -25.9292$$

$$V_{T4} := V_{N8} - I_{T4} \cdot Z_{T4}$$

$$|V_{T4}| = 2516.1944$$

$$\frac{\arg(V_{T4})}{\deg} = -1.1321$$

$$V_{N9} := V_{T4} \cdot \left(\frac{V_{low}}{kV_{hi} \cdot 1000} \right)$$

$$|V_{N9}| = 251.6194$$

$$\frac{\arg(V_{N9})}{\deg} = -1.1321$$

Definitions for Part 7

$$P3_{N2} := V_{N2} \quad P3_{N4} := V_{N4} \quad P3_{N6} := V_{N6} \quad P3_{N8} := V_{N8}$$

$$P3_{N3} := V_{N3} \quad P3_{N5} := V_{N5} \quad P3_{N7} := V_{N7} \quad P3_{N9} := V_{N9}$$

Problem 2.5.d

$$kVADemand_{N1N2} = 97.5524 + 47.2028j$$

$$MaxDivDemand := \frac{kVADemand_{N1N2}}{18}$$

$$MaxDivDemand = 5.4196 + 2.6224j$$

$$kVADemand_{N2N4} := MaxDivDemand \cdot 14$$

$$kVADemand_{T1} := 4 \cdot MaxDivDemand$$

$$kVADemand_{N4N6} := MaxDivDemand \cdot 10$$

$$kVADemand_{T2} := 4 \cdot MaxDivDemand$$

$$kVADemand_{N6N8} := MaxDivDemand \cdot 5$$

$$kVADemand_{T3} := 5 \cdot MaxDivDemand$$

$$I_{N1N2} := \frac{\overline{kVADemand_{N1N2}}}{\frac{V_{N1}}{1000}}$$

$$|I_{N1N2}| = 41.6817$$

$$\frac{\arg(I_{N1N2})}{\deg} = -25.8210$$

$$V_{N2} := V_{N1} - Z_{N1N2} \cdot I_{N1N2}$$

$$|V_{N2}| = 2591.4805$$

$$\frac{\arg(V_{N2})}{\deg} = -0.0338$$

$$I_{T1} := \frac{\overline{kVADemand_{T1}}}{\frac{V_{N2}}{1000}}$$

$$|I_{T1}| = 9.2931$$

$$\frac{\arg(I_{T1})}{\deg} = -25.7871$$

$V_{T1} := V_{N2} - I_{T1} \cdot Z_{T1}$	$ V_{T1} = 2560.2226$	$\frac{\arg(V_{T1})}{\deg} = -0.7582$
$V_{N3} := V_{T1} \cdot \left(\frac{V_{low}}{kV_{hi} \cdot 1000} \right)$	$ V_{N3} = 256.0223$	$\frac{\arg(V_{N3})}{\deg} = -0.7582$
$I_{N2N4} := \frac{\overline{kVADemand_{N2N4}}}{\frac{V_{N2}}{1000}}$	$ I_{N2N4} = 32.5257$	$\frac{\arg(I_{N2N4})}{\deg} = -25.8548$
$V_{N4} := V_{N2} - Z_{N2N4} \cdot I_{N2N4}$	$ V_{N4} = 2583.2579$	$\frac{\arg(V_{N4})}{\deg} = -0.0666$
$I_{T2} := \frac{\overline{kVADemand_{T2}}}{\frac{V_{N4}}{1000}}$	$ I_{T2} = 9.3226$	$\frac{\arg(I_{T2})}{\deg} = -25.7544$
$V_{T2} := V_{N4} - I_{T2} \cdot Z_{T2}$	$ V_{T2} = 2551.9395$	$\frac{\arg(V_{T2})}{\deg} = -0.7965$
$V_{N5} := V_{T2} \cdot \left(\frac{V_{low}}{kV_{hi} \cdot 1000} \right)$	$ V_{N5} = 255.1939$	$\frac{\arg(V_{N5})}{\deg} = -0.7965$
$I_{N4N6} := \frac{\overline{kVADemand_{N4N6}}}{\frac{V_{N4}}{1000}}$	$ I_{N4N6} = 23.3066$	$\frac{\arg(I_{N4N6})}{\deg} = -25.8876$
$V_{N6} := V_{N4} - Z_{N4N6} \cdot I_{N4N6}$	$ V_{N6} = 2573.8559$	$\frac{\arg(V_{N6})}{\deg} = -0.1042$
$I_{T3} := \frac{\overline{kVADemand_{T3}}}{\frac{V_{N6}}{1000}}$	$ I_{T3} = 11.6959$	$\frac{\arg(I_{T3})}{\deg} = -25.7168$
$V_{T3} := V_{N6} - I_{T3} \cdot Z_{T3}$	$ V_{T3} = 2535.4711$	$\frac{\arg(V_{T3})}{\deg} = -0.8678$
$V_{N7} := V_{T3} \cdot \left(\frac{V_{low}}{kV_{hi} \cdot 1000} \right)$	$ V_{N7} = 253.5471$	$\frac{\arg(V_{N7})}{\deg} = -0.8678$
$I_{N6N8} := \frac{\overline{kVADemand_{N6N8}}}{\frac{V_{N6}}{1000}}$	$ I_{N6N8} = 11.6959$	$\frac{\arg(I_{N6N8})}{\deg} = -25.9252$
$V_{N8} := V_{N6} - Z_{N6N8} \cdot I_{N6N8}$	$ V_{N8} = 2568.6973$	$\frac{\arg(V_{N8})}{\deg} = -0.1249$

$$\begin{aligned}
I_{T4} &:= I_{N6N8} & |I_{T4}| &= 11.6959 & \frac{\arg(I_{T4})}{\deg} &= -25.9252 \\
V_{T4} &:= V_{N8} - I_{T4} \cdot Z_{T4} & |V_{T4}| &= 2530.2006 & \frac{\arg(V_{T4})}{\deg} &= -0.8872 \\
V_{N9} &:= V_{T4} \cdot \left(\frac{V_{\text{low}}}{kV_{\text{hi}} \cdot 1000} \right) & |V_{N9}| &= 253.0201 & \frac{\arg(V_{N9})}{\deg} &= -0.8872
\end{aligned}$$

Definitions for Part 7

$$\begin{aligned}
P4_{N2} &:= V_{N2} & P4_{N4} &:= V_{N4} & P4_{N6} &:= V_{N6} & P4_{N8} &:= V_{N8} \\
P4_{N3} &:= V_{N3} & P4_{N5} &:= V_{N5} & P4_{N7} &:= V_{N7} & P4_{N9} &:= V_{N9}
\end{aligned}$$

Problem 2.5.e

$$\begin{aligned}
I_{\text{Cust}} &:= \frac{I_{N1N2}}{18} & I_{\text{Cust}} &= 2.0845 - 1.0086j \\
I_{N2N4} &:= I_{\text{Cust}} \cdot 14 & I_{N2N4} &= 29.1824 - 14.1205j \\
I_{N4N6} &:= I_{\text{Cust}} \cdot 10 & I_{N4N6} &= 20.8445 - 10.0861j \\
I_{N6N8} &:= I_{\text{Cust}} \cdot 5 & I_{N6N8} &= 10.4223 - 5.0430j \\
I_{T1} &:= I_{\text{Cust}} \cdot 4 & I_{T1} &= 8.3378 - 4.0344j \\
I_{T2} &:= I_{\text{Cust}} \cdot 4 & I_{T2} &= 8.3378 - 4.0344j \\
I_{T3} &:= I_{\text{Cust}} \cdot 5 & I_{T3} &= 10.4223 - 5.0430j \\
I_{T4} &:= I_{\text{Cust}} \cdot 5 & I_{T4} &= 10.4223 - 5.0430j \\
V_{N2} &:= V_{N1} - Z_{N1N2} \cdot I_{N1N2} & |V_{N2}| &= 2591.4805 & \frac{\arg(V_{N2})}{\deg} &= -0.0338 \\
V_{T1} &:= V_{N2} - I_{T1} \cdot Z_{T1} & |V_{T1}| &= 2560.3051 & \frac{\arg(V_{T1})}{\deg} &= -0.7554 \\
V_{N3} &:= V_{T1} \cdot \left(\frac{V_{\text{low}}}{kV_{\text{hi}} \cdot 1000} \right) & |V_{N3}| &= 256.0305 & \frac{\arg(V_{N3})}{\deg} &= -0.7554 \\
V_{N4} &:= V_{N2} - Z_{N2N4} \cdot I_{N2N4} & |V_{N4}| &= 2583.2858 & \frac{\arg(V_{N4})}{\deg} &= -0.0666 \\
V_{T2} &:= V_{N4} - I_{T2} \cdot Z_{T2} & |V_{T2}| &= 2552.1296 & \frac{\arg(V_{T2})}{\deg} &= -0.7909 \\
V_{N5} &:= V_{T2} \cdot \left(\frac{V_{\text{low}}}{kV_{\text{hi}} \cdot 1000} \right) & |V_{N5}| &= 255.2130 & \frac{\arg(V_{N5})}{\deg} &= -0.7909 \\
V_{N6} &:= V_{N4} - Z_{N4N6} \cdot I_{N4N6} & |V_{N6}| &= 2573.9463 & \frac{\arg(V_{N6})}{\deg} &= -0.1042
\end{aligned}$$

$$V_{T3} := V_{N6} - I_{T3} \cdot Z_{T3} \quad |V_{T3}| = 2535.8834 \quad \frac{\arg(V_{T3})}{\deg} = -0.8584$$

$$V_{N7} := V_{T3} \cdot \left(\frac{V_{\text{low}}}{kV_{hi} \cdot 1000} \right) \quad |V_{N7}| = 253.5883 \quad \frac{\arg(V_{N7})}{\deg} = -0.8584$$

$$V_{N8} := V_{N6} - Z_{N6N8} \cdot I_{N6N8} \quad |V_{N8}| = 2568.8411 \quad \frac{\arg(V_{N8})}{\deg} = -0.1249$$

$$V_{T4} := V_{N8} - I_{T4} \cdot Z_{T4} \quad |V_{T4}| = 2530.7909 \quad \frac{\arg(V_{T4})}{\deg} = -0.8809$$

$$V_{N9} := V_{T4} \cdot \left(\frac{V_{\text{low}}}{kV_{hi} \cdot 1000} \right) \quad |V_{N9}| = 253.0791 \quad \frac{\arg(V_{N9})}{\deg} = -0.8809$$

Definitions for Part 7

$$P5_{N2} := V_{N2} \quad P5_{N4} := V_{N4} \quad P5_{N6} := V_{N6} \quad P5_{N8} := V_{N8}$$

$$P5_{N3} := V_{N3} \quad P5_{N5} := V_{N5} \quad P5_{N7} := V_{N7} \quad P5_{N9} := V_{N9}$$

Problem 2.5.f

$$AF := \frac{kVADemand_{N1N2}}{175} \quad AF = 0.5574 + 0.2697j$$

$$kVADemand_{T1} := kVA_{T1} \cdot AF \quad kVADemand_{T1} = 20.9041 + 10.1149j$$

$$kVADemand_{T2} := kVA_{T2} \cdot AF \quad kVADemand_{T2} = 20.9041 + 10.1149j$$

$$kVADemand_{T3} := kVA_{T3} \cdot AF \quad kVADemand_{T3} = 27.8721 + 13.4865j$$

$$kVADemand_{T4} := kVA_{T4} \cdot AF \quad kVADemand_{T4} = 27.8721 + 13.4865j$$

$$kVADemand_{N2N4} := kVADemand_{T2} + kVADemand_{T3} + kVADemand_{T4}$$

$$kVADemand_{N4N6} := kVADemand_{T3} + kVADemand_{T4}$$

$$kVADemand_{N6N8} := kVADemand_{T4}$$

$$I_{N1N2} := \frac{\overline{kVADemand_{N1N2}}}{\frac{V_{N1}}{1000}} \quad |I_{N1N2}| = 41.6817 \quad \frac{\arg(I_{N1N2})}{\deg} = -25.8210$$

$$V_{N2} := V_{N1} - Z_{N1N2} \cdot I_{N1N2} \quad |V_{N2}| = 2591.4805 \quad \frac{\arg(V_{N2})}{\deg} = -0.0338$$

$$I_{T1} := \frac{\overline{kVADemand_{T1}}}{\frac{V_{N2}}{1000}} \quad |I_{T1}| = 8.9612 \quad \frac{\arg(I_{T1})}{\deg} = -25.7871$$

$V_{T1} := V_{N2} - I_{T1} \cdot Z_{T1}$	$ V_{T1} = 2561.3318$	$\frac{\arg(V_{T1})}{\deg} = -0.7320$
$V_{N3} := V_{T1} \cdot \left(\frac{V_{\text{low}}}{kV_{\text{hi}} \cdot 1000} \right)$	$ V_{N3} = 256.1332$	$\frac{\arg(V_{N3})}{\deg} = -0.7320$
$I_{N2N4} := \frac{\overline{kVADemand_{N2N4}}}{\frac{V_{N2}}{1000}}$	$ I_{N2N4} = 32.8576$	$\frac{\arg(I_{N2N4})}{\deg} = -25.8548$
$V_{N4} := V_{N2} - Z_{N2N4} \cdot I_{N2N4}$	$ V_{N4} = 2583.1740$	$\frac{\arg(V_{N4})}{\deg} = -0.0670$
$I_{T2} := \frac{\overline{kVADemand_{T2}}}{\frac{V_{N4}}{1000}}$	$ I_{T2} = 8.9900$	$\frac{\arg(I_{T2})}{\deg} = -25.7540$
$V_{T2} := V_{N4} - I_{T2} \cdot Z_{T2}$	$ V_{T2} = 2552.9663$	$\frac{\arg(V_{T2})}{\deg} = -0.7705$
$V_{N5} := V_{T2} \cdot \left(\frac{V_{\text{low}}}{kV_{\text{hi}} \cdot 1000} \right)$	$ V_{N5} = 255.2966$	$\frac{\arg(V_{N5})}{\deg} = -0.7705$
$I_{N4N6} := \frac{\overline{kVADemand_{N4N6}}}{\frac{V_{N4}}{1000}}$	$ I_{N4N6} = 23.9733$	$\frac{\arg(I_{N4N6})}{\deg} = -25.8880$
$V_{N6} := V_{N4} - Z_{N4N6} \cdot I_{N4N6}$	$ V_{N6} = 2573.5031$	$\frac{\arg(V_{N6})}{\deg} = -0.1057$
$I_{T3} := \frac{\overline{kVADemand_{T3}}}{\frac{V_{N6}}{1000}}$	$ I_{T3} = 12.0317$	$\frac{\arg(I_{T3})}{\deg} = -25.7153$
$V_{T3} := V_{N6} - I_{T3} \cdot Z_{T3}$	$ V_{T3} = 2534.0247$	$\frac{\arg(V_{T3})}{\deg} = -0.8916$
$V_{N7} := V_{T3} \cdot \left(\frac{V_{\text{low}}}{kV_{\text{hi}} \cdot 1000} \right)$	$ V_{N7} = 253.4025$	$\frac{\arg(V_{N7})}{\deg} = -0.8916$
$I_{N6N8} := \frac{\overline{kVADemand_{N6N8}}}{\frac{V_{N6}}{1000}}$	$ I_{N6N8} = 12.0317$	$\frac{\arg(I_{N6N8})}{\deg} = -25.9266$
$V_{N8} := V_{N6} - Z_{N6N8} \cdot I_{N6N8}$	$ V_{N8} = 2568.1963$	$\frac{\arg(V_{N8})}{\deg} = -0.1269$

$$I_{T4} := I_{N6N8}$$

$$|I_{T4}| = 12.0317$$

$$\frac{\arg(I_{T4})}{\deg} = -25.9266$$

$$V_{T4} := V_{N8} - I_{T4} \cdot Z_{T4}$$

$$|V_{T4}| = 2528.6015$$

$$\frac{\arg(V_{T4})}{\deg} = -0.9116$$

$$V_{N9} := V_{T4} \cdot \left(\frac{V_{low}}{kV_{hi} \cdot 1000} \right)$$

$$|V_{N9}| = 252.8602$$

$$\frac{\arg(V_{N9})}{\deg} = -0.9116$$

Definitions for Part g

$$P_{6N2} := V_{N2} \quad P_{6N4} := V_{N4} \quad P_{6N6} := V_{N6} \quad P_{6N8} := V_{N8}$$

$$P_{6N3} := V_{N3} \quad P_{6N5} := V_{N5} \quad P_{6N7} := V_{N7} \quad P_{6N9} := V_{N9}$$

Problem 2.5.g

$$\%DiffN_{24} := \frac{|P_{4N2}| - |P_{3N2}|}{|P_{3N2}|} \cdot 100$$

$$\%DiffN_{25} := \frac{|P_{5N2}| - |P_{3N2}|}{|P_{3N2}|} \cdot 100$$

$$\%DiffN_{26} := \frac{|P_{6N2}| - |P_{3N2}|}{|P_{3N2}|} \cdot 100$$

$$\%DiffN_{34} := \frac{|P_{4N3}| - |P_{3N3}|}{|P_{3N3}|} \cdot 100$$

$$\%DiffN_{35} := \frac{|P_{5N3}| - |P_{3N3}|}{|P_{3N3}|} \cdot 100$$

$$\%DiffN_{36} := \frac{|P_{6N3}| - |P_{3N3}|}{|P_{3N3}|} \cdot 100$$

$$\%DiffN_{44} := \frac{|P_{4N4}| - |P_{3N4}|}{|P_{3N4}|} \cdot 100$$

$$\%DiffN_{45} := \frac{|P_{5N4}| - |P_{3N4}|}{|P_{3N4}|} \cdot 100$$

$$\%DiffN_{46} := \frac{|P_{6N4}| - |P_{3N4}|}{|P_{3N4}|} \cdot 100$$

$$\%DiffN_{54} := \frac{|P_{4N5}| - |P_{3N5}|}{|P_{3N5}|} \cdot 100$$

$$\%DiffN_{55} := \frac{|P_{5N5}| - |P_{3N5}|}{|P_{3N5}|} \cdot 100$$

$$\%DiffN_{56} := \frac{|P_{6N5}| - |P_{3N5}|}{|P_{3N5}|} \cdot 100$$

$$\%DiffN_{64} := \frac{|P_{4N6}| - |P_{3N6}|}{|P_{3N6}|} \cdot 100$$

$$\%DiffN_{65} := \frac{|P_{5N6}| - |P_{3N6}|}{|P_{3N6}|} \cdot 100$$

$$\%DiffN_{66} := \frac{|P_{6N6}| - |P_{3N6}|}{|P_{3N6}|} \cdot 100$$

$$\%DiffN_{74} := \frac{|P_{4N7}| - |P_{3N7}|}{|P_{3N7}|} \cdot 100$$

$$\%DiffN_{75} := \frac{|P_{5N7}| - |P_{3N7}|}{|P_{3N7}|} \cdot 100$$

$$\%DiffN_{76} := \frac{|P_{6N7}| - |P_{3N7}|}{|P_{3N7}|} \cdot 100$$

$$\%DiffN_{84} := \frac{|P_{4N8}| - |P_{3N8}|}{|P_{3N8}|} \cdot 100$$

$$\%DiffN_{85} := \frac{|P_{5N8}| - |P_{3N8}|}{|P_{3N8}|} \cdot 100$$

$$\%DiffN_{86} := \frac{|P_{6N8}| - |P_{3N8}|}{|P_{3N8}|} \cdot 100$$

$$\%DiffN_{94} := \frac{|P_{4N9}| - |P_{3N9}|}{|P_{3N9}|} \cdot 100$$

$$\%DiffN_{95} := \frac{|P_{5N9}| - |P_{3N9}|}{|P_{3N9}|} \cdot 100$$

$$\%DiffN_{96} := \frac{|P_{6N9}| - |P_{3N9}|}{|P_{3N9}|} \cdot 100$$

Node	Problem 4	Problem 5	Problem 6
2	%DiffN ₂ ₄ = 0.0000	%DiffN ₂ ₅ = 0.0000	%DiffN ₂ ₆ = 0.0000
3	%DiffN ₃ ₄ = 0.4398	%DiffN ₃ ₅ = 0.4430	%DiffN ₃ ₆ = 0.4833
4	%DiffN ₄ ₄ = 0.0092	%DiffN ₄ ₅ = 0.0102	%DiffN ₄ ₆ = 0.0059
5	%DiffN ₅ ₄ = 0.4515	%DiffN ₅ ₅ = 0.4590	%DiffN ₅ ₆ = 0.4919
6	%DiffN ₆ ₄ = 0.0382	%DiffN ₆ ₅ = 0.0417	%DiffN ₆ ₆ = 0.0245
7	%DiffN ₇ ₄ = 0.4923	%DiffN ₇ ₅ = 0.5086	%DiffN ₇ ₆ = 0.4350
8	%DiffN ₈ ₄ = 0.0987	%DiffN ₈ ₅ = 0.1043	%DiffN ₈ ₆ = 0.0792
9	%DiffN ₉ ₄ = 0.5566	%DiffN ₉ ₅ = 0.5801	%DiffN ₉ ₆ = 0.4931