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Test Distribution Systems: Network Parameters and Diagrams of Electrical Structural

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ABSTRACT Nowadays, specialized literature uses different test systems to verify their proposed models and methodologies regarding reconfiguration and operation of distribution networks. However, none of these research works include various test systems with enough information in order to endorse studies that approach distribution system reconfiguration and operation issues. This paper contains several test systems including the load data, network configuration, line characteristics, maximum current of branches, and nominal powers and voltages. The main objective is to provide all the details and information required to evaluate models and methods developed for reconfiguration and operation of radial distribution systems. Verification of all presented data and information has been performed by solving the network reconfiguration problem using established techniques. Moreover, in order to check the radiality of test systems and correctness of their given data, a data visualization technique is employed to online depict network topologies based on the electrical distance between buses.

INDEX TERMS Data visualization, electric power distribution networks, reconfiguration and operation, test systems.

I. INTRODUCTION

DISTRIBUTION networks are essential part of the electric power system that links transmission networks [1] to end-users of electric energy in order to deliver the electricity produced by the generation system [2] to individual customers [3]. Distribution networks in urban areas are typically constructed as a meshed structure and are usually operated in a suitable radial topology, which can be set or changed by opening normally closed sectional switches and closing normally open tie line switches, which is commonly denoted as distribution network reconfiguration (DNR) [4]. Historically, the DSR problem was considered for minimizing active power losses during normal operating conditions, as these losses directly affect the operational cost and the system voltage profile and are therefore important for increasing the distribution system efficiency and improving operational performance.

After publication of Merlin and Back's paper in 1975 [5], much research has been done on the field of distribution system reconfiguration till now. Some of these research works are related to the problem solution method. Some others, irrespective of the solution method, proposed new models for DNR considering parameters such as load balancing [6], uncertainty [7]–[9], reliability [10], [11], voltage stability [12]–[17], and protective coordination [18]. Also, some of them investigated this problem and capacitor placement together [19], [20]. However, none of these research works has presented various test systems with their complete information including network configuration, line and load characteristics, and other required data for researching reconfiguration and operation of electric power distribution systems. For this, [21] developed large-scale distribution test systems based on load estimation, smart dataset, and operational experiences. Although [21] can provide useful data for applying new ideas to smart grids, especially those include solar units, electric vehicles, and energy storage systems, application of new models and methodologies first should be implemented on standard test systems and then applied to real large distribution networks.

Test systems play an important role in showing the efficiency of proposed models and methodologies. Thus, it is desirable to have a reference paper that incorporates test systems with all basic data needed in distribution network reconfiguration and operation. The present paper describes the load data, network configurations, characteristics and maximum currents of distribution lines, and rated powers and voltages. Also, it provides the topologies of the most important practical and standard distribution systems drawn based on a visualization method that can be used in the monitoring and control rooms for online observation of the topology of the distribution networks. In this paper, the system diagrams are drawn using the technique in [22], which positions buses in a two dimensional diagram based on the electrical distances between them. In this application, the total parallel impedance between each node pair is calculated using the Klein resistance method [23] and this is projected into two dimensions using multidimensional scaling [24]. This visualization function is available as part of the MATPOWER package, version 6.0 [25] and online at [26].

Therefore, the provided diagrams in the present paper are electrically meaningful: for instance, a node that is seen to be remote from the nearest voltage-controlling transformer might be prone to under-voltage problems, as any power consumed there must flow through a substantial impedance. Verification of all presented data and information has been done by CPLEX in a mathematical programming language (AMPL) [27], as well as decimal codification genetic algorithm (DCGA) [1] and discrete particle swarm optimization (DPSO) [2] in MATLAB. To the best knowledge of the authors, this paper, for the first time, provides electrically meaningful diagrams of a range of test distribution networks alongside their simulation parameters. Hence, the main contributions of the current paper are:

- Providing all basic parameters such as load data, network configurations, maximum currents of lines, and nominal powers and voltages for reconfiguration and operation studies.
- Data visualization of the most important practical and standard distribution systems.
- Verification of all information by data visualization technique, AMPL software, and DCGA and DPSO algorithms at the same time.

II. TEST SYSTEMS AND EXAMPLE NETWORKS

In order to provide information required for efficient implementation of models and methodologies related to reconfiguration and operation of distribution networks, several test systems including example and real distribution networks with all their required data are described in this section. Distribution systems are often shown by single-line diagrams without enough explanations about results of their power flow calculations. Understanding the inner electrical structure of the network can be more important for distribution system operators and researchers. To this end, a network diagramming technique based on inter-node electrical distances is used to explicitly portray the topological connectivity of the network [22]. In these data visualizations, tie switches of each test system were considered to be open in order to recognize radiality and connectivity of original topologies. The data visualization technique uses multidimensional scaling [24] to project the calculated matrix of inter-node electrical distances into two dimensions. Multidimensional scaling is a well-established dimensionality reduction technique that iteratively repositions each node in a Cartesian plane until the fitted distances are maximally consistent with the calculated electrical distances, as measured through a particular *stress function*. The electrical distance between each node is calculated using the Klein resistance [23], which uses the elements of the Z_{bus} matrix to ascertain the effective parallel impedance between any pair of buses.

Full data for each system is available in the persistent online repository at [26].

TABLE 1. Line characteristics for test system 1.

Branch (Br)	From Bus (F)	To Bus (To)	Resistance (R)	Reactance (X)	Maximum Current Flow (I)
1	1	2	0.0922 Ω	0.0407 Ω	500 A
2	2	3	0.4930 Ω	0.2510 Ω	500 A
3	3	4	0.3660 Ω	0.1864 Ω	500 A
4	4	5	0.3811 Ω	0.1941 Ω	500 A
5	5	6	0.1872 Ω	0.6188 Ω	500 A
6	6	7	1.7114 Ω	1.2351 Ω	500 A
7	7	1	1.0300 Ω	0.7400 Ω	500 A

TABLE 2. Load data of test system 1.

Bus (B)	Type (T)	Active Power Demand (P)	Reactive Power Demand (Q)
1	Generation (G)	0 kW	0 kVAr
2	Load (L)	100 kW	60 kVAr
3	Load (L)	90 kW	40 kVAr
4	Load (L)	90 kW	40 kVAr
5	Load (L)	120 kW	80 kVAr
6	Load (L)	60 kW	30 kVAr
7	Load (L)	60 kW	20 kVAr

A. SMALL SYSTEMS

• *Test System 1:* Single-line diagram of this 7-bus test system with one substation bus is shown by Fig. 2 in [27]. All data related to this system are listed in Tables 1 and 2. The base power, nominal voltage, and initial losses (before reconfiguration) are 1 MVA, 12.66 kV, and 1.44 kW, respectively. A diagram of test system 1, drawn in Fig. 1 using the introduced visualization method so that distances between buses

FIGURE 1. Diagram of test system 1 based on a projection of inter-node impedances into two dimensions.

TABLE 3. Line characteristics for test system 2.

Br	F	To	R (Ω)	X (Ω)	Br	F	To	R (Ω)	X (Ω)
1	0	1	0.0558	0.04770	8	7	8	0.0165	0.01750
2	1	2	0.0495	0.05250	9	8	9	0.0330	0.03500
3	2	3	0.0660	0.07000	10	9	10	0.0115	0.01225
4	3	4	0.0082	0.00875	11	10	11	0.0495	0.05250
5	4	5	0.0825	0.08750	12	7	8	0.0558	0.04770
6	5	6	0.0330	0.03500	13	7	11	0.00742	0.00787
7	6	7	0.0247	0.02625	-	-	-	-	-

TABLE 4. Load data of test system 2.

B	T	P (kW)	Q (kVAr)	B	T	P (kW)	Q (kVAr)
0	G	0	0	6	L	178.711	149.504
1	L	0	0	7	L	178.711	149.504
2	L	178.711	149.504	8	L	178.711	149.504
3	L	178.711	149.504	9	L	178.711	149.504
4	L	0	0	10	L	178.711	149.504
5	L	178.711	149.504	11	L	178.711	149.504

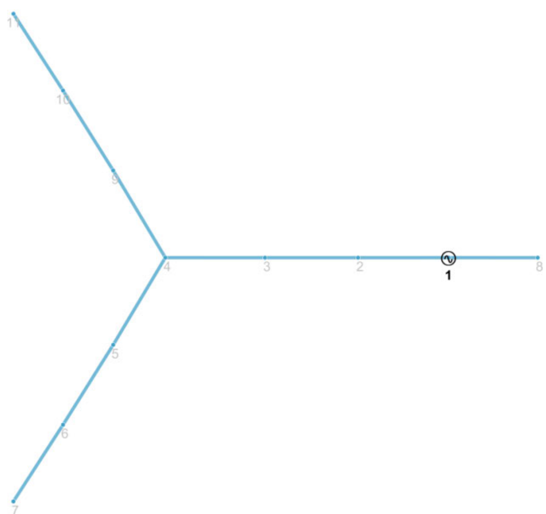

FIGURE 2. Diagram of test system 2 based on a projection of inter-node impedances into two dimensions.

gives a visual indication of the impedance between them. This topology is drawn considering that the tie line between bus 1 and bus 7 is open according to the normal operation situation.

• *Test System 2:* This 12-bus network represents an actual system, which is part of the distribution network of Baghdad city in Iraq. Its single line diagram is shown in Fig. 6 of [27]. The feeder is connected to the Al-Mansoor substation, which has a nominal (base) voltage of 11.1 kV and a capacity of 2250 kVA. The relevant data of system are given in Tables 3 and 4. The maximum current flow (I) of each branch is 500 A. Also, the configuration of this real network

TABLE 5. Line characteristics for test system 3.

Br	F	To	R (Ω)	X (Ω)	Br	F	To	R (Ω)	X (Ω)
11	1	4	0.39675	0.5290	20	9	12	0.4232	0.5819
12	4	5	0.42320	0.5819	22	3	13	0.5819	0.5819
13	4	6	0.47610	0.9522	23	13	15	0.4232	0.5819
14	6	7	0.21160	0.2116	24	13	14	0.4761	0.6348
16	2	8	0.58190	0.5819	25	15	16	0.2116	0.2116
17	8	10	0.58190	0.5819	15	5	11	0.2116	0.2116
18	8	9	0.42320	0.5819	21	10	14	0.2116	0.2116
19	9	11	0.58190	0.5819	26	7	16	0.6348	0.6348

TABLE 6. Load data of test system 3.

B	T	P (kW)	Q (kVAr)	B	T	P (kW)	Q (kVAr)
1	G	0	0	9	L	5000	1800
2	G	0	0	10	L	1000	900
3	G	0	0	11	L	600	– 500
4	L	2000	1600	12	L	4500	– 1700
5	L	3000	400	13	L	1000	900
6	L	2000	– 400	14	L	1000	– 1100
7	L	1500	1200	15	L	1000	900
8	L	4000	2700	16	L	2100	– 800

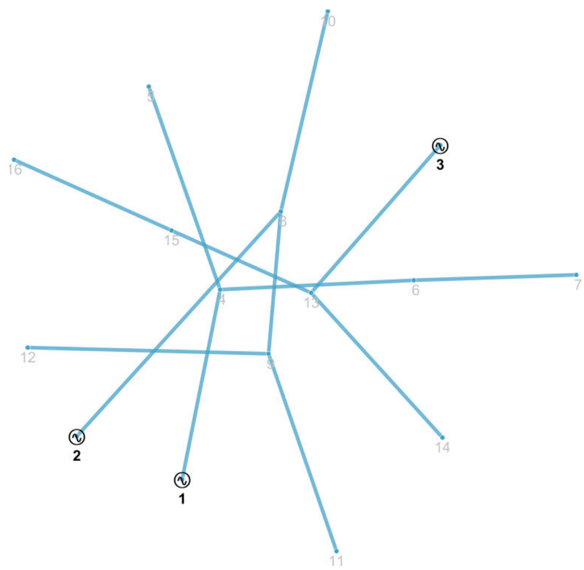

FIGURE 3. Diagram of test system 3 based on a projection of inter-node impedances into two dimensions.

is simulated by data visualization method according to information of Tables 3 and 4 (see Fig. 2). In Fig. 2, substation bus 0 is represented by bus 1, because defining number 0 in MATPOWER is not possible.

• *Test System 3:* A three-feeder 23 kV distribution system connected to substation buses 1, 2 and 3 has been shown in Fig. 10 of [27]. All data, such as resistance and reactance of branches, and nodal active and reactive demand have been provided in Tables 5 and 6. The base power and

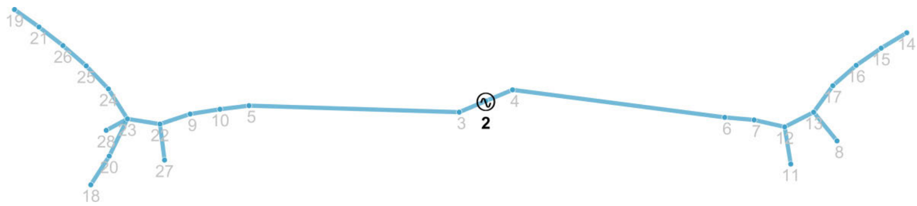

FIGURE 4. Diagram of test system 4 based on a projection of inter-node impedances into two dimensions.

TABLE 7. Line characteristics for test system 4.

Br	F	To	R (mΩ)	X (mΩ)	Br	F	To	R (mΩ)	X (mΩ)
2	2	3	280.49	37.398	18	18	20	79.928	47.336
3	2	4	18.768	15.776	19	19	21	76.220	42.550
6	5	10	278.10	164.70	20	20	23	129.99	76.982
7	6	7	29.252	17.324	21	21	26	16.480	10.736
8	7	12	515.20	16.100	22	22	23	179.01	106.02
9	13	8	27.840	8.7000	23	23	24	23.690	14.030
10	9	10	77.200	40.000	24	24	25	47.478	24.600
11	11	12	145.60	45.500	25	25	26	39.565	20.500
12	12	13	55.391	28.700	26	22	27	164.16	51.300
13	9	22	58.710	34.770	27	23	28	64.066	37.942
14	13	17	64.640	20.200	28	3	4	23.124	30.833
15	14	15	44.800	14.000	29	10	11	85.490	50.630
16	15	16	61.800	36.600	30	14	18	51.200	16.000
17	16	17	61.800	36.600	31	17	19	13.019	72.680

TABLE 8. Data of transformers for test system 4.

Br	F	To	R (Ω)	X (Ω)	Primary Voltage	Secondary Voltage	Nominal Power
1	1	2	1.3000	32.656	110 kV	35 kV	40 kVA
4	3	5	1.0311	10.645	35 kV	10 kV	8 kVA
5	4	6	1.0311	10.645	35 kV	10 kV	8 kVA

TABLE 9. Load data of test system 4.

B	T	P (kW)	Q (kVAr)	Voltage (V)	B	T	P (kW)	Q (kVAr)	V (kV)
1	-	0	0	110 kV	15	L	54.9	16	10
2	G	0	0	35 kV	16	L	71.1	21.6	10
3	L	0	0	35 kV	17	L	100.3	27.7	10
4	L	0	0	35 kV	18	L	129.7	37.8	10
5	L	0	0	10 kV	19	L	194.5	56.7	10
6	L	0	0	10 kV	20	L	8.3	2.4	10
7	L	127.6	37.2	10 kV	21	L	84.9	24.8	10
8	L	121.6	36.3	10 kV	22	L	50.5	20.2	10
9	L	130.2	38	10 kV	23	L	124.7	36.4	10
10	L	75.6	22	10 kV	24	L	105.3	30.7	10
11	L	68.3	19.9	10 kV	25	L	33.4	9.7	10
12	L	106.4	22.4	10 kV	26	L	256.8	74.9	10
13	L	100.7	22.2	10 kV	27	L	98.2	28.6	10
14	L	105.4	30.7	10 kV	28	L	72.6	21.2	10

initial power losses (before reconfiguration) are 10 MVA and 511.44 kW, respectively. Also, the maximum currents of branches 11, 16, and 18 are considered 500 A, 500 A, and 300 A, respectively, while those of all other branches 250 A. Furthermore, the diagram of this test system is shown in Fig. 3 using data visualization where the distance between buses is based on the electrical distance which can provide important information to operators in monitoring rooms.

- *Test System 4:* This real network is part of the electrical power distribution system in the city of Koprivnica, Croatia. It consists of 28 buses and two radial feeders with one substation bus. The single-line diagram of the Koprivnica distribution system is shown in Fig. 14 of [27] and its data are presented in Tables 7 to 9. The maximum current of all branches and the initial active power losses are 500 A and 46 kW, respectively. A diagram of test system 4 is also drawn in Fig. 4 based on the visualization techniques so that distances between buses may give a visual indication of the impedance between them.
- *Test System 5:* Single-line diagram of this example system with six tie lines and 28 normal branches is shown in Fig. 17 of [27]. Also, the network data are listed in Tables 10 and 11. Diagram of the network is depicted in Fig. 5 using data visualization which reflects the electrical distance between buses. The nominal values are 1 MVA and 18.6 kV and initial losses are 1240 kW.

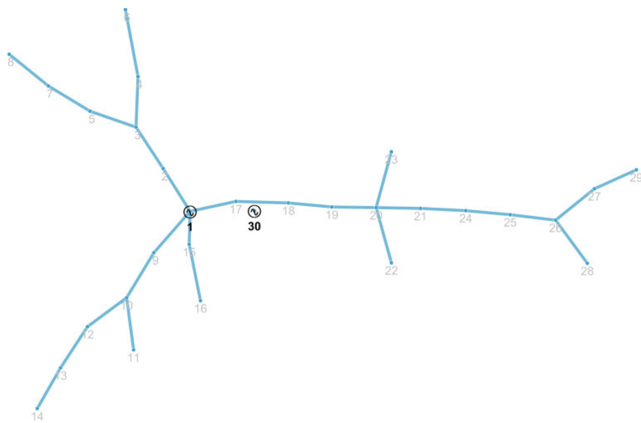

FIGURE 5. Diagram of test system 5 based on a projection of inter-node impedances into two dimensions.

- *Test System 6:* The system includes two 12.66 kV radial feeders and 32 sectional switches, as shown in Fig. 20 of [27]. The data of this test system are available in Tables 12 and 13, in which they were visualized according to Fig. 6. In this figure, substation bus (node 0) is represented by bus 1. Moreover, maximum current flow of each branch and the power losses of initial network are 500 A and 202.68 kW, respectively. The MVA and kV base are 1 and 12.66, respectively. The visualized diagram in Fig. 6 presents the electrical distances between buses so that it gives a visual indication of the impedance between them.

TABLE 10. Line characteristics for test system 5.

Br	F	To	R (Ω)	X (Ω)	I (A)	Br	F	To	R (Ω)	X (Ω)	I (A)	Br	F	To	R (Ω)	X (Ω)	I (A)
1	2	1	0.0840	0.0630	144	13	14	13	0.2033	0.4280	510	25	26	25	0.4272	0.5981	340
2	3	2	1.3860	1.0395	215	14	15	1	0.1800	0.1350	144	26	27	26	0.9940	0.7384	230
3	4	3	0.6018	0.4513	215	15	16	15	0.1800	0.1350	215	27	28	26	0.7357	0.5465	230
4	5	3	0.8220	0.6165	215	16	17	1	0.4455	0.6237	228	28	29	27	1.3440	0.9984	230
5	6	4	4.5752	4.4548	125	17	18	17	0.4455	0.6237	340	29	29	30	0.1079	0.2158	355
6	7	5	2.3862	1.7897	215	18	19	18	0.3870	0.5418	340	30	8	30	1.3931	2.7862	355
7	8	7	3.8640	2.8980	215	19	20	19	0.1650	0.2310	340	31	4	18	0.0825	0.1155	340
8	9	1	0.1463	0.3080	342	20	21	20	1.3554	1.8976	340	32	6	22	0.7194	0.5396	215
9	10	9	0.5960	1.2548	400	21	22	20	0.0480	0.0360	215	33	14	28	0.0414	0.0311	215
10	11	10	2.0280	1.5210	215	22	23	20	0.2400	0.1800	215	34	11	23	0.0180	0.0135	215
11	12	10	0.9595	2.0200	400	23	24	21	0.2535	0.3549	340	-	-	-	-	-	-
12	13	12	0.3268	0.6880	400	24	25	24	0.3150	0.4410	340	-	-	-	-	-	-

TABLE 11. Load data of test system 5.

B	T	P (kW)	Power Factor (PF)	B	T	P	PF	B	T	P	PF	B	T	P	PF	B	T	P	PF
1	G	0	1	7	L	906.1	0.85	13	L	947.4	0.85	19	L	35.7	0.85	25	L	873.9	0.85
2	L	0	1	8	L	1091.6	0.85	14	L	3051.4	0.85	20	L	7.1	0.85	26	L	85.6	0.85
3	L	452.4	0.86	9	L	0	1	15	L	0	1	21	L	3.6	0.85	27	L	428.1	0.85
4	L	260.4	0.85	10	L	444.5	0.85	16	L	3124.8	0.85	22	L	0	1	28	L	2214.5	0.85
5	L	139.1	0.85	11	L	49.9	0.85	17	L	0	1	23	L	42.8	0.85	29	L	2238.8	0.85
6	L	776.2	0.85	12	L	231.9	0.85	18	L	71.3	0.85	24	L	164.1	0.85	30	G	0	1

TABLE 12. Load data of test system 6.

B	T	P (kW)	Q (kVAr)	B	T	P	Q	B	T	P	Q
1	G	0	0	12	L	60	35	23	L	90	50
2	L	100	60	13	L	60	35	24	L	420	200
3	L	90	40	14	L	120	80	25	L	420	200
4	L	120	80	15	L	60	10	26	L	60	25
5	L	60	30	16	L	60	20	27	L	60	25
6	L	60	20	17	L	60	20	28	L	60	20
7	L	200	100	18	L	90	40	29	L	120	70
8	L	200	100	19	L	90	40	30	L	200	600
9	L	60	20	20	L	90	40	31	L	150	70
10	L	60	20	21	L	90	40	32	L	210	100
11	L	45	30	22	L	90	40	33	L	60	40

TABLE 13. Line characteristics for test system 6.

Br	F	To	R (Ω)	X (Ω)	Br	F	To	R (Ω)	X (Ω)
1	1	2	0.0922	0.0477	20	20	21	0.4095	0.4784
2	2	3	0.4930	0.2511	21	21	22	0.7089	0.9373
3	3	4	0.3660	0.1864	22	3	23	0.4512	0.3083
4	4	5	0.3811	0.1941	23	23	24	0.8980	0.7091
5	5	6	0.8190	0.7070	24	24	25	0.8960	0.7011
6	6	7	0.1872	0.6188	25	6	26	0.2030	0.1034
7	7	8	0.7114	0.2351	26	26	27	0.2842	0.1447
8	8	9	1.0300	0.7400	27	27	28	1.0590	0.9337
9	9	10	1.0440	0.7400	28	28	29	0.8042	0.7006
10	10	11	0.1966	0.0650	29	29	30	0.5075	0.2585
11	11	12	0.3744	0.1238	30	30	31	0.9744	0.9630
12	12	13	1.4680	1.1550	31	31	32	0.3105	0.3619
13	13	14	0.5416	0.7129	32	32	33	0.3410	0.5302
14	14	15	0.5910	0.5260	33	8	21	2.0000	2.0000
15	15	16	0.7463	0.5450	34	9	15	2.0000	2.0000
16	16	17	1.2890	1.7210	35	12	22	2.0000	2.0000
17	17	18	0.7320	0.5740	36	18	33	0.5000	0.5000
18	2	19	0.1640	0.1565	37	25	29	0.5000	0.5000
19	19	20	1.5042	1.3554	-	-	-	-	-

B. MEDIUM-SIZE SYSTEMS

• *Test System 7:* The test system is part of the real distribution network of Baghdad city in Iraq with 49 buses, five tie lines, 48 sectional switches, and an 11 kV radial feeder. The single-line diagram of the system has been shown in Fig. 24 of [27] and its data are listed in Tables 14 and 15. The active power loss of network before reconfiguration is 10.5 kW. Maximum current of each branch is 500 A. Result of data visualization is shown in Fig. 7, where substation bus 0 is represented by bus 49.

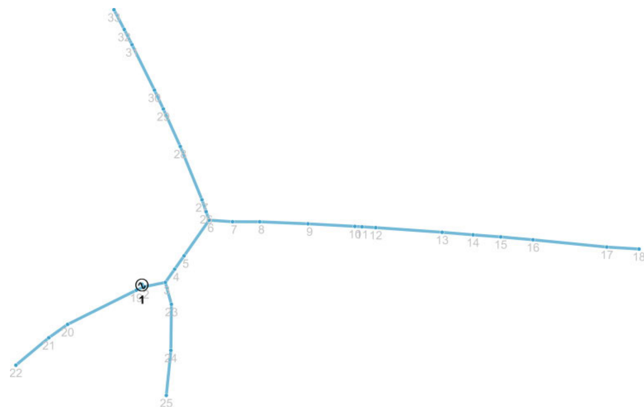

FIGURE 6. Diagram of test system 6 based on a projection of inter-node impedances into two dimensions.

• *Test System 8:* Fig. 28 in [27] shows single-line diagram of this 33 kV real distribution network. It is a region of the distribution system of the city of Ahvaz in the south of Iran. Load and line data for this real distribution network are given in Tables 16 and 17. The active power losses of original network configuration are 178.66 kW. Also, maximum current of each branch in system 8 is 500 A and the result of data visualization is shown by Fig. 8, so that distances between buses reflecting a visual indication of the impedance between them are clearly shown.

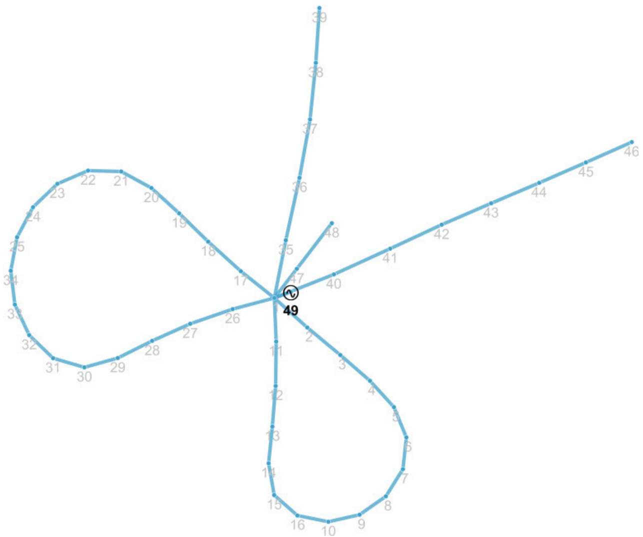

FIGURE 7. Diagram of test system 7 based on a projection of inter-node impedances into two dimensions.

TABLE 14. Line characteristics for test system 7.

Br	F	To	R (Ω)	X (Ω)	Br	F	To	R (Ω)	X (Ω)
1	0	1	0.0310	0.0220	28	27	28	0.4400	0.3230
2	1	2	0.0310	0.0220	29	28	29	0.3660	0.2690
3	2	3	0.7440	0.5470	30	29	30	0.4500	0.3300
4	3	4	0.8680	0.6380	31	30	31	0.2950	0.2160
5	4	5	0.4340	0.3190	32	31	32	0.2850	0.2100
6	5	6	0.1628	0.1200	33	32	33	0.4590	0.3370
7	6	7	0.6200	0.4600	34	33	34	1.0217	1.0160
8	7	8	0.5890	0.4330	35	1	35	0.0372	0.0273
9	8	9	0.3570	0.2620	36	35	36	0.2880	0.2120
10	9	10	1.0186	1.0137	37	36	37	0.4190	0.3080
11	1	11	0.0434	0.0319	38	37	38	0.4030	0.2960
12	11	12	1.0171	1.0125	39	38	39	0.8680	0.6380
13	12	13	0.4340	0.3190	40	1	40	0.0620	0.0456
14	13	14	1.0403	1.0296	41	40	41	0.2110	0.1550
15	14	15	0.3660	0.2690	42	41	42	0.2170	0.1600
16	15	16	0.1860	0.1370	43	42	43	0.4190	0.3080
17	1	17	0.0233	0.0171	44	43	44	1.0388	1.0285
18	17	18	0.3880	0.2850	45	44	45	0.6360	0.4670
19	18	19	0.2790	0.2050	46	45	46	1.0140	0.6105
20	19	20	0.5520	0.4050	47	1	47	0.1023	0.0752
21	20	21	0.3970	0.2920	48	47	48	0.0285	0.0210
22	21	22	1.0233	1.0171	49	10	16	0.388	0.285
23	22	23	0.0780	0.0570	50	25	34	0.118	0.087
24	23	24	0.9900	0.7300	51	39	46	0.481	0.353
25	24	25	0.9900	0.7300	52	39	48	0.837	0.615
26	1	26	0.0160	0.0120	53	46	48	0.357	0.262
27	26	27	0.3720	0.2730	-	-	-	-	-

TABLE 15. Load data of test system 7.

B	T	P (kW)	Q (kVAr)	B	T	P (kW)	Q (kVAr)
0	G	0.00000	0.00000	25	L	632.267	306.220
1	L	0.00000	0.00000	26	L	559.313	270.888
2	L	969.679	469.637	27	L	838.970	406.332
3	L	401.246	194.333	28	L	1258.45	609.499
4	L	100.311	48.582	29	L	1258.45	609.499
5	L	401.246	194.333	30	L	1817.77	880.386
6	L	1003.11	485.832	31	L	2237.25	1083.55
7	L	936.243	453.470	32	L	1817.77	880.38
8	L	735.619	356.284	33	L	1957.59	948.108
9	L	869.369	421.054	34	L	1957.59	948.108
10	L	1270.61	615.388	35	L	607.950	294.444
11	L	922.058	446.572	36	L	1925.17	932.40
12	L	1276.69	618.332	37	L	303.975	147.221
13	L	638.347	309.166	38	L	3343.72	1619.44
14	L	2908.02	1408.41	39	L	222.915	107.962
15	L	922.058	446.572	40	L	719.407	348.425
16	L	425.565	48.7060	41	L	1726.57	836.220
17	L	1791.42	867.626	42	L	1582.69	766.535
18	L	1264.53	612.442	43	L	3597.03	1742.12
19	L	948.402	459.332	44	L	2877.63	1393.69
20	L	421.512	204.147	45	L	3884.79	1881.49
21	L	1896.80	918.663	46	L	4677.46	2265.39
22	L	1686.04	816.590	47	L	1491.50	722.367
23	L	316.134	153.110	48	L	1750.89	847.99
24	L	1053.78	510.368	-	-	-	-

TABLE 16. Line characteristics for test system 8.

Br	F	To	R (Ω)	X (Ω)	Br	F	To	R (Ω)	X (Ω)
1	1	2	0.081	0.061	33	33	34	0.027	0.020
2	2	3	0.135	0.101	34	34	35	0.054	0.041
3	3	4	0.027	0.020	35	35	36	0.027	0.020
4	4	5	0.027	0.020	36	36	37	0.027	0.020
5	5	6	0.027	0.020	37	37	38	0.027	0.020
6	6	7	0.027	0.020	38	34	39	0.027	0.020
7	7	8	0.540	0.405	39	39	40	0.027	0.020
8	8	9	0.540	0.405	40	40	41	0.054	0.041
9	9	10	0.270	0.203	41	40	42	0.054	0.041
10	10	11	0.540	0.405	42	42	43	0.027	0.020
11	11	12	0.540	0.405	43	43	44	0.027	0.020
12	8	13	0.027	0.020	44	44	45	0.027	0.020
13	13	14	0.027	0.020	45	45	46	0.027	0.020
14	8	15	0.027	0.020	46	43	47	0.270	0.203
15	15	16	0.027	0.020	47	47	48	0.027	0.020
16	15	17	0.027	0.020	48	48	49	0.270	0.203
17	17	18	0.027	0.020	49	47	50	0.027	0.020
18	18	19	0.027	0.020	50	50	51	0.027	0.020
19	19	20	0.027	0.020	51	51	52	0.027	0.020
20	20	21	0.027	0.020	52	52	53	0.027	0.020
21	21	22	0.270	0.203	53	53	54	0.081	0.061
22	22	23	0.027	0.020	54	52	55	0.540	0.405
23	23	24	0.027	0.020	55	55	56	0.135	0.101
24	24	25	0.027	0.020	56	56	57	0.054	0.041
25	25	26	0.270	0.203	57	57	58	0.027	0.020
26	26	27	0.027	0.020	58	58	59	0.054	0.041
27	27	28	0.027	0.020	59	16	26	0.500	0.500
28	28	29	0.027	0.020	60	14	50	0.500	0.500
29	29	30	0.027	0.020	61	12	32	0.500	0.500
30	30	31	0.027	0.020	62	38	57	0.500	0.500
31	31	32	0.027	0.020	63	41	54	0.500	0.500
32	31	33	0.135	0.101	-	-	-	-	-

• *Test System 9:* This 12.66 kV radial distribution system with one substation is shown in Fig. 31 of [27]. Tables 18 and 19 list data of this example network and Fig. 9 shows result of data visualization. The initial loss is 225 kW and base MVA is 1. The maximum currents of all branches are 200 A except for those of branches 1 to 9 that are 400 A and branches 46 to 49 and 52 to 64 that are 300 A, respectively.

• *Test System 10:* This test system is an 11 kV radial distribution network with two substation buses and four feeders, as shown in Fig. 35 of [27]. Data for this system are provided in Tables 20 and 21. Diagram of the network is drawn in Fig. 10 using data visualization based on the electrical impedance between buses. The active power losses for initial network configuration are 227.5 kW with nominal power of 1 MVA. The maximum currents of branches 1 to 8, 17 to 23, 31 to 39, and 52 to 56 are 270 A, while those of branches 69 to 79 and all others are 234 A and 208 A, respectively.

• *Test System 11:* As shown in Fig. 39 of [27], this actual 11.4 kV network consists of two substations with data presented in Tables 22 and 23. The power base value and the initial power losses for this system are 1 MVA and 532 kW, respectively. Each line current-carrying capacity (I) is 410 A. Fig. 11 shows the result of data visualization of Tables 22 and 23 where the distance between buses

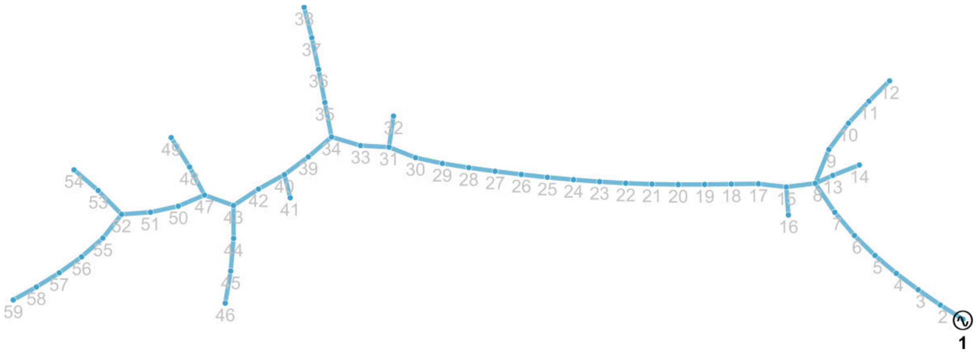

FIGURE 8. Diagram of test system 8 based on a projection of inter-node impedances into two dimensions.

TABLE 17. Load data of test system 8.

B	T	P (kW)	Q (kVAr)	B	T	P (kW)	Q (kVAr)
1	G	0	0	31	L	260	199.5
2	L	72	54	32	L	240	186.25
3	L	51	38.25	33	L	150	112.5
4	L	50	37.5	34	L	0	0
5	L	50	37.5	35	L	158	118.5
6	L	85	63.75	36	L	40	30
7	L	108	81	37	L	190	142.5
8	L	0	0	38	L	87	65.25
9	L	80	60	39	L	450	337.5
10	L	320	240	40	L	0	0
11	L	288	216	41	L	420	315
12	L	125	93.75	42	L	100	75
13	L	108	81	43	L	0	0
14	L	200	150	44	L	199	149.25
15	L	0	0	45	L	80	60
16	L	95	71.25	46	L	420	315
17	L	200	150	47	L	0	0
18	L	225	168.75	48	L	141	105.75
19	L	100	75	49	L	165	123.75
20	L	231	173.25	50	L	0	0
21	L	410	307.5	51	L	300	225
22	L	450	337.5	52	L	0	0
23	L	230	172.5	53	L	100	80.23
24	L	262	196.5	54	L	178	133.5
25	L	250	187.5	55	L	0	0
26	L	400	310.43	56	L	235	176.25
27	L	203	152.25	57	L	154	123.55
28	L	200	150	58	L	0	0
29	L	320	240	59	L	310	248.71
30	L	200	150	-	-	-	-

is based on the electrical distance instead of the physical one.

C. LARGE SYSTEMS

- *Test System 12:* This test system, as shown in Fig. 43 of [27], is an 11 kV distribution network with three radial feeders and one substation on bus 0. The data of the system have been provided as MATPOWER and AMPL files in [26]. The base MVA and initial power losses are 10 and 1298 kW, respectively. Also, Fig. 12 shows the network configuration depicted by data visualization, in which substation bus 1 represents generation bus 0.
- *Test System 13:* Fig. 47 of [27] shows this real network, which is part of the Tres Lagoas distribution system in Brazil. It has eight radial feeders and one substation bus, with nominal voltage and nominal power of 13.8 kV and 1MVA, respectively. Also, the initial power losses and the maximum current of each branch are 320.37 kW and 200 A, respectively. The parameters and related data of this test system have been presented in [26]. The result of data visualization is shown in Fig. 13, in which bus 224 indicates substation bus 0.
- *Test System 14:* The initial configuration of this real 13.8 kV distribution network with three feeders, 201 sectional switches, and three substations is shown in Fig. 52 of [27]. The system data are given in [26]. Diagram of the network is presented in Fig. 14 using data visualization technique, where substation bus 0 is represented by bus 204.
- *Test System 15:* Network topology is illustrated in Fig. 15 using data visualization. Data of this real

TABLE 18. Line characteristics for test system 9.

Br	F	To	R (Ω)	X (Ω)	Br	F	To	R (Ω)	X (Ω)
1	1	2	0.0005	0.0012	38	38	39	0.0304	0.0355
2	2	3	0.0005	0.0012	39	39	40	0.0018	0.0021
3	3	4	0.0015	0.0036	40	40	41	0.7283	0.8509
4	4	5	0.0251	0.0294	41	41	42	0.3100	0.3623
5	5	6	0.3660	0.1864	42	42	43	0.0410	0.0478
6	6	7	0.381	0.1941	43	43	44	0.0092	0.0116
7	7	8	0.0922	0.0470	44	44	45	0.1089	0.1373
8	8	9	0.0493	0.0251	45	45	46	0.0009	0.0012
9	9	10	0.8190	0.2707	46	4	47	0.0034	0.0084
10	10	11	0.1872	0.0691	47	47	48	0.0851	0.2083
11	11	12	0.7114	0.2351	48	48	49	0.2898	0.7091
12	12	13	1.0300	0.3400	49	49	50	0.0822	0.2011
13	13	14	1.0440	0.3450	50	8	51	0.0928	0.0473
14	14	15	1.0580	0.3496	51	51	52	0.3319	0.1114
15	15	16	0.1966	0.0650	52	9	53	0.1740	0.0886
16	16	17	0.3744	0.1238	53	53	54	0.2030	0.1034
17	17	18	0.0047	0.0016	54	54	55	0.2842	0.1447
18	18	19	0.3276	0.1083	55	55	56	0.2813	0.1433
19	19	20	0.2106	0.0690	56	56	57	1.5900	0.5337
20	20	21	0.3416	0.1129	57	57	58	0.7837	0.2630
21	21	22	0.0140	0.0046	58	58	59	0.3042	0.1006
22	22	23	0.1591	0.0526	59	59	60	0.3861	0.1172
23	23	24	0.3463	0.1145	60	60	61	0.5075	0.2585
24	24	25	0.7488	0.2475	61	61	62	0.0974	0.0496
25	25	26	0.3089	0.1021	62	62	63	0.1450	0.0738
26	26	27	0.1732	0.0572	63	63	64	0.7105	0.3619
27	3	28	0.0044	0.0108	64	64	65	1.0410	0.5302
28	28	29	0.0640	0.1565	65	11	66	0.2012	0.0611
29	29	30	0.3978	0.1315	66	66	67	0.0047	0.0014
30	30	31	0.0702	0.0232	67	12	68	0.7394	0.2444
31	31	32	0.3510	0.1160	68	68	69	0.0047	0.0016
32	32	33	0.8390	0.2816	69	11	43	0.5000	0.5000
33	33	34	1.7080	0.5646	70	13	21	0.5000	0.5000
34	34	35	1.4740	0.4873	71	15	46	1.0000	0.5000
35	3	36	0.0044	0.0108	72	50	59	2.0000	1.0000
36	36	37	0.0640	0.1565	73	27	65	1.0000	0.5000
37	37	38	0.1053	0.1230	-	-	-	-	-

TABLE 19. Load data of test system 9.

B	P (kW)	Q (kVAr)	B	P	Q	B	P	Q
1	0	0	24	28	20	47	0	0
2	0	0	25	0	0	48	79	56.4
3	0	0	26	14	10	49	384.7	274.5
4	0	0	27	14	10	50	384.7	274.5
5	0	0	28	26	18.6	51	40.5	28.3
6	2.6	2.2	29	26	18.6	52	3.6	2.7
7	40.4	30	30	0	0	53	4.35	3.5
8	75	54	31	0	0	54	26.4	19
9	30	22	32	0	0	55	24	17.2
10	28	19	33	14	10	56	0	0
11	145	104	34	19.5	14	57	0	0
12	145	104	35	6	4	58	0	0
13	8	5	36	26	18.55	59	100	72
14	8	5.5	37	26	18.55	60	0	0
15	0	0	38	0	0	61	1244	888
16	45.5	30	39	24	17	62	32	23
17	60	35	40	24	17	63	0	0
18	60	35	41	1.2	1	64	227	162
19	0	0	42	0	0	65	59	42
20	1	0.6	43	6	4.3	66	18	13
21	114	81	44	0	0	67	18	13
22	5	3.5	45	39.22	26.3	68	28	20
23	0	0	46	39.22	26.3	69	28	20

TABLE 20. Load data of test system 10.

B	T	P (kW)	Q (kVAr)	B	T	P	Q	B	T	P	Q
1	G	0	0	25	L	80	65	49	L	100	70
2	L	100	90	26	L	100	60	50	L	140	90
3	L	60	40	27	L	100	55	51	L	60	40
4	L	150	130	28	L	120	70	52	L	20	11
5	L	75	50	29	L	105	70	53	L	40	30
6	L	15	9	30	L	80	50	54	L	36	24
7	L	18	14	31	L	60	40	55	L	30	20
8	L	13	10	32	L	13	8	56	L	43	30
9	L	16	11	33	L	16	9	57	L	80	50
10	L	20	10	34	L	50	30	58	L	240	120
11	L	16	9	35	L	40	28	59	L	125	110
12	L	50	40	36	L	60	40	60	L	25	10
13	L	105	90	37	L	40	30	61	L	10	5
14	L	25	15	38	L	30	25	62	L	150	130
15	L	40	25	39	L	150	100	63	L	50	30
16	L	60	30	40	L	60	35	64	L	30	20
17	L	40	25	41	L	120	70	65	L	130	120
18	L	15	9	42	L	90	60	66	L	150	130
19	L	13	7	43	L	18	10	67	L	25	15
20	L	30	20	44	L	16	10	68	L	100	60
21	L	90	50	45	L	100	50	69	L	40	30
22	L	50	30	46	L	60	40	70	G	0	0
23	L	60	40	47	L	90	70	-	-	-	-
24	L	100	80	48	L	85	55	-	-	-	-

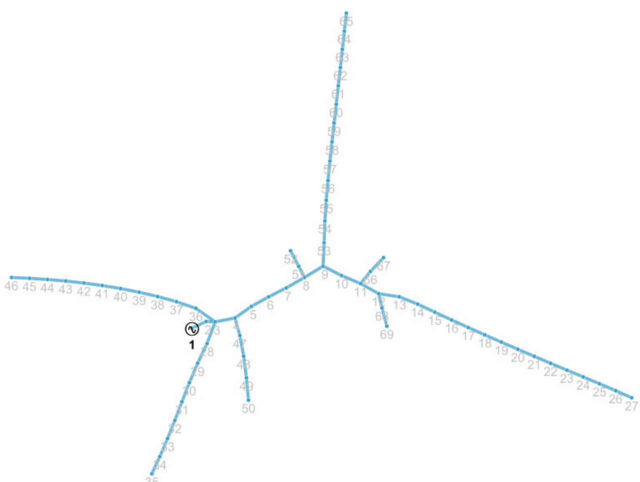

FIGURE 9. Diagram of test system 9 based on a projection of inter-node impedances into two dimensions.

distribution system with 415 buses and nominal voltage of 10 kV are available in [26]. In this system, bus 1

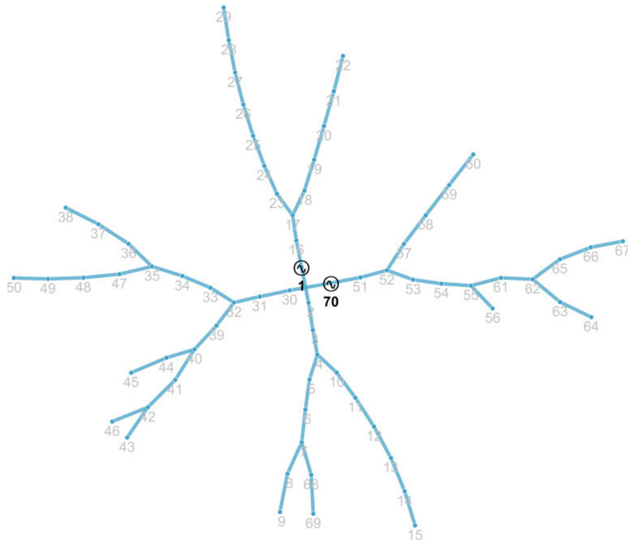

FIGURE 10. Diagram of test system 10 based on a projection of inter-node impedances into two dimensions.

TABLE 21. Line characteristics for test system 10.

Br	F	To	R (Ω)	X (Ω)	Br	F	To	R (Ω)	X (Ω)
1	1	2	1.097	1.074	41	39	40	0.540	0.367
2	2	3	1.463	1.432	42	40	41	1.080	0.734
3	3	4	0.731	0.716	43	41	42	1.836	1.248
4	4	5	0.366	0.358	44	42	43	1.296	0.881
5	5	6	1.828	1.790	45	40	44	1.188	0.807
6	6	7	1.097	1.074	46	44	45	0.540	0.367
7	7	8	0.731	0.716	47	42	46	1.080	0.734
8	8	9	0.731	0.716	48	35	47	0.540	0.367
9	4	10	1.080	0.734	49	47	48	1.080	0.734
10	10	11	1.620	1.101	50	48	49	1.080	0.734
11	11	12	1.080	0.734	51	49	50	1.080	0.734
12	12	13	1.350	0.917	52	70	51	0.366	0.358
13	13	14	0.810	0.550	53	51	52	1.463	1.432
14	14	15	1.944	1.321	54	52	53	1.463	1.432
15	7	68	1.080	0.734	55	53	54	0.914	0.895
16	68	69	1.620	1.101	56	54	55	1.097	1.074
17	1	16	1.097	1.074	57	55	56	1.097	1.074
18	16	17	0.366	0.358	58	52	57	0.270	0.183
19	17	18	1.463	1.432	59	57	58	0.270	0.183
20	18	19	0.914	0.895	60	58	59	0.810	0.550
21	19	20	0.804	0.787	61	59	60	1.296	0.881
22	20	21	1.133	1.110	62	55	61	1.188	0.807
23	21	22	0.475	0.465	63	61	62	1.188	0.807
24	17	23	2.214	1.505	64	62	63	0.810	0.550
25	23	24	1.620	1.110	65	63	64	1.620	1.101
26	24	25	1.080	0.734	66	62	65	1.080	0.734
27	25	26	0.540	0.367	67	65	66	0.540	0.367
28	26	27	0.540	0.367	68	66	67	1.080	0.734
29	27	28	1.080	0.734	69	9	50	0.908	0.726
30	28	29	1.080	0.734	70	9	38	0.381	0.244
31	70	30	0.366	0.358	71	15	46	0.681	0.544
32	30	31	0.731	0.716	72	22	67	0.254	0.203
33	31	32	0.731	0.716	73	29	64	0.254	0.203
34	32	33	0.804	0.787	74	45	60	0.254	0.203
35	33	34	1.170	1.145	75	43	38	0.454	0.363
36	34	35	0.768	0.752	76	39	59	0.454	0.363
37	35	36	0.731	0.716	77	21	27	0.454	0.363
38	36	37	1.097	1.074	78	15	9	0.681	0.544
39	37	38	1.463	1.432	79	67	15	0.454	0.363
40	32	39	1.080	0.734	-	-	-	-	-

is the generation bus and others are load buses. Also, the maximum current flow and base MVA are 550 A and 1, respectively.

- *Test System 16:* As shown in Fig. 1 of [28], this 8500-node test system contains 4800 buses, 170 km medium voltage lines, and four capacitor banks. Maximum current

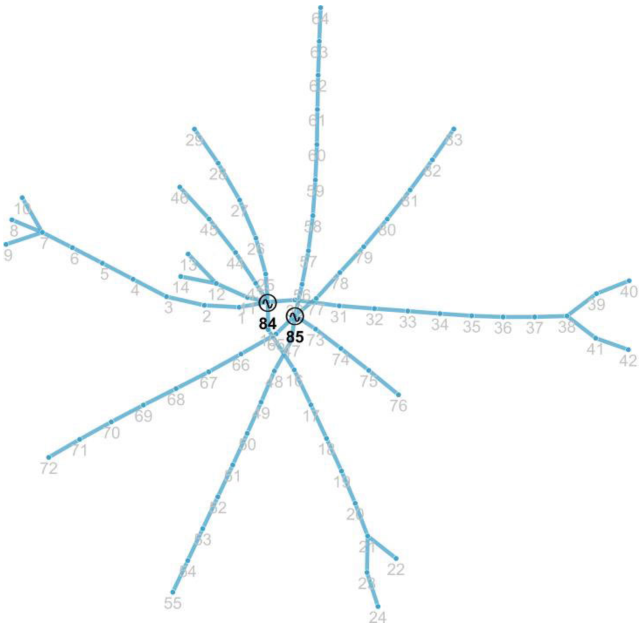

FIGURE 11. Diagram of test system 11 based on a projection of inter-node impedances into two dimensions.

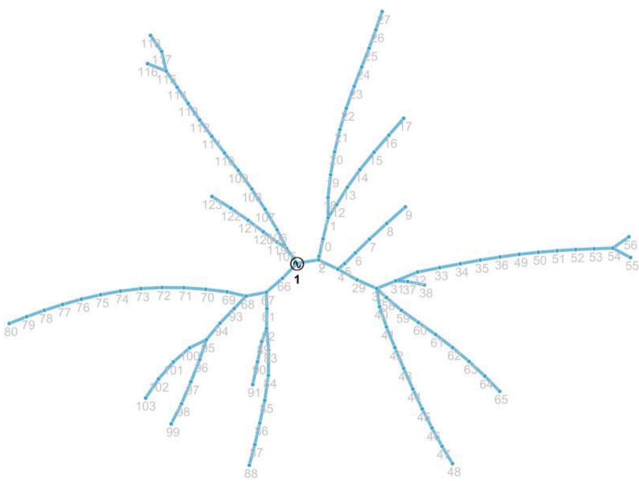

FIGURE 12. Diagram of test system 12 based on a projection of inter-node impedances into two dimensions.

flow of each line is 16.275 A per phase. All data of this large distribution network are available in [29].

III. TEST SYSTEMS ASSESSMENT

Data visualization results confirmed radiality and connectivity of all test systems described in section II, in which none of original networks are meshed or have isolated buses. Only test system 5 has a one isolated bus because of reconfiguration aims. It means that bus 30 is intentionally is considered as a separate bus to show importance of addition of a new substation to the network through tie line 29 and 30 after reconfiguration. The results show that this bus is connected to the network because of its important role in power losses mitigation. In order to verify all presented data, efficient mathematical model of [27] was applied to all above-mentioned test systems except for the last one with the aim of power loss minimization and the results were listed in Table 24. It should be noted that all results given in this table was obtained by

TABLE 22. Line characteristics for test system 11.

Br	F	To	R (Ω)	X (Ω)	Br	F	To	R (Ω)	X (Ω)
1	A	1	0.1944	0.6624	49	48	49	0.0655	0.1345
2	1	2	0.2096	0.4304	50	49	50	0.0393	0.0807
3	2	3	0.2358	0.4842	51	50	51	0.0786	0.1614
4	3	4	0.0917	0.1883	52	51	52	0.0393	0.0807
5	4	5	0.2096	0.4304	53	52	53	0.0786	0.1614
6	5	6	0.0393	0.0807	54	53	54	0.0524	0.1076
7	6	7	0.0405	0.1380	55	54	55	0.1310	0.2690
8	7	8	0.1048	0.2152	56	H	56	0.2268	0.7728
9	7	9	0.2358	0.4842	57	56	57	0.5371	1.1029
10	7	10	0.1048	0.2152	58	57	58	0.0524	0.1076
11	B	11	0.0786	0.1614	59	58	59	0.0405	0.1380
12	11	12	0.3406	0.6944	60	59	60	0.0393	0.0807
13	12	13	0.0262	0.0538	61	60	61	0.0262	0.0538
14	12	14	0.0786	0.1614	62	61	62	0.1048	0.2152
15	C	15	0.1134	0.3864	63	62	63	0.2358	0.4842
16	15	16	0.0524	0.1076	64	63	64	0.0243	0.0828
17	16	17	0.0524	0.1076	65	I	65	0.0486	0.1656
18	17	18	0.1572	0.3228	66	65	66	0.1703	0.3497
19	18	19	0.0393	0.0807	67	66	67	0.1215	0.4140
20	19	20	0.1703	0.3497	68	67	68	0.2187	0.7452
21	20	21	0.2358	0.4842	69	68	69	0.0486	0.1656
22	21	22	0.1572	0.3228	70	69	70	0.0729	0.2484
23	21	23	0.1965	0.4035	71	70	71	0.0567	0.1932
24	23	24	0.1310	0.2690	72	71	72	0.0262	0.0528
25	D	25	0.0567	0.1932	73	J	73	0.3240	1.1040
26	25	26	0.1048	0.2152	74	73	74	0.0324	0.1104
27	26	27	0.2489	0.5111	75	74	75	0.0567	0.1932
28	27	28	0.0486	0.1656	76	75	76	0.0486	0.1656
29	28	29	0.1310	0.2690	77	K	77	0.2511	0.8556
30	E	30	0.1965	0.3960	78	77	78	0.1296	0.4416
31	30	31	0.1310	0.2690	79	78	79	0.0486	0.1656
32	31	32	0.1310	0.2690	80	79	80	0.1310	0.2640
33	32	33	0.0262	0.0538	81	80	81	0.1310	0.2640
34	33	34	0.1703	0.3497	82	81	82	0.0917	0.1883
35	34	35	0.0524	0.1076	83	82	83	0.3144	0.6456
36	35	36	0.4978	1.0222	84	5	55	0.1310	0.2690
37	36	37	0.0393	0.0807	85	7	60	0.1310	0.2690
38	37	38	0.0393	0.0807	86	11	43	0.1310	0.2690
39	38	39	0.0786	0.1614	87	12	72	0.3406	0.6994
40	39	40	0.2096	0.4304	88	13	76	0.4585	0.9415
41	38	41	0.1965	0.4035	89	14	18	0.5371	1.0824
42	41	42	0.2096	0.4304	90	16	26	0.0917	0.1883
43	F	43	0.0486	0.1656	91	20	83	0.0786	0.1614
44	43	44	0.0393	0.0807	92	28	32	0.0524	0.1076
45	44	45	0.1310	0.2690	93	29	39	0.0786	0.1614
46	45	46	0.2358	0.4842	94	34	46	0.0262	0.0538
47	G	47	0.2430	0.8280	95	40	42	0.1965	0.4035
48	47	48	0.0655	0.1345	96	53	64	0.0393	0.0807

TABLE 23. Load data of test system 11.

B	P (kW)	Q (kVAr)	B	P	Q	B	P	Q
1	0	0	29	200	120	57	30	20
2	100	0.05	30	0	0	58	600	420
3	300	200	31	1800	1600	59	0	0
4	350	250	32	200	150	60	20	10
5	220	100	33	200	100	61	20	10
6	1100	800	34	800	600	62	200	130
7	400	320	35	100	60	63	300	240
8	300	200	36	100	60	64	300	200
9	300	230	37	20	10	65	0	0
10	300	260	38	20	10	66	50	30
11	0	0	39	20	10	67	0	0
12	1200	800	40	20	10	68	400	360
13	800	600	41	200	160	69	0	0
14	700	500	42	50	30	70	0	0
15	0	0	43	0	0	71	2000	1500
16	300	150	44	30	20	72	200	150
17	500	350	45	800	700	73	0	0
18	700	400	46	200	150	74	0	0
19	1200	1000	47	0	0	75	1200	950
20	300	300	48	0	0	76	300	180
21	400	350	49	0	0	77	0	0
22	50	20	50	200	160	78	400	360
23	50	20	51	800	600	79	2000	1300
24	50	10	52	500	300	80	200	140
25	50	30	53	500	350	81	500	360
26	100	60	54	500	300	82	100	30
27	100	70	55	200	80	83	400	360
28	1800	1300	56	0	0	-	-	-

TABLE 24. Numerical results for the test systems.

Test Systems	Open Switches After Reconfiguration	Before Reconfiguration		After Reconfiguration	
		Losses (kW)	Min. Voltage (p.u.)	Losses	Min. Voltage
1	5	1.44	0.995	0.82	0.99
2	3-9	3.55	0.997	1.31	0.998
3	17-19-26	511.44	0.9693	466.1	0.9716
4	11-20-21-28	46	0.91	40	0.936
5	3-5-7-10-25-33	1240	0.8251	361	0.93
6	7-9-14-32-37	202.68	0.9131	139.5	0.9378
7	34-39-45-49-51	10.5	0.9957	8	0.9970
8	25-31-39-40-62	178.66	0.9767	131.69	0.9847
9	14-57-61-69-70	225	0.9092	99.62	0.9428
10	13-30-45-51-66-70-75-76-77-78-79	227.5	0.9052	201.36	0.9311
11	7-13-34-39-42-55-62-72-83-86-89-90-92	532	0.9285	469.88	0.9532
12	24-27-35-40-43-52-59-72-75-96-98-110-123-130-131	1298	0.869	869.7	0.9323
14	12-26-43-82-118-131-133-140-168-202-203-208-212-213-214	548.9	0.9574	511.19	0.9611
13	7-35-51-90-96-106-118-126-135-137-138-141-142-144-145-146-147-148-150-151-155	320.37	0.9307	280.19	0.9589
15	1-2-13-15-16-30-31-40-41-50- 59-73-75-82-94-96-97-111-115-136-142-150-155-156-158-163-168-169-178-179-191-195-209-214-230-254-256-270-294-314-317-325-358-362-385-389-392-395-403-404-423-424-426-436-437-439-446-449-466	708.77	0.9453	583	0.9534

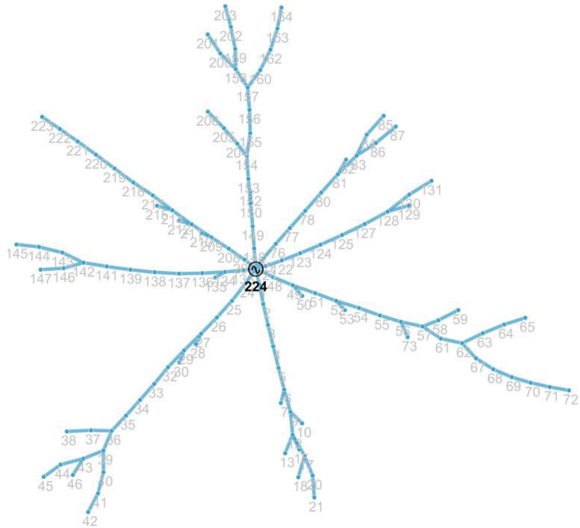

FIGURE 13. **Diagram of test system 13 based on a projection of inter-node impedances into two dimensions.**

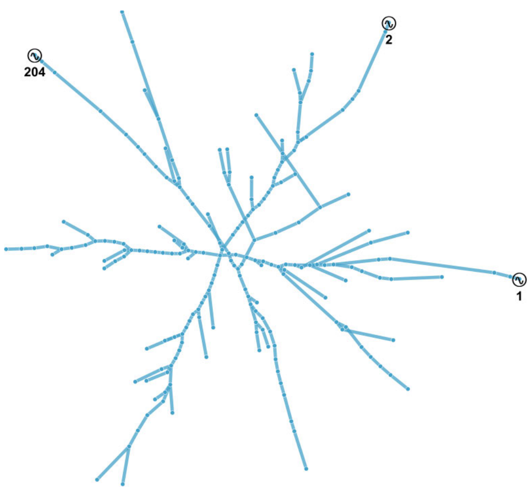

FIGURE 14. **Diagram of test system 14 based on a projection of inter-node impedances into two dimensions.**

solver CPLEX in AMPL and were verified using DCGA and DPSO algorithms in MATLAB. Moreover, the accuracy of the results has been validated by comparing them with other

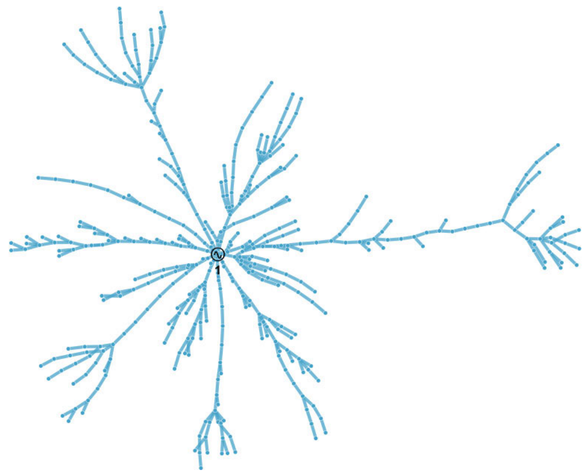

FIGURE 15. **Diagram of test system 15 based on a projection of inter-node impedances into two dimensions.**

proposed models and methodologies regarding distribution system reconfiguration. Results of this table before reconfiguration, in which all tie line switches are open (original network), and after reconfiguration are useful for operation and reconfiguration objectives, respectively.

IV. CONCLUSION

In this paper, the main properties and important data of several test systems and real distribution networks were described. The data include network configurations, line characteristics, generation arrangements, load amounts, nominal voltages, rated powers, and maximum current of distribution branches. The presented data and information allows incorporation of various parameters into integrated models, contributing to the research on distribution network reconfiguration and operation. The applicability of the dataset was verified by solving a network reconfiguration problem and comparing with the results reported in other specialized literature. Network radiality and connectivity of all test systems were confirmed by an electrically meaningful network diagramming technique.

The complete set of information provided makes the presented test systems highly useful to researchers in order to demonstrate robustness and effectiveness of proposed methodologies and models in reconfiguration and operation of distribution systems. Current research provides important information for researchers who are trying to solve the distribution system reconfiguration problem more efficiently.

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