Radial Test Feeder including Primary and Secondary Distribution Network

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Abstract—**This paper describes development of a three-phase unbalanced distribution network test case, considering primary and secondary level distribution systems. Primary feeders, lateral feeders, and secondary feeders are modeled from the substation transformer to the house level based on the network's physical hierarchical structure. Researchers can use the developed benchmark for test case analysis and to address issues associated with integration of rooftop photovoltaics (PVs) and distributed energy resources (DER) in existing unbalanced networks, including incremental power losses, voltage violations, voltage fluctuations, volt/var control, and other power quality concerns.**

I. Introduction

A majority of algorithms for solving problems in distribution systems have been proposed under the assumption that the distribution system is a balanced three-phase system [1]-[8]. Therefore, a single-phase equivalent model for a primary distribution network has been used to solve the problems. However, future distribution systems will deploy smart devices such as smart meters, smart inverters, rooftop solar photovoltaics (PVs), battery storage, and electric vehicles into homes located at the secondary level. For example, it is very likely that rooftop PV installations could make the system more unbalanced due to unequal number and sizes of PV installations on the three phases. In order to resolve issues associated with integration of rooftop PVs and other distributed energy resources (DER), primary and secondary distribution networks should be considered concurrently.

The Test Feeders Working Group of the IEEE PES Distribution System Analysis Subcommittee has published several test feeders for analysis of unbalanced three-phase radial distribution feeders based on a primary distribution network [9]. A test feeder recently has been developed that considers both primary and secondary networks without an elaborate house level model [10]. In order to leverage integration and coordination of rooftop PV generators, this paper describes development of a three-phase unbalanced distribution network test case from substation transformer all the way down to the house level. The developed test feeder can be used to study challenges of rooftop PV integration as well as house level battery storage [11] and electric vehicles [7], [8], such as energy efficiency and power losses analysis, voltage rise control [11], voltage fluctuations mitigation [12], [13], volt/var control [4]-[6], [14]-[16], and optimal operation management of DER [17].

II. Network Description and Modeling

The developed radial distribution test feeder consists of 559 nodes, including both primary and secondary distribution networks. The nodes are distributed in 1-, 2-, and 3-phase bus locations.

A. Three-phase primary system description

The IEEE 37 node test system [9] is used to model three-phase primary feeders. The original IEEE 37 node test feeder is a three-wire delta that operates at a nominal voltage of 4.8 kV with unbalanced loading and underground line segments.

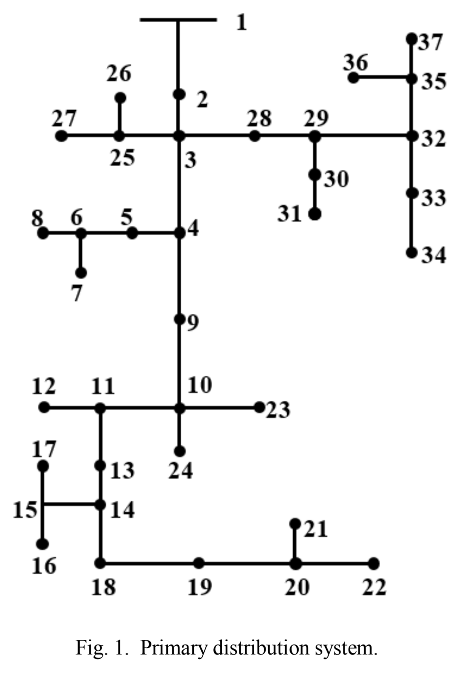

Fig. 1. Primary distribution system.

The single line diagram of the primary feeder model is shown in Fig. 1. In this study, the load is modified to achieve a less unbalanced network, thus the imbalance in the network typically originates from placement of rooftop PVs, battery storage, and electric vehicles on different phases of the three-phase system. Moreover, part of the load on node 2 is moved to node 24, resulting in higher power losses in the network and making the test feeder a good case study for power loss minimization and reduction studies. All loads are assumed to be star connected and comprised of residential customers on each feeder. Aggregated load data for the primary feeder are provided in Section III. Aggregated loads were used to determine the number of homes to place in each phase of the secondary network.

B. Lateral feeders description

Lateral feeders are directly connected to the primary feeder and operate at the same voltage. Based on the specified load type (1-, 2-, or 3-phase load) for a generic node in the primary feeder, 1-, 2-, or 3-phase lateral feeders are tapped from the primary feeder. Lateral feeders route power to a community of houses via wooden poles. Fig. 2 shows a sample lateral feeder distributing power to seven clusters of houses. In order to simplify the model, all pole to pole lateral feeder lines are wired with #1 overhead conductor and distance between poles are set to 250 ft as representative of typical distance between houses in the U.S. Overhead lateral conductor data are provided in Table II.

C. Secondary system description

In the secondary distribution network, short line-segments branch off pole-mounted transformers and distribute energy to a neighborhood. It is assumed that the system load is star-connected and comprised of residential customers on each feeder. For simplicity and without loss of generality, each pole distributes energy via a pole-mounted transformer to a neighborhood consisting of four homes (i.e., four service drops per transformer are considered as shown in Fig. 3). Pole-mounted transformer is modeled as a single-phase center-tapped transformer [18]. Each home is connected to the secondary circuit of a single-phase transformer through triplex overhead drop cable 4/0 AAC [19] of length 90 ft. Detailed data are provided in Table III.

D. Load model

Home wiring is typically 120 or 240 volts. In most households, lighting and small appliances are on 15 or 20 amps circuits, while large appliances are on 50 amps circuits [20]. Therefore, at full load, the customer requires 50 × 240 = 12 kW. However, not all customers simultaneously run all electrical equipment and most households rarely exceed half the capacity of their service rating. Therefore, 25 kVA single-phase pole-mounted transformers are considered to serve a group of four homes. Pole-mounted transformer data are provided in Table III. The total number of pole-mounted transformers at each feeder can be calculated based on primary feeder nodal load requirements. For example, bus 31 has 85 kW load (Table I). The total numbers of pole-mounted transformers on lateral feeders downstream of this bus are 85/25=3.4, rounded to four transformers. Fig. 4 shows a

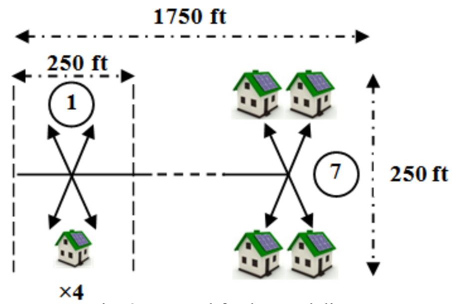

Fig. 2. Lateral feeder modeling.

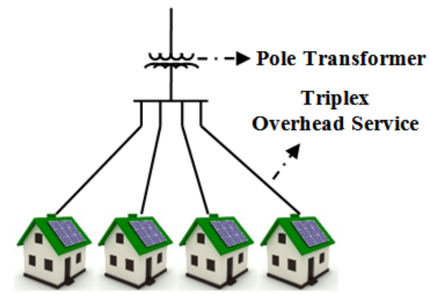

Fig. 3. Secondary feeder modeling.

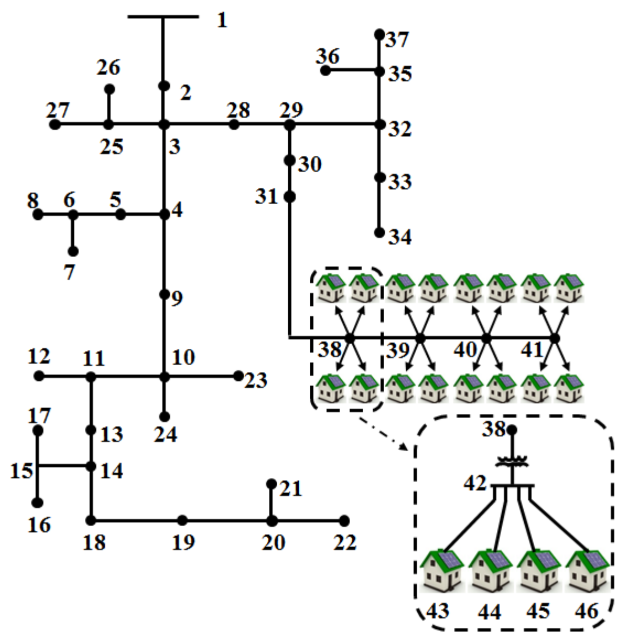

Fig. 4. Test feeder including primary feeders, lateral feeders, and secondary network.

portion of the test feeder in which the extended lateral feeder is modeled via a line branching out of primary feeder node 31 (i.e., from node 38 to 41) and corresponding pole-mounted transformers and clusters of houses (i.e., from node 42 to 46). Conductor data used to extend the primary network is presented in Section III. Phase impedance and admittance matrices corresponding to feeder laterals, triplex overhead drop cable, pole-mounted transformers, and test feeder line segment data are provided in the Appendix.

III. SYSTEM DATA

This section presents the complete data to model the test feeder.

TABLE I. AGGREGATED PRIMARY SYSTEM LOAD DATA

Node	Ph-1	Ph-1	Ph-2	Ph-2	Ph-3	Ph-3
	kW	kVAr	kW	kVAr	kW	kVAr
2	84	44	84	44	84	38
5	0	0	0	0	42	21
6	42	21	0	0	0	0
7	42	21	42	21	42	21
8	42	21	0	0	0	0
9	0	0	0	0	85	40
12	0	0	0	0	42	21
13	85	40	0	0	0	0
14	0	0	0	0	42	21
16	0	0	0	0	85	40
17	0	0	42	21	0	0
18	140	70	0	0	0	0
19	126	62	0	0	0	0
21	0	0	85	40	0	0
22	0	0	0	0	42	21
23	0	0	85	40	0	0
24	126	66	126	66	126	57
26	0	0	0	0	85	40
27	8	4	85	40	0	0
28	0	0	0	0	85	40
30	17	8	21	10	0	0
31	85	40	0	0	0	0
34	0	0	42	21	0	0
36	0	0	140	70	21	10
37	0	0	42	21	0	0
Total	797	397	794	394	866	410

TABLE II. OVERHEAD LATERAL CONDUCTOR DATA

Type of conductor	GMR	Diam. (inch)	Ampacity (A)	60 Hz (Ohms/mile)	
				Resistance	Reactance
#1	0.00418	5	200	1.3873	1.6033

TABLE III. TRILEX OVERHEAD SERVICE DROP CABLE DATA

Type of conductor	60 Hz resistance (Ohms/1000 ft)			Inductive reactance (Ohms/1000 ft)
	25°C	50°C	75°C	X1
Triplex	0.4227	0.4645	0.5064	0.0268

Note: Soil (RHO) Resistivity=100; resistance in 25°C is used.

TABLE IV. POLE-MOUNTED TRANSFORMER DATA

Type	kVA	Voltage	%R	%X
Single-phase center-tapped	25	4.8/√3kV-120/240V	1.6	2.3

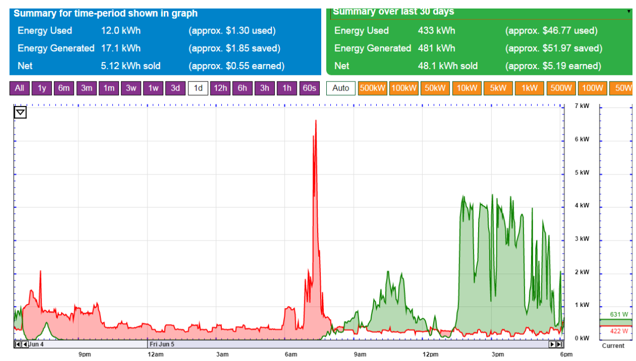

Figure 5. Typical home consumption and PV generation

Customer data was extracted from eGauge website [21] which provides real household consumption and PV generation data (open to public) from daily to 1-minute resolution in Excel format. Load reactive power can be defined in proportion to the real load connected to the same bus with a power factor of 0.9 lagging. Typical home consumption and PV generation from 6/4/2015 6:15 pm to 6/5/2015 6:15 pm are shown in Fig. 5.

V. CONCLUSION

The paradigm shift to smart grids will require future power distribution systems to be increasingly complex due to massive deployment of rooftop PVs, battery storage, electric vehicles, and other DER devices at the residential level. Therefore, analysis with a detailed network model is required in order to capture benefits from DERs and provide insight into control and management of distribution systems. In this paper, a three-phase unbalanced test case is developed with consideration of primary and secondary level distribution systems. Detailed primary feeders, lateral feeders, and secondary feeders are described in order to build a network consisting of 559 nodes. Researchers can use the developed benchmark for test case analysis and resolve issues associated with integration of rooftop PVs and DER devices in existing unbalanced networks, such as incremental power losses, voltage violations, voltage fluctuations, volt/var control and other power quality concerns.

VI. ACKNOWLEDGMENT

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VII. References

[1] C. Niannian, J. Mitra, "A multi-level control architecture for master-slave organized microgrids with power electronic interfaces" *Electr. Pow. Syst. Res.*, Volume 109, April 2014, pp 8–19.

[2] A.R. Malekpour, T. Niknam, A. Pahwa, and A. Kavousi Fard, "Multi-Objective Stochastic Distribution Feeder Reconfiguration in Systems With Wind Power Generators and Fuel Cells Using the Point Estimate Method", *IEEE Trans. Power Syst.*, vol. 28 (2), pp. 1483–1492, May 2013.

[3] M. B. Liu, C. A. Canizares, and W. Huang, "Reactive Power and Voltage Control in Distribution Systems with Limited Switching Operations"*IEEE Trans. Power Syst.*, vol. 24, No. 2, May 2009.

[4] A. R. Malekpour, T. Niknam, "A probabilistic multi-objective daily volt/var control at distribution networks including renewable energy sources", *J. Energy*, vol. 36, pp. 3477–3488, May 2011.

[5] A.R. Malekpour, A. Pahwa, "Reactive power and voltage control in distribution systems with photovoltaic generation," *44th North American Power Symposium (NAPS)*, Urbana-Champaign, Illinois, Sept. 2012.

[6] F. C. Lu and Y. Y. Hsu, "Fuzzy dynamic programming approach to reactive power/voltage control in a distribution substation," *IEEE Trans. Power Syst.*, vol. 12, no. 2, pp. 681-688, May 1997.

[7] Y. Weifeng, Z. Junhua, W. Fushuan, X. Yusheng, G. Ledwich, "A Hierarchical Decomposition Approach for Coordinated Dispatch of Plug-in Electric Vehicles" *IEEE Trans. Power Syst.* vol. 28, no. 3, pp. 2768 – 2778, Aug. 2013.

[8] L. Feng, M.P. Polis, W. Caisheng, W. Le Yi, Z. Hongwei "Hierarchical control and management of virtual microgrids for vehicle electrification" Transportation Electrification Conference and Expo (ITEC), 2012 IEEE pp. 1-6.

[9] IEEE PES Distribution Systems Analysis Subcommittee Radial Test Feeders, http://ewh.ieee.org/soc/pes/dsacom/testfeeders.html.

[10] R. F. Arritt, and R. C. Dugan, "The IEEE 8500-Node Test Feeder", in Proc. 2010 IEEE PES Transmission and Distribution Conference and Exposition, pp. 1-6.

[11] X. Liu, A. Aichhorn, L. Liu, H. Li, "Coordinated Control of Distributed Energy Storage System With Tap Changer Transformers for Voltage Rise Mitigation Under High Photovoltaic Penetration," *IEEE Transactions on Smart Grid*, Vol: PP, Issue: 99, 2012, pp. 1- 10.

[12] A.R. Malekpour, A. Pahwa, S. Das, "Inverter-based var control in low voltage distribution systems with rooftop solar pv" 45th North American Power Symposium (NAPS), 2013, IEEE (2013) 1–5.

[13] R. Walling, Z. Gao, "Eliminating Voltage Variation Due to Distribution-Connected Renewable Generation," 2011 DistribuTECH Conference and Expo, San Diego, Feb. 2011.

[14] T. Senjyu, Y. Miyazato, A. Yona, N. Urasaki, T. Funabashi, , "Optimal Distribution Voltage Control and Coordination With Distributed Generation," *IEEE Transactions on Power Delivery*, Vol: 23 , Issue: 2, 2008, pp. 1236- 1242.

[15] A. Cagnano, E. De Tuglie, M. Liserre, R.A. Mastromauro, "Online Optimal Reactive Power Control Strategy of PV Inverters," *IEEE Transactions on Industrial Electronics*, Vol: 58, Issue: 10, 2011, pp. 4549- 4558.

[16] A. R. Malekpour, A. Pahwa, "Distributed Volt/var Control in Unbalanced Distribution Systems with Distributed Generations" *Proc. 2014, IEEE Symposium on Computational Intelligence Applications in Smart Grid*, Orlando, FL.

[17] A. Pahwa, S. A. DeLoach, B. Natarajan, S. Das, A. R. Malekpour, S. M. Alam, and D. M. Case. Goal-based holonic multi-agent system for operation of power distribution systems. *IEEE Transactions on Smart Grid*, 2015.

[18] Gonen T., Electric Power Distribution System Engineering, McGraw-Hill Book Company, New York, 1986

[19] [Online].MultiplexOverheadServiceCableBrochure.pdf https://www.platt.com/CutSheets/Generic/ACSR%20Alum.pdf

[20] [Online].http://www.georgiapower.com/in-your-community/electric-safety/chart.cshtml.

[21] [Online].http://egauge360.egaug.es/

Appendix

Table V lists load data of 42 homes. The data are extracted from eGauge website. Phases A, B, and C contains 144, 144, and 160 homes, respectively. Random selection is utilized in order to determine which home type is in which node (receiving node), as shown in Table VI. Home type 0 indicates no home in that node.

TABLE V. HOME TYPE AND WEB LINK TO EXTRACT THE LOAD

Home Type	Link	Home Type	Link	Home Type	Link
1	http://egauge297.egaug.es/	15	http://egauge380.egaug.es/	29	http://egauge676.egaug.es/
2	http://egauge300.egaug.es/	16	http://egauge397.egaug.es/	30	http://egauge705.egaug.es/
3	http://egauge230.egaug.es/	17	http://egauge500.egaug.es/	31	http://egauge56.egaug.es/
4	http://egauge303.egaug.es/	18	http://egauge502.egaug.es/	32	http://egauge46.egaug.es/
5	http://egauge305.egaug.es/	19	http://egauge505.egaug.es/	33	http://egauge38.egaug.es/
6	http://egauge312.egaug.es/	20	http://egauge556.egaug.es/	34	http://egauge61.egaug.es/
7	http://egauge343.egaug.es/	21	http://egauge602.egaug.es/	35	http://egauge62.egaug.es/
8	http://egauge339.egaug.es/	22	http://egauge608.egaug.es/	36	http://egauge73.egaug.es/
9	http://egauge346.egaug.es/	23	http://egauge612.egaug.es/	37	http://egauge169.egaug.es/
10	http://egauge348.egaug.es/	24	http://egauge616.egaug.es/	38	http://egauge89.egaug.es/
11	http://egauge354.egaug.es/	25	http://egauge628.egaug.es/	39	http://egauge117.egaug.es/
12	http://egauge360.egaug.es/	26	http://egauge651.egaug.es/	40	http://egauge104.egaug.es/
13	http://egauge361.egaug.es/	27	http://egauge662.egaug.es/	41	http://egauge141.egaug.es/
14	http://egauge363.egaug.es/	28	http://egauge665.egaug.es/	42	http://egauge142.egaug.es/

Test feeder line segment data are given in Table VI. Admittance matrices for configurations types 721, 722, 723, and 724 are available in [9]. Configurations types 725, 726, and 727 correspond to feeder laterals, triplex overhead drop cable, and pole-mounted transformer, respectively.

TABLE VI. TEST FEEDER LINE SEGMENT AND LOAD TYPE DATA

From	To	Length (ft.)	Conductor Type	Home Type			From	To	Length (ft.)	Conductor Type	Home Type		
				Phase A	Phase B	Phase C					Phase A	Phase B	Phase C
1	2	1850	721	0	0	0	62	64	1	727	0	0	0
2	3	960	722	0	0	0	64	65	90	726	0	36	0
3	4	1320	722	0	0	0	64	66	90	726	0	6	0
4	5	240	724	0	0	0	64	67	90	726	0	9	0
5	6	280	723	0	0	0	64	68	90	726	0	31	0
6	7	200	724	0	0	0	63	69	1	727	0	0	0
6	8	280	724	0	0	0	69	70	90	726	0	22	0
4	9	600	723	0	0	0	69	71	90	726	0	40	0
9	10	200	723	0	0	0	69	72	90	726	0	30	0
10	11	320	723	0	0	0	69	73	90	726	0	10	0
11	12	320	724	0	0	0	32	74	125	725	0	0	0
11	13	320	723	0	0	0	74	75	250	725	0	0	0
13	14	560	723	0	0	0	75	76	250	725	0	0	0
14	15	520	724	0	0	0	76	77	250	725	0	0	0
15	16	200	724	0	0	0	74	78	1	727	0	0	0
15	17	1280	724	0	0	0	78	79	90	726	0	0	42
14	18	640	723	0	0	0	78	80	90	726	0	0	14
18	19	400	723	0	0	0	78	81	90	726	0	0	42
19	20	400	723	0	0	0	78	82	90	726	0	0	24
20	21	200	724	0	0	0	75	83	1	727	0	0	0
20	22	400	723	0	0	0	83	84	90	726	0	0	31
10	23	600	723	0	0	0	83	85	90	726	0	0	26
10	24	300	721	0	0	0	83	86	90	726	0	0	3
3	25	400	724	0	0	0	83	87	90	726	0	0	29
25	26	240	724	0	0	0	76	88	1	727	0	0	0
25	27	320	724	0	0	0	88	89	90	726	0	0	30
3	28	360	723	0	0	0	88	90	90	726	0	0	2
28	29	520	723	0	0	0	88	91	90	726	0	0	20
29	30	80	724	0	0	0	88	92	90	726	0	0	25
30	31	520	724	0	0	0	77	93	1	727	0	0	0
29	32	800	723	0	0	0	93	94	90	726	0	0	6
32	33	600	723	0	0	0	93	95	90	726	0	0	21
33	34	280	724	0	0	0	93	96	90	726	0	0	31
32	35	920	724	0	0	0	93	97	90	726	0	0	22
35	36	120	724	0	0	0	36	98	125	725	0	0	0
35	37	760	724	0	0	0	98	99	250	725	0	0	0
31	38	125	725	0	0	0	99	100	250	725	0	0	0
38	39	250	725	0	0	0	100	101	250	725	0	0	0
39	40	250	725	0	0	0	101	102	250	725	0	0	0
40	41	250	725	0	0	0	102	103	250	725	0	0	0
38	42	1	727	0	0	0	98	104	1	727	0	0	0
42	43	90	726	19	0	0	104	105	90	726	0	17	28
42	44	90	726	21	0	0	104	106	90	726	0	23	37
42	45	90	726	11	0	0	104	107	90	726	0	26	39
42	46	90	726	27	0	0	104	108	90	726	0	26	21
39	47	1	727	0	0	0	99	109	1	727	0	0	0
47	48	90	726	37	0	0	109	110	90	726	0	26	0
47	49	90	726	9	0	0	109	111	90	726	0	21	0
47	50	90	726	36	0	0	109	112	90	726	0	15	0
47	51	90	726	6	0	0	109	113	90	726	0	6	0
40	52	1	727	0	0	0	100	114	1	727	0	0	0
52	53	90	726	30	0	0	114	115	90	726	0	3	0
52	54	90	726	42	0	0	114	116	90	726	0	15	0
52	55	90	726	3	0	0	114	117	90	726	0	18	0
52	56	90	726	29	0	0	114	118	90	726	0	20	0
41	57	1	727	0	0	0	101	119	1	727	0	0	0
57	58	90	726	40	0	0	119	120	90	726	0	5	0
57	59	90	726	41	0	0	119	121	90	726	0	19	0
57	60	90	726	40	0	0	119	122	90	726	0	36	0
57	61	90	726	5	0	0	119	123	90	726	0	8	0
34	62	125	725	0	0	0	102	124	1	727	0	0	0
62	63	250	725	0	0	0	124	125	90	726	0	34	0

From	To	Length (ft.)	Conductor Type	Home Type			From	To	Length (ft.)	Conductor Type	Home Type		
				Phase A	Phase B	Phase C					Phase A	Phase B	Phase C
124	126	90	726	0	37	0	185	188	90	726	0	0	10
124	127	90	726	0	42	0	185	189	90	726	0	0	25
124	128	90	726	0	11	0	178	190	1	727	0	0	0
103	129	1	727	0	0	0	190	191	90	726	0	0	3
129	130	90	726	0	27	0	190	192	90	726	0	0	32
129	131	90	726	0	28	0	190	193	90	726	0	0	17
129	132	90	726	0	34	0	190	194	90	726	0	0	27
129	133	90	726	0	5	0	179	195	1	727	0	0	0
37	134	125	725	0	0	0	195	196	90	726	0	0	14
134	135	250	725	0	0	0	195	197	90	726	0	0	35
134	136	1	727	0	0	0	195	198	90	726	0	0	5
136	137	90	726	0	5	0	195	199	90	726	0	0	16
136	138	90	726	0	29	0	27	200	125	725	0	0	0
136	139	90	726	0	7	0	200	201	250	725	0	0	0
136	140	90	726	0	12	0	201	202	250	725	0	0	0
135	141	1	727	0	0	0	202	203	250	725	0	0	0
141	142	90	726	0	17	0	200	204	1	727	0	0	0
141	143	90	726	0	10	0	204	205	90	726	28	15	0
141	144	90	726	0	8	0	204	206	90	726	5	36	0
141	145	90	726	0	16	0	204	207	90	726	1	7	0
28	146	125	725	0	0	0	204	208	90	726	10	42	0
146	147	250	725	0	0	0	201	209	1	727	0	0	0
147	148	250	725	0	0	0	209	210	90	726	0	32	0
148	149	250	725	0	0	0	209	211	90	726	0	24	0
146	150	1	727	0	0	0	209	212	90	726	0	2	0
150	151	90	726	0	0	33	209	213	90	726	0	29	0
150	152	90	726	0	0	34	202	214	1	727	0	0	0
150	153	90	726	0	0	1	214	215	90	726	0	13	0
150	154	90	726	0	0	38	214	216	90	726	0	35	0
147	155	1	727	0	0	0	214	217	90	726	0	21	0
155	156	90	726	0	0	39	214	218	90	726	0	24	0
155	157	90	726	0	0	36	203	219	1	727	0	0	0
155	158	90	726	0	0	15	219	220	90	726	0	30	0
155	159	90	726	0	0	27	219	221	90	726	0	31	0
148	160	1	727	0	0	0	219	222	90	726	0	37	0
160	161	90	726	0	0	16	219	223	90	726	0	39	0
160	162	90	726	0	0	7	8	224	125	725	0	0	0
160	163	90	726	0	0	34	224	225	250	725	0	0	0
160	164	90	726	0	0	29	224	226	1	727	0	0	0
149	165	1	727	0	0	0	226	227	90	726	24	0	0
165	166	90	726	0	0	9	226	228	90	726	21	0	0
165	167	90	726	0	0	20	226	229	90	726	38	0	0
165	168	90	726	0	0	41	226	230	90	726	7	0	0
165	169	90	726	0	0	13	225	231	1	727	0	0	0
30	170	125	725	0	0	0	231	232	90	726	24	0	0
170	171	1	727	0	0	0	231	233	90	726	21	0	0
171	172	90	726	31	28	0	231	234	90	726	38	0	0
171	173	90	726	35	38	0	231	235	90	726	7	0	0
171	174	90	726	2	14	0	6	236	125	725	0	0	0
171	175	90	726	7	12	0	236	237	250	725	0	0	0
26	176	125	725	0	0	0	236	238	1	727	0	0	0
176	177	250	725	0	0	0	238	239	90	726	15	0	0
177	178	250	725	0	0	0	238	240	90	726	26	0	0
178	179	250	725	0	0	0	238	241	90	726	31	0	0
176	180	1	727	0	0	0	238	242	90	726	14	0	0
180	181	90	726	0	0	28	237	243	1	727	0	0	0
180	182	90	726	0	0	19	243	244	90	726	27	0	0
180	183	90	726	0	0	13	243	245	90	726	21	0	0
180	184	90	726	0	0	35	243	246	90	726	20	0	0
177	185	1	727	0	0	0	243	247	90	726	32	0	0
185	186	90	726	0	0	5	7	248	125	725	0	0	0
185	187	90	726	0	0	10	248	249	250	725	0	0	0

From	To	Length (ft.)	Conductor Type	Home Type			From	To	Length (ft.)	Conductor Type	Home Type		
				Phase A	Phase B	Phase C					Phase A	Phase B	Phase C
248	250	1	727	0	0	0	310	312	90	726	0	22	0
250	251	90	726	14	25	24	310	313	90	726	0	21	0
250	252	90	726	26	4	9	310	314	90	726	0	16	0
250	253	90	726	42	1	4	299	315	1	727	0	0	0
250	254	90	726	37	19	18	315	316	90	726	0	8	0
249	255	1	727	0	0	0	315	317	90	726	0	15	0
255	256	90	726	23	20	39	315	318	90	726	0	33	0
255	257	90	726	33	29	7	315	319	90	726	0	11	0
255	258	90	726	6	20	18	12	320	125	725	0	0	0
255	259	90	726	33	35	16	320	321	250	725	0	0	0
5	260	125	725	0	0	0	320	322	1	727	0	0	0
260	261	250	725	0	0	0	322	323	90	726	0	0	26
260	262	1	727	0	0	0	322	324	90	726	0	0	10
262	263	90	726	0	0	38	322	325	90	726	0	0	5
262	264	90	726	0	0	8	322	326	90	726	0	0	6
262	265	90	726	0	0	34	321	327	1	727	0	0	0
262	266	90	726	0	0	2	327	328	90	726	0	0	15
261	267	1	727	0	0	0	327	329	90	726	0	0	6
267	268	90	726	0	0	29	327	330	90	726	0	0	12
267	269	90	726	0	0	28	327	331	90	726	0	0	32
267	270	90	726	0	0	25	13	332	125	725	0	0	0
267	271	90	726	0	0	17	332	333	250	725	0	0	0
9	272	125	725	0	0	0	333	334	250	725	0	0	0
272	273	250	725	0	0	0	334	335	250	725	0	0	0
273	274	250	725	0	0	0	332	336	1	727	0	0	0
274	275	250	725	0	0	0	336	337	90	726	10	0	0
272	276	1	727	0	0	0	336	338	90	726	3	0	0
276	277	90	726	0	0	22	336	339	90	726	39	0	0
276	278	90	726	0	0	37	336	340	90	726	3	0	0
276	279	90	726	0	0	23	333	341	1	727	0	0	0
276	280	90	726	0	0	39	341	342	90	726	16	0	0
273	281	1	727	0	0	0	341	343	90	726	39	0	0
281	282	90	726	0	0	24	341	344	90	726	28	0	0
281	283	90	726	0	0	23	341	345	90	726	13	0	0
281	284	90	726	0	0	32	334	346	1	727	0	0	0
281	285	90	726	0	0	3	346	347	90	726	12	0	0
274	286	1	727	0	0	0	346	348	90	726	33	0	0
286	287	90	726	0	0	11	346	349	90	726	36	0	0
286	288	90	726	0	0	19	346	350	90	726	39	0	0
286	289	90	726	0	0	11	335	351	1	727	0	0	0
286	290	90	726	0	0	40	351	352	90	726	23	0	0
275	291	1	727	0	0	0	351	353	90	726	4	0	0
291	292	90	726	0	0	31	351	354	90	726	29	0	0
291	293	90	726	0	0	22	351	355	90	726	18	0	0
291	294	90	726	0	0	33	14	356	125	725	0	0	0
291	295	90	726	0	0	9	356	357	250	725	0	0	0
23	296	125	725	0	0	0	356	358	1	727	0	0	0
296	297	250	725	0	0	0	358	359	90	726	0	0	11
297	298	250	725	0	0	0	358	360	90	726	0	0	36
298	299	250	725	0	0	0	358	361	90	726	0	0	14
296	300	1	727	0	0	0	358	362	90	726	0	0	40
300	301	90	726	0	10	0	357	363	1	727	0	0	0
300	302	90	726	0	31	0	363	364	90	726	0	0	33
300	303	90	726	0	34	0	363	365	90	726	0	0	1
300	304	90	726	0	41	0	363	366	90	726	0	0	9
297	305	1	727	0	0	0	363	367	90	726	0	0	27
305	306	90	726	0	33	0	16	368	125	725	0	0	0
305	307	90	726	0	20	0	368	369	250	725	0	0	0
305	308	90	726	0	41	0	369	370	250	725	0	0	0
305	309	90	726	0	9	0	370	371	250	725	0	0	0
298	310	1	727	0	0	0	368	372	1	727	0	0	0
310	311	90	726	0	23	0	372	373	90	726	0	39	0

From	To	Length (ft.)	Conductor Type	Home Type			From	To	Length (ft.)	Conductor Type	Home Type		
				Phase A	Phase B	Phase C					Phase A	Phase B	Phase C
372	374	90	726	0	11	0	435	436	90	726	13	0	0
372	375	90	726	0	5	0	435	437	90	726	30	0	0
372	376	90	726	0	29	0	435	438	90	726	20	0	0
369	377	1	727	0	0	0	435	439	90	726	25	0	0
377	378	90	726	0	30	0	21	440	125	725	0	0	0
377	379	90	726	0	40	0	440	441	250	725	0	0	0
377	380	90	726	0	17	0	441	442	250	725	0	0	0
377	381	90	726	0	39	0	442	443	250	725	0	0	0
370	382	1	727	0	0	0	440	444	1	727	0	0	0
382	383	90	726	0	4	0	444	445	90	726	0	0	42
382	384	90	726	0	14	0	444	446	90	726	0	0	20
382	385	90	726	0	26	0	444	447	90	726	0	0	42
382	386	90	726	0	1	0	444	448	90	726	0	0	35
371	387	1	727	0	0	0	441	449	1	727	0	0	0
387	388	90	726	0	18	0	449	450	90	726	0	0	35
387	389	90	726	0	18	0	449	451	90	726	0	0	14
387	390	90	726	0	32	0	449	452	90	726	0	0	24
387	391	90	726	0	17	0	449	453	90	726	0	0	32
17	392	125	725	0	0	0	442	454	1	727	0	0	0
392	393	250	725	0	0	0	454	455	90	726	0	0	25
392	394	1	727	0	0	0	454	456	90	726	0	0	17
394	395	90	726	0	42	0	454	457	90	726	0	0	1
394	396	90	726	0	14	0	454	458	90	726	0	0	23
394	397	90	726	0	11	0	443	459	1	727	0	0	0
394	398	90	726	0	9	0	459	460	90	726	0	0	15
393	399	1	727	0	0	0	459	461	90	726	0	0	27
399	400	90	726	0	4	0	459	462	90	726	0	0	30
399	401	90	726	0	38	0	459	463	90	726	0	0	23
399	402	90	726	0	12	0	22	464	125	725	0	0	0
399	403	90	726	0	33	0	464	465	250	725	0	0	0
18	404	125	725	0	0	0	464	466	1	727	0	0	0
404	405	250	725	0	0	0	466	467	90	726	0	0	12
405	406	250	725	0	0	0	466	468	90	726	0	0	18
406	407	250	725	0	0	0	466	469	90	726	0	0	26
407	408	250	725	0	0	0	466	470	90	726	0	0	34
408	409	250	725	0	0	0	465	471	1	727	0	0	0
404	410	1	727	0	0	0	471	472	90	726	0	0	3
410	411	90	726	2	0	0	471	473	90	726	0	0	22
410	412	90	726	20	0	0	471	474	90	726	0	0	2
410	413	90	726	17	0	0	471	475	90	726	0	0	18
410	414	90	726	10	0	0	19	476	125	725	0	0	0
405	415	1	727	0	0	0	476	477	250	725	0	0	0
415	416	90	726	12	0	0	477	478	250	725	0	0	0
415	417	90	726	36	0	0	478	479	250	725	0	0	0
415	418	90	726	11	0	0	479	480	250	725	0	0	0
415	419	90	726	18	0	0	476	481	1	727	0	0	0
406	420	1	727	0	0	0	481	482	90	726	4	0	0
420	421	90	726	14	0	0	481	483	90	726	26	0	0
420	422	90	726	12	0	0	481	484	90	726	40	0	0
420	423	90	726	34	0	0	481	485	90	726	12	0	0
420	424	90	726	25	0	0	477	486	1	727	0	0	0
407	425	1	727	0	0	0	486	487	90	726	33	0	0
425	426	90	726	4	0	0	486	488	90	726	15	0	0
425	427	90	726	18	0	0	486	489	90	726	32	0	0
425	428	90	726	9	0	0	486	490	90	726	2	0	0
425	429	90	726	7	0	0	478	491	1	727	0	0	0
408	430	1	727	0	0	0	491	492	90	726	38	0	0
430	431	90	726	31	0	0	491	493	90	726	22	0	0
430	432	90	726	1	0	0	491	494	90	726	11	0	0
430	433	90	726	28	0	0	491	495	90	726	38	0	0
430	434	90	726	22	0	0	479	496	1	727	0	0	0
409	435	1	727	0	0	0	496	497	90	726	16	0	0

From	To	Length (ft.)	Conductor Type	Home Type		
				Phase A	Phase B	Phase C
496	498	90	726	13	0	0
496	499	90	726	35	0	0
496	500	90	726	19	0	0
480	501	1	727	0	0	0
501	502	90	726	39	0	0
501	503	90	726	17	0	0
501	504	90	726	7	0	0
501	505	90	726	11	0	0
2	506	125	725	0	0	0
506	507	250	725	0	0	0
507	508	250	725	0	0	0
508	509	250	725	0	0	0
506	510	1	727	0	0	0
510	511	90	726	32	32	21
510	512	90	726	6	37	13
510	513	90	726	9	13	19
510	514	90	726	30	10	7
507	515	1	727	0	0	0
515	516	90	726	24	16	21
515	517	90	726	28	33	4
515	518	90	726	36	39	15
515	519	90	726	29	41	16
508	520	1	727	0	0	0
520	521	90	726	21	35	41
520	522	90	726	19	42	1
520	523	90	726	25	3	36
520	524	90	726	37	38	40
509	525	1	727	0	0	0
525	526	90	726	37	3	30
525	527	90	726	8	22	38
525	528	90	726	38	24	33
525	529	90	726	35	8	13
24	530	125	725	0	0	0
530	531	250	725	0	0	0
531	532	250	725	0	0	0
532	533	250	725	0	0	0
533	534	250	725	0	0	0
530	535	1	727	0	0	0
535	536	90	726	14	19	20
535	537	90	726	1	16	12
535	538	90	726	32	21	11
535	539	90	726	24	37	7
531	540	1	727	0	0	0
540	541	90	726	25	40	41
540	542	90	726	15	25	2
540	543	90	726	34	41	26
540	544	90	726	41	38	28
532	545	1	727	0	0	0
545	546	90	726	15	18	36
545	547	90	726	27	13	4
545	548	90	726	34	23	10
545	549	90	726	31	6	8
533	550	1	727	0	0	0
550	551	90	726	23	23	5
550	552	90	726	17	9	19
550	553	90	726	8	25	6
550	554	90	726	10	27	8
534	555	1	727	0	0	0
555	556	90	726	3	3	30
555	557	90	726	20	13	17
555	558	90	726	1	7	37
555	559	90	726	23	34	37