##### Appendix A

TEST SYSTEMS

A.1 34-Bus Distribution System

The single line diagram of 34-bus distribution system is shown in Fig. A.1. Tables A.1 and A.2 show the buses and lines data of 34-bus system, where the rated line voltage is 11 kV and rated MVA is 100.

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Fig. A.1 Single line diagram of 34-bus radial distribution system

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| Table A.1 Lines data for 34-bus distribution system | | | | |
| Line No. | Sending bus | Receiving bus | R (Ω) | X (Ω) |
| 1 | 1 | 2 | 0.1170 | 0.0480 |
| 2 | 2 | 3 | 0.1073 | 0.0440 |
| 3 | 3 | 4 | 0.1645 | 0.0457 |
| 4 | 4 | 5 | 0.1495 | 0.0415 |
| 5 | 5 | 6 | 0.1495 | 0.0415 |
| 6 | 6 | 7 | 0.3144 | 0.0540 |
| 7 | 7 | 8 | 0.2096 | 0.0360 |
| 8 | 8 | 9 | 0.3144 | 0.0540 |
| 9 | 9 | 10 | 0.2096 | 0.0360 |
| 10 | 10 | 11 | 0.1310 | 0.0225 |
| 11 | 11 | 12 | 0.1048 | 0.0180 |
| 12 | 3 | 13 | 0.1572 | 0.0270 |
| 13 | 13 | 14 | 0.2096 | 0.0360 |
| 14 | 14 | 15 | 0.1048 | 0.0180 |
| 15 | 15 | 16 | 0.0524 | 0.0090 |
| 16 | 6 | 17 | 0.1794 | 0.0498 |
| 17 | 17 | 18 | 0.1645 | 0.0457 |
| 18 | 18 | 19 | 0.2079 | 0.0473 |
| 19 | 19 | 20 | 0.1890 | 0.0430 |
| 20 | 20 | 21 | 0.1890 | 0.0430 |
| 21 | 21 | 22 | 0.2620 | 0.0450 |
| 22 | 22 | 23 | 0.2620 | 0.0450 |
| 23 | 23 | 24 | 0.3144 | 0.0540 |
| 24 | 24 | 25 | 0.2096 | 0.0360 |
| 25 | 25 | 26 | 0.1310 | 0.0225 |
| 26 | 26 | 27 | 0.1048 | 0.0180 |
| 27 | 7 | 28 | 0.1572 | 0.0270 |
| 28 | 28 | 29 | 0.1572 | 0.0270 |
| 29 | 29 | 30 | 0.1572 | 0.0270 |
| 30 | 10 | 31 | 0.1572 | 0.0270 |
| 31 | 31 | 32 | 0.2096 | 0.0360 |
| 32 | 32 | 33 | 0.1572 | 0.0270 |
| 33 | 33 | 34 | 0.1048 | 0.0180 |

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| Table A.2 Bus data for 34-bus distribution system | | |
| Line No. | P (kW) | Q (kVAR) |
| 1 | 0 | 0 |
| 2 | 230 | 142.5 |
| 3 | 0 | 0 |
| 4 | 230 | 142.5 |
| 5 | 230 | 142.5 |
| 6 | 0 | 0 |
| 7 | 0 | 0 |
| 8 | 230 | 142.5 |
| 9 | 230 | 142.5 |
| 10 | 0 | 0 |
| 11 | 230 | 142.5 |
| 12 | 137 | 84 |
| 13 | 72 | 45 |
| 14 | 72 | 45 |
| 15 | 72 | 45 |
| 16 | 13.5 | 7.5 |
| 17 | 230 | 142.5 |
| 18 | 230 | 142.5 |
| 19 | 230 | 142.5 |
| 20 | 230 | 142.5 |
| 21 | 230 | 142.5 |
| 22 | 230 | 142.5 |
| 23 | 230 | 142.5 |
| 24 | 230 | 142.5 |
| 25 | 230 | 142.5 |
| 26 | 230 | 142.5 |
| 27 | 137 | 85 |
| 28 | 75 | 48 |
| 29 | 75 | 48 |
| 30 | 75 | 48 |
| 31 | 57 | 34.5 |
| 32 | 57 | 34.5 |
| 33 | 57 | 34.5 |
| 34 | 57 | 34.5 |

A.2 East Delta Network (EDN) System

The single line diagram of EDN 30-bus distribution system is shown in Fig. A.2. Table A.3 shows the buses and lines data of EDN 30-bus system, where the rated line voltage is 11 kV and rated MVA is 100.

Switching tie-line

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Fig. A.2 Single line diagram of the EDN distribution system

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| Table A.3 Buses and lines data for EDN distribution system | | | | | | |
| Line No. | Sending bus | Receiving bus | R (Ω) | X (Ω) | Load at Receiving bus | |
| P (kW) | Q (kVAR) |
| 1 | 1 | 2 | 0.05630 | 0.031500 | 2875 | 1814 |
| 2 | 2 | 3 | 0.07155 | 0.025974 | 1100 | 695 |
| 3 | 3 | 4 | 0.01855 | 0.006734 | 1058 | 669 |
| 4 | 4 | 5 | 0.05565 | 0.020202 | 899 | 568 |
| 5 | 5 | 6 | 0.05300 | 0.019240 | 770 | 486 |
| 6 | 6 | 7 | 0.05300 | 0.019240 | 668 | 423 |
| 7 | 7 | 8 | 0.02120 | 0.007696 | 598 | 378 |
| 8 | 8 | 9 | 0.10070 | 0.036556 | 546 | 345 |
| 9 | 9 | 10 | 0.04505 | 0.016354 | 380 | 240 |
| 10 | 10 | 11 | 0.03975 | 0.014430 | 210 | 132 |
| 11 | 11 | 12 | 0.11130 | 0.040404 | 94.586 | 59.368 |
| 12 | 12 | 13 | 0.01325 | 0.004810 | 34.423 | 21.518 |
| 13 | 2 | 14 | 0.06360 | 0.023088 | 1772 | 1118 |
| 14 | 14 | 15 | 0.07155 | 0.025974 | 1640 | 1035 |
| 15 | 15 | 16 | 0.02650 | 0.009620 | 1452 | 915 |
| 16 | 16 | 17 | 0.01060 | 0.003848 | 1434 | 904 |
| 17 | 17 | 18 | 0.09275 | 0.033670 | 1212 | 765 |
| 18 | 18 | 19 | 0.01060 | 0.003848 | 1086 | 685 |
| 19 | 19 | 20 | 0.02650 | 0.009620 | 953 | 602 |
| 20 | 20 | 21 | 0.04505 | 0.016354 | 827 | 521 |
| 21 | 21 | 22 | 0.05300 | 0.019240 | 716 | 452 |
| 22 | 22 | 23 | 0.05300 | 0.019240 | 550 | 347 |
| 23 | 23 | 24 | 0.0663 | 0.0240 | 434 | 273 |
| 24 | 24 | 25 | 0.2253 | 0.0818 | 346 | 218 |
| 25 | 25 | 26 | 0.0265 | 0.0096 | 316 | 199 |
| 26 | 26 | 27 | 0.0265 | 0.0096 | 184 | 116 |
| 27 | 27 | 28 | 0.0133 | 0.0048 | 139 | 87.911 |
| 28 | 28 | 29 | 0.1723 | 0.0625 | 113 | 71.734 |
| 29 | 29 | 30 | 0.0080 | 0.0029 | 34.25 | 21.734 |