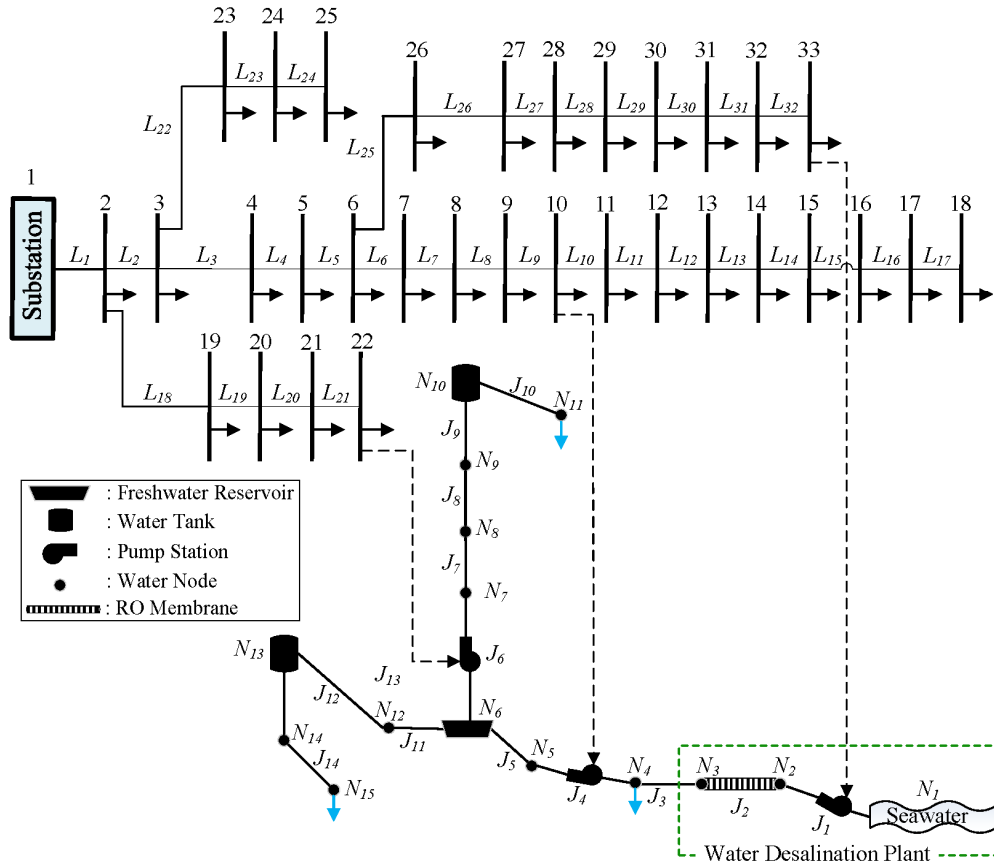


# Interdependent 33-Bus Power Distribution and 15-Node Water Distribution Test Systems with Desalination Plant



- **15-Node Water Distribution System Data**

### Pump Performance Characteristic Function Data

| Pumps      | a   | b  | c | d   | e   |
|------------|-----|----|---|-----|-----|
| P1 (Arc 1) | 178 | 95 | 2 | 295 | 134 |
| P2 (Arc 4) | 178 | 42 | 2 | 295 | 134 |
| P3 (Arc 6) | 178 | 30 | 2 | 295 | 134 |

### Water Storage Tank Characteristic Data

| Tanks        | Volume (m <sup>3</sup> ) | Maximum Charge/Discharge Flow Rate (m <sup>3</sup> /hour) |
|--------------|--------------------------|---|
| T1 (Node 10) | 5000                     | 720   |
| T2 (Node 13) | 5000                     | 720   |

### Residential, Commercial and Industrial Water Demand Data

| Hour | Residential:<br>Node N4 (m <sup>3</sup> /sec) | Commercial:<br>Node N11 (m <sup>3</sup> /sec) | Industrial:<br>Node N15 (m <sup>3</sup> /sec) |
|------|---|---|---|
| 1    | 0.03996                                       | 0.18864                                       | 0.52967                                       |
| 2    | 0.02569                                       | 0.17728                                       | 0.28416                                       |
| 3    | 0.022833                                      | 0.18752                                       | 0.28738                                       |
| 4    | 0.02569                                       | 0.18236                                       | 0.29327                                       |
| 5    | 0.031397                                      | 0.16744                                       | 0.46575                                       |
| 6    | 0.071357                                      | 0.17060                                       | 0.52882                                       |
| 7    | 0.148423                                      | 0.17556                                       | 0.56833                                       |
| 8    | 0.191237                                      | 0.22320                                       | 0.54474                                       |
| 9    | 0.1998  | 0.32780                                       | 0.55666                                       |
| 10   | 0.19409                                       | 0.43572                                       | 0.46412                                       |
| 11   | 0.17982                                       | 0.45112                                       | 0.53237                                       |
| 12   | 0.15984                                       | 0.45260                                       | 0.57689                                       |
| 13   | 0.13986                                       | 0.44976                                       | 0.56816                                       |
| 14   | 0.128443                                      | 0.43572                                       | 0.55439                                       |
| 15   | 0.117027                                      | 0.40500                                       | 0.52886                                       |
| 16   | 0.11988                                       | 0.43020                                       | 0.54780                                       |
| 17   | 0.128443                                      | 0.35736                                       | 0.51574                                       |
| 18   | 0.14557                                       | 0.34220                                       | 0.49525                                       |
| 19   | 0.156987                                      | 0.28340                                       | 0.51681                                       |
| 20   | 0.156987                                      | 0.26660                                       | 0.48517                                       |
| 21   | 0.14557                                       | 0.26916                                       | 0.45331                                       |
| 22   | 0.13415                                       | 0.24904                                       | 0.48045                                       |
| 23   | 0.111317                                      | 0.20728                                       | 0.49980                                       |
| 24   | 0.077067                                      | 0.21812                                       | 0.49436                                       |

### Water Node Data

| Nodes | Elevation (m) | Minimum Pressure (m) | Maximum Pressure (m) |
|-------|---------------|----------------------|----------------------|
| I1    | 10.6          | 0                    | 1000                 |
| I2    | 9.7           | 20                   | 1000                 |
| I3    | 0             | 20                   | 1000                 |
| I4    | 5             | 20                   | 1000                 |
| I5    | 55            | 20                   | 1000                 |
| I6    | 126           | 20                   | 1000                 |
| I7    | 121           | 20                   | 1000                 |
| I8    | 126           | 20                   | 1000                 |
| I9    | 157           | 20                   | 1000                 |
| I10   | 156           | 20                   | 1000                 |
| I11   | 156.65        | 20                   | 1000                 |

|     |        |    |      |
|-----|--------|----|------|
| I12 | 128    | 20 | 1000 |
| I13 | 124.13 | 20 | 1000 |
| I14 | 123    | 20 | 1000 |
| I15 | 106.42 | 20 | 1000 |

### Water Pipes Data

| Pipes | Length (m) | Diameter (m) | Minimum Flow Rate (m <sup>3</sup> /sec) | Maximum Flow Rate (m <sup>3</sup> /sec) |
|-------|------------|--------------|---|---|
| J1    | 18         | 0.15         | 0                                       | 0.9                                     |
| J2    | 401        | 0.15         | 0                                       | 0.9                                     |
| J3    | 18         | 0.30         | 0                                       | 0.9                                     |
| J4    | 1087       | 0.25         | 0                                       | 0.9                                     |
| J5    | 1002       | 0.15         | 0                                       | 0.9                                     |
| J6    | 846        | 0.10         | 0                                       | 0.9                                     |
| J7    | 44         | 0.25         | 0                                       | 0.9                                     |
| J8    | 18         | 0.25         | 0                                       | 0.9                                     |
| J9    | 23         | 0.25         | 0                                       | 0.9                                     |
| J10   | 16         | 0.10         | 0                                       | 0.9                                     |
| J11   | 1003       | 0.20         | 0                                       | 0.9                                     |
| J12   | 30         | 0.15         | 0                                       | 0.9                                     |
| J13   | 6          | 0.23         | 0                                       | 0.9                                     |
| J14   | 13         | 0.30         | 0                                       | 0.9                                     |

### Water Desalination Plant Data

| Desalination Plant | Desalination Technology | Recovery Ratio% | Osmotic Pressure Coefficient Constant | Membrane active surface area (m <sup>2</sup> ) | Membrane permeability Constant |
|--------------------|-------------------------|-----------------|---------------------------------------|--|--------------------------------|
| D1 (Arc 2)         | Reverse Osmosis         | 20-70           | 78.7                                  | 33.9   | 0.78×10 <sup>-10</sup>         |

### Water Reservoir Data

| Water Reservoir     | Maximum Inflow Rate (m <sup>3</sup> /sec) |
|---------------------|---|
| Freshwater (Node 6) | 0.9                                       |
| Seawater (Node 1)   | 0.9                                       |

### Water Desalination Plant Data

| Desalination Plant | Desalination Technology | Recovery Ratio% | Osmotic Pressure Coefficient Constant | Membrane active surface area (m <sup>2</sup> ) | Membrane permeability Constant | Saline Concentration (kg/m <sup>2</sup> ) |
|--------------------|-------------------------|-----------------|---------------------------------------|--|--------------------------------|---|
| D1 (Arc 2)         | Reverse Osmosis         | 20-70           | 78.7                                  | 33.9   | $0.78 \times 10^{-10}$         | 30  |

### Energy Tariffs Applied to Water Distribution System

| Hour | Flat (\$/kWh) | Night (\$/kWh) | Dynamic (\$/kWh) |
|------|---------------|----------------|------------------|
| 1    | 0.1271        | 0.0400         | 0.0924           |
| 2    | 0.1271        | 0.0400         | 0.0815           |
| 3    | 0.1271        | 0.0400         | 0.0724           |
| 4    | 0.1271        | 0.0400         | 0.0765           |
| 5    | 0.1271        | 0.0400         | 0.0834           |
| 6    | 0.1271        | 0.1706         | 0.1259           |
| 7    | 0.1271        | 0.1706         | 0.2226           |
| 8    | 0.1271        | 0.1706         | 0.2677           |
| 9    | 0.1271        | 0.1706         | 0.1082           |
| 10   | 0.1271        | 0.1706         | 0.0630           |
| 11   | 0.1271        | 0.1706         | 0.0439           |
| 12   | 0.1271        | 0.1706         | 0.0422           |
| 13   | 0.1271        | 0.1706         | 0.0286           |
| 14   | 0.1271        | 0.1706         | 0.0241           |
| 15   | 0.1271        | 0.1706         | 0.0442           |
| 16   | 0.1271        | 0.1706         | 0.0716           |
| 17   | 0.1271        | 0.1706         | 0.1230           |
| 18   | 0.1271        | 0.1706         | 0.2436           |
| 19   | 0.1271        | 0.1706         | 0.3410           |
| 20   | 0.1271        | 0.1706         | 0.2622           |
| 21   | 0.1271        | 0.0400         | 0.2235           |
| 22   | 0.1271        | 0.0400         | 0.1595           |
| 23   | 0.1271        | 0.0400         | 0.1371           |
| 24   | 0.1271        | 0.0400         | 0.1117           |

- **33-Bus Power Distribution System Data**

**Substation (Slack) Bus Data**

| Bus | Apparent Power Base (MVA) | Nominal Voltage Base (kV) |
|-----|---------------------------|---------------------------|
| b1  | 100                       | 13.3                      |

**Bus Data**

| Buses  | Minimum Voltage Limit (p.u) | Maximum Voltage Limit (p.u) |
|--------|-----------------------------|-----------------------------|
| b1-b33 | 0.9                         | 1.04                        |

**Coupling Points**

| Pumps      | Buses |
|------------|-------|
| P1 (Arc 1) | b33   |
| P2 (Arc 4) | b10   |
| P3 (Arc 6) | b22   |

**Non-Slack Bus Active Power Demand Data (kW)**

| Time | t1    | t2    | t3    | t4    | t5    | t6    | t7    | t8    | t9    | t10   | t11   | t12   |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| b2   | 71.3  | 68.9  | 68.3  | 69.3  | 71.4  | 77.6  | 87.1  | 92.4  | 90.2  | 87.4  | 85.5  | 82.9  |
| b3   | 64.2  | 62.0  | 61.4  | 62.4  | 64.3  | 69.9  | 78.4  | 83.2  | 81.2  | 78.6  | 77.0  | 74.7  |
| b4   | 85.6  | 82.6  | 81.9  | 83.2  | 85.7  | 93.2  | 104.6 | 110.9 | 108.3 | 104.8 | 102.6 | 99.5  |
| b5   | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b6   | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b7   | 142.6 | 137.7 | 136.5 | 138.6 | 142.9 | 155.3 | 174.3 | 184.9 | 180.5 | 174.7 | 171.1 | 165.9 |
| b8   | 142.6 | 137.7 | 136.5 | 138.6 | 142.9 | 155.3 | 174.3 | 184.9 | 180.5 | 174.7 | 171.1 | 165.9 |
| b9   | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b10  | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b11  | 32.1  | 31.0  | 30.7  | 31.2  | 32.1  | 34.9  | 39.2  | 41.6  | 40.6  | 39.3  | 38.5  | 37.3  |
| b12  | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b13  | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b14  | 85.6  | 82.6  | 81.9  | 83.2  | 85.7  | 93.2  | 104.6 | 110.9 | 108.3 | 104.8 | 102.6 | 99.5  |
| b15  | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b16  | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b17  | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b18  | 64.2  | 62.0  | 61.4  | 62.4  | 64.3  | 69.9  | 78.4  | 83.2  | 81.2  | 78.6  | 77.0  | 74.7  |
| b19  | 64.2  | 62.0  | 61.4  | 62.4  | 64.3  | 69.9  | 78.4  | 83.2  | 81.2  | 78.6  | 77.0  | 74.7  |
| b20  | 64.2  | 62.0  | 61.4  | 62.4  | 64.3  | 69.9  | 78.4  | 83.2  | 81.2  | 78.6  | 77.0  | 74.7  |
| b21  | 64.2  | 62.0  | 61.4  | 62.4  | 64.3  | 69.9  | 78.4  | 83.2  | 81.2  | 78.6  | 77.0  | 74.7  |
| b22  | 64.2  | 62.0  | 61.4  | 62.4  | 64.3  | 69.9  | 78.4  | 83.2  | 81.2  | 78.6  | 77.0  | 74.7  |
| b23  | 64.2  | 62.0  | 61.4  | 62.4  | 64.3  | 69.9  | 78.4  | 83.2  | 81.2  | 78.6  | 77.0  | 74.7  |
| b24  | 299.4 | 289.2 | 286.7 | 291.1 | 300.0 | 326.0 | 366.0 | 388.2 | 379.0 | 366.9 | 359.2 | 348.4 |

|             |            |            |            |            |            |            |            |            |            |            |            |            |
|-------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| b25         | 299.4      | 289.2      | 286.7      | 291.1      | 300.0      | 326.0      | 366.0      | 388.2      | 379.0      | 366.9      | 359.2      | 348.4      |
| b26         | 42.8       | 41.3       | 41.0       | 41.6       | 42.9       | 46.6       | 52.3       | 55.5       | 54.1       | 52.4       | 51.3       | 49.8       |
| b27         | 42.8       | 41.3       | 41.0       | 41.6       | 42.9       | 46.6       | 52.3       | 55.5       | 54.1       | 52.4       | 51.3       | 49.8       |
| b28         | 42.8       | 41.3       | 41.0       | 41.6       | 42.9       | 46.6       | 52.3       | 55.5       | 54.1       | 52.4       | 51.3       | 49.8       |
| b29         | 85.6       | 82.6       | 81.9       | 83.2       | 85.7       | 93.2       | 104.6      | 110.9      | 108.3      | 104.8      | 102.6      | 99.5       |
| b30         | 142.6      | 137.7      | 136.5      | 138.6      | 142.9      | 155.3      | 174.3      | 184.9      | 180.5      | 174.7      | 171.1      | 165.9      |
| b31         | 106.9      | 103.3      | 102.4      | 104.0      | 107.2      | 116.4      | 130.7      | 138.6      | 135.4      | 131.0      | 128.3      | 124.4      |
| b32         | 149.7      | 144.6      | 143.4      | 145.6      | 150.0      | 163.0      | 183.0      | 194.1      | 189.5      | 183.4      | 179.6      | 174.2      |
| b33         | 42.8       | 41.3       | 41.0       | 41.6       | 42.9       | 46.6       | 52.3       | 55.5       | 54.1       | 52.4       | 51.3       | 49.8       |
| <b>Time</b> | <b>t13</b> | <b>t14</b> | <b>t15</b> | <b>t16</b> | <b>t17</b> | <b>t18</b> | <b>t19</b> | <b>t20</b> | <b>t21</b> | <b>t22</b> | <b>t23</b> | <b>t24</b> |
| b2          | 81.5       | 81.3       | 80.8       | 80.8       | 84.2       | 94.5       | 100.0      | 97.3       | 94.8       | 89.7       | 82.1       | 75.1       |
| b3          | 73.4       | 73.2       | 72.7       | 72.7       | 75.8       | 85.0       | 90.0       | 87.6       | 85.3       | 80.7       | 73.9       | 67.6       |
| b4          | 97.9       | 97.6       | 96.9       | 96.9       | 101.1      | 113.4      | 120.0      | 116.8      | 113.8      | 107.6      | 98.5       | 90.1       |
| b5          | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b6          | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b7          | 163.1      | 162.7      | 161.5      | 161.6      | 168.4      | 189.0      | 200.0      | 194.7      | 189.6      | 179.3      | 164.2      | 150.1      |
| b8          | 163.1      | 162.7      | 161.5      | 161.6      | 168.4      | 189.0      | 200.0      | 194.7      | 189.6      | 179.3      | 164.2      | 150.1      |
| b9          | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b10         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b11         | 36.7       | 36.6       | 36.3       | 36.4       | 37.9       | 42.5       | 45.0       | 43.8       | 42.7       | 40.4       | 36.9       | 33.8       |
| b12         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b13         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b14         | 97.9       | 97.6       | 96.9       | 96.9       | 101.1      | 113.4      | 120.0      | 116.8      | 113.8      | 107.6      | 98.5       | 90.1       |
| b15         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b16         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b17         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b18         | 73.4       | 73.2       | 72.7       | 72.7       | 75.8       | 85.0       | 90.0       | 87.6       | 85.3       | 80.7       | 73.9       | 67.6       |
| b19         | 73.4       | 73.2       | 72.7       | 72.7       | 75.8       | 85.0       | 90.0       | 87.6       | 85.3       | 80.7       | 73.9       | 67.6       |
| b20         | 73.4       | 73.2       | 72.7       | 72.7       | 75.8       | 85.0       | 90.0       | 87.6       | 85.3       | 80.7       | 73.9       | 67.6       |
| b21         | 73.4       | 73.2       | 72.7       | 72.7       | 75.8       | 85.0       | 90.0       | 87.6       | 85.3       | 80.7       | 73.9       | 67.6       |
| b22         | 73.4       | 73.2       | 72.7       | 72.7       | 75.8       | 85.0       | 90.0       | 87.6       | 85.3       | 80.7       | 73.9       | 67.6       |
| b23         | 73.4       | 73.2       | 72.7       | 72.7       | 75.8       | 85.0       | 90.0       | 87.6       | 85.3       | 80.7       | 73.9       | 67.6       |
| b24         | 342.5      | 341.6      | 339.2      | 339.3      | 353.7      | 396.9      | 420.0      | 408.9      | 398.1      | 376.6      | 344.8      | 315.2      |
| b25         | 342.5      | 341.6      | 339.2      | 339.3      | 353.7      | 396.9      | 420.0      | 408.9      | 398.1      | 376.6      | 344.8      | 315.2      |
| b26         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b27         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b28         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |
| b29         | 97.9       | 97.6       | 96.9       | 96.9       | 101.1      | 113.4      | 120.0      | 116.8      | 113.8      | 107.6      | 98.5       | 90.1       |
| b30         | 163.1      | 162.7      | 161.5      | 161.6      | 168.4      | 189.0      | 200.0      | 194.7      | 189.6      | 179.3      | 164.2      | 150.1      |
| b31         | 122.3      | 122.0      | 121.1      | 121.2      | 126.3      | 141.7      | 150.0      | 146.0      | 142.2      | 134.5      | 123.1      | 112.6      |
| b32         | 171.2      | 170.8      | 169.6      | 169.6      | 176.9      | 198.4      | 210.0      | 204.4      | 199.1      | 188.3      | 172.4      | 157.6      |
| b33         | 48.9       | 48.8       | 48.5       | 48.5       | 50.5       | 56.7       | 60.0       | 58.4       | 56.9       | 53.8       | 49.3       | 45.0       |

### Non-Slack Bus Reactive Power Demand Data (kVAr)

| Time | t1    | t2    | t3    | t4    | t5    | t6    | t7    | t8    | t9    | t10   | t11   | t12   |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| b2   | 42.8  | 41.3  | 41.0  | 41.6  | 42.9  | 46.6  | 52.3  | 55.5  | 54.1  | 52.4  | 51.3  | 49.8  |
| b3   | 28.5  | 27.5  | 27.3  | 27.7  | 28.6  | 31.1  | 34.9  | 37.0  | 36.1  | 34.9  | 34.2  | 33.2  |
| b4   | 57.0  | 55.1  | 54.6  | 55.5  | 57.2  | 62.1  | 69.7  | 73.9  | 72.2  | 69.9  | 68.4  | 66.4  |
| b5   | 21.4  | 20.7  | 20.5  | 20.8  | 21.4  | 23.3  | 26.1  | 27.7  | 27.1  | 26.2  | 25.7  | 24.9  |
| b6   | 14.3  | 13.8  | 13.7  | 13.9  | 14.3  | 15.5  | 17.4  | 18.5  | 18.0  | 17.5  | 17.1  | 16.6  |
| b7   | 71.3  | 68.9  | 68.3  | 69.3  | 71.4  | 77.6  | 87.1  | 92.4  | 90.2  | 87.4  | 85.5  | 82.9  |
| b8   | 71.3  | 68.9  | 68.3  | 69.3  | 71.4  | 77.6  | 87.1  | 92.4  | 90.2  | 87.4  | 85.5  | 82.9  |
| b9   | 14.3  | 13.8  | 13.7  | 13.9  | 14.3  | 15.5  | 17.4  | 18.5  | 18.0  | 17.5  | 17.1  | 16.6  |
| b10  | 14.3  | 13.8  | 13.7  | 13.9  | 14.3  | 15.5  | 17.4  | 18.5  | 18.0  | 17.5  | 17.1  | 16.6  |
| b11  | 21.4  | 20.7  | 20.5  | 20.8  | 21.4  | 23.3  | 26.1  | 27.7  | 27.1  | 26.2  | 25.7  | 24.9  |
| b12  | 25.0  | 24.1  | 23.9  | 24.3  | 25.0  | 27.2  | 30.5  | 32.4  | 31.6  | 30.6  | 29.9  | 29.0  |
| b13  | 25.0  | 24.1  | 23.9  | 24.3  | 25.0  | 27.2  | 30.5  | 32.4  | 31.6  | 30.6  | 29.9  | 29.0  |
| b14  | 57.0  | 55.1  | 54.6  | 55.5  | 57.2  | 62.1  | 69.7  | 73.9  | 72.2  | 69.9  | 68.4  | 66.4  |
| b15  | 7.1   | 6.9   | 6.8   | 6.9   | 7.1   | 7.8   | 8.7   | 9.2   | 9.0   | 8.7   | 8.6   | 8.3   |
| b16  | 14.3  | 13.8  | 13.7  | 13.9  | 14.3  | 15.5  | 17.4  | 18.5  | 18.0  | 17.5  | 17.1  | 16.6  |
| b17  | 14.3  | 13.8  | 13.7  | 13.9  | 14.3  | 15.5  | 17.4  | 18.5  | 18.0  | 17.5  | 17.1  | 16.6  |
| b18  | 28.5  | 27.5  | 27.3  | 27.7  | 28.6  | 31.1  | 34.9  | 37.0  | 36.1  | 34.9  | 34.2  | 33.2  |
| b19  | 28.5  | 27.5  | 27.3  | 27.7  | 28.6  | 31.1  | 34.9  | 37.0  | 36.1  | 34.9  | 34.2  | 33.2  |
| b20  | 28.5  | 27.5  | 27.3  | 27.7  | 28.6  | 31.1  | 34.9  | 37.0  | 36.1  | 34.9  | 34.2  | 33.2  |
| b21  | 28.5  | 27.5  | 27.3  | 27.7  | 28.6  | 31.1  | 34.9  | 37.0  | 36.1  | 34.9  | 34.2  | 33.2  |
| b22  | 28.5  | 27.5  | 27.3  | 27.7  | 28.6  | 31.1  | 34.9  | 37.0  | 36.1  | 34.9  | 34.2  | 33.2  |
| b23  | 35.6  | 34.4  | 34.1  | 34.7  | 35.7  | 38.8  | 43.6  | 46.2  | 45.1  | 43.7  | 42.8  | 41.5  |
| b24  | 142.6 | 137.7 | 136.5 | 138.6 | 142.9 | 155.3 | 174.3 | 184.9 | 180.5 | 174.7 | 171.1 | 165.9 |
| b25  | 142.6 | 137.7 | 136.5 | 138.6 | 142.9 | 155.3 | 174.3 | 184.9 | 180.5 | 174.7 | 171.1 | 165.9 |
| b26  | 17.8  | 17.2  | 17.1  | 17.3  | 17.9  | 19.4  | 21.8  | 23.1  | 22.6  | 21.8  | 21.4  | 20.7  |
| b27  | 17.8  | 17.2  | 17.1  | 17.3  | 17.9  | 19.4  | 21.8  | 23.1  | 22.6  | 21.8  | 21.4  | 20.7  |
| b28  | 14.3  | 13.8  | 13.7  | 13.9  | 14.3  | 15.5  | 17.4  | 18.5  | 18.0  | 17.5  | 17.1  | 16.6  |
| b29  | 49.9  | 48.2  | 47.8  | 48.5  | 50.0  | 54.3  | 61.0  | 64.7  | 63.2  | 61.1  | 59.9  | 58.1  |
| b30  | 427.8 | 413.1 | 409.6 | 415.9 | 428.6 | 465.8 | 522.9 | 554.6 | 541.5 | 524.1 | 513.2 | 497.7 |
| b31  | 49.9  | 48.2  | 47.8  | 48.5  | 50.0  | 54.3  | 61.0  | 64.7  | 63.2  | 61.1  | 59.9  | 58.1  |
| b32  | 71.3  | 68.9  | 68.3  | 69.3  | 71.4  | 77.6  | 87.1  | 92.4  | 90.2  | 87.4  | 85.5  | 82.9  |
| b33  | 28.5  | 27.5  | 27.3  | 27.7  | 28.6  | 31.1  | 34.9  | 37.0  | 36.1  | 34.9  | 34.2  | 33.2  |
| Time | t13   | t14   | t15   | t16   | t17   | t18   | t19   | t20   | t21   | t22   | t23   | t24   |
| b2   | 48.9  | 48.8  | 48.5  | 48.5  | 50.5  | 56.7  | 60.0  | 58.4  | 56.9  | 53.8  | 49.3  | 45.0  |
| b3   | 32.6  | 32.5  | 32.3  | 32.3  | 33.7  | 37.8  | 40.0  | 38.9  | 37.9  | 35.9  | 32.8  | 30.0  |
| b4   | 65.2  | 65.1  | 64.6  | 64.6  | 67.4  | 75.6  | 80.0  | 77.9  | 75.8  | 71.7  | 65.7  | 60.0  |
| b5   | 24.5  | 24.4  | 24.2  | 24.2  | 25.3  | 28.3  | 30.0  | 29.2  | 28.4  | 26.9  | 24.6  | 22.5  |
| b6   | 16.3  | 16.3  | 16.2  | 16.2  | 16.8  | 18.9  | 20.0  | 19.5  | 19.0  | 17.9  | 16.4  | 15.0  |
| b7   | 81.5  | 81.3  | 80.8  | 80.8  | 84.2  | 94.5  | 100.0 | 97.3  | 94.8  | 89.7  | 82.1  | 75.1  |
| b8   | 81.5  | 81.3  | 80.8  | 80.8  | 84.2  | 94.5  | 100.0 | 97.3  | 94.8  | 89.7  | 82.1  | 75.1  |

|     |       |       |       |       |       |       |       |       |       |       |       |       |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| b9  | 16.3  | 16.3  | 16.2  | 16.2  | 16.8  | 18.9  | 20.0  | 19.5  | 19.0  | 17.9  | 16.4  | 15.0  |
| b10 | 16.3  | 16.3  | 16.2  | 16.2  | 16.8  | 18.9  | 20.0  | 19.5  | 19.0  | 17.9  | 16.4  | 15.0  |
| b11 | 24.5  | 24.4  | 24.2  | 24.2  | 25.3  | 28.3  | 30.0  | 29.2  | 28.4  | 26.9  | 24.6  | 22.5  |
| b12 | 28.5  | 28.5  | 28.3  | 28.3  | 29.5  | 33.1  | 35.0  | 34.1  | 33.2  | 31.4  | 28.7  | 26.3  |
| b13 | 28.5  | 28.5  | 28.3  | 28.3  | 29.5  | 33.1  | 35.0  | 34.1  | 33.2  | 31.4  | 28.7  | 26.3  |
| b14 | 65.2  | 65.1  | 64.6  | 64.6  | 67.4  | 75.6  | 80.0  | 77.9  | 75.8  | 71.7  | 65.7  | 60.0  |
| b15 | 8.2   | 8.1   | 8.1   | 8.1   | 8.4   | 9.5   | 10.0  | 9.7   | 9.5   | 9.0   | 8.2   | 7.5   |
| b16 | 16.3  | 16.3  | 16.2  | 16.2  | 16.8  | 18.9  | 20.0  | 19.5  | 19.0  | 17.9  | 16.4  | 15.0  |
| b17 | 16.3  | 16.3  | 16.2  | 16.2  | 16.8  | 18.9  | 20.0  | 19.5  | 19.0  | 17.9  | 16.4  | 15.0  |
| b18 | 32.6  | 32.5  | 32.3  | 32.3  | 33.7  | 37.8  | 40.0  | 38.9  | 37.9  | 35.9  | 32.8  | 30.0  |
| b19 | 32.6  | 32.5  | 32.3  | 32.3  | 33.7  | 37.8  | 40.0  | 38.9  | 37.9  | 35.9  | 32.8  | 30.0  |
| b20 | 32.6  | 32.5  | 32.3  | 32.3  | 33.7  | 37.8  | 40.0  | 38.9  | 37.9  | 35.9  | 32.8  | 30.0  |
| b21 | 32.6  | 32.5  | 32.3  | 32.3  | 33.7  | 37.8  | 40.0  | 38.9  | 37.9  | 35.9  | 32.8  | 30.0  |
| b22 | 32.6  | 32.5  | 32.3  | 32.3  | 33.7  | 37.8  | 40.0  | 38.9  | 37.9  | 35.9  | 32.8  | 30.0  |
| b23 | 40.8  | 40.7  | 40.4  | 40.4  | 42.1  | 47.2  | 50.0  | 48.7  | 47.4  | 44.8  | 41.0  | 37.5  |
| b24 | 163.1 | 162.7 | 161.5 | 161.6 | 168.4 | 189.0 | 200.0 | 194.7 | 189.6 | 179.3 | 164.2 | 150.1 |
| b25 | 163.1 | 162.7 | 161.5 | 161.6 | 168.4 | 189.0 | 200.0 | 194.7 | 189.6 | 179.3 | 164.2 | 150.1 |
| b26 | 20.4  | 20.3  | 20.2  | 20.2  | 21.1  | 23.6  | 25.0  | 24.3  | 23.7  | 22.4  | 20.5  | 18.8  |
| b27 | 20.4  | 20.3  | 20.2  | 20.2  | 21.1  | 23.6  | 25.0  | 24.3  | 23.7  | 22.4  | 20.5  | 18.8  |
| b28 | 16.3  | 16.3  | 16.2  | 16.2  | 16.8  | 18.9  | 20.0  | 19.5  | 19.0  | 17.9  | 16.4  | 15.0  |
| b29 | 57.1  | 56.9  | 56.5  | 56.5  | 59.0  | 66.1  | 70.0  | 68.1  | 66.4  | 62.8  | 57.5  | 52.5  |
| b30 | 489.3 | 488.0 | 484.6 | 484.7 | 505.3 | 567.0 | 600.0 | 584.1 | 568.8 | 538.0 | 492.5 | 450.3 |
| b31 | 57.1  | 56.9  | 56.5  | 56.5  | 59.0  | 66.1  | 70.0  | 68.1  | 66.4  | 62.8  | 57.5  | 52.5  |
| b32 | 81.5  | 81.3  | 80.8  | 80.8  | 84.2  | 94.5  | 100.0 | 97.3  | 94.8  | 89.7  | 82.1  | 75.1  |
| b33 | 32.6  | 32.5  | 32.3  | 32.3  | 33.7  | 37.8  | 40.0  | 38.9  | 37.9  | 35.9  | 32.8  | 30.0  |

### Power Distribution Lines Data

| From bus | To bus | Resistance (Ohm) | Reactance (Ohm) |
|----------|--------|------------------|-----------------|
| b1       | b2     | 0.0922           | 0.047           |
| b2       | b3     | 0.493            | 0.2511          |
| b3       | b4     | 0.366            | 0.1864          |
| b4       | b5     | 0.3811           | 0.1941          |
| b5       | b6     | 0.819            | 0.707           |
| b6       | b7     | 0.1872           | 0.6188          |
| b7       | b8     | 1.7114           | 1.2351          |
| b8       | b9     | 1.03             | 0.74            |
| b9       | b10    | 1.044            | 0.74            |
| b10      | b11    | 0.1966           | 0.065           |
| b11      | b12    | 0.3744           | 0.1238          |
| b12      | b13    | 1.468            | 1.155           |
| b13      | b14    | 0.5416           | 0.7129          |
| b14      | b15    | 0.591            | 0.526           |



|     |     |        |        |
|-----|-----|--------|--------|
| b15 | b16 | 0.7463 | 0.545  |
| b16 | b17 | 1.289  | 1.721  |
| b17 | b18 | 0.732  | 0.574  |
| b2  | b19 | 0.164  | 0.1565 |
| b19 | b20 | 1.5042 | 1.3554 |
| b20 | b21 | 0.4095 | 0.4784 |
| b21 | b22 | 0.7089 | 0.9373 |
| b3  | b23 | 0.4512 | 0.3083 |
| b23 | b24 | 0.898  | 0.7091 |
| b24 | b25 | 0.896  | 0.7011 |
| b6  | b26 | 0.203  | 0.1034 |
| b26 | b27 | 0.2842 | 0.1447 |
| b27 | b28 | 1.059  | 0.9337 |
| b28 | b29 | 0.8042 | 0.7006 |
| b29 | b30 | 0.5075 | 0.2585 |
| b30 | b31 | 0.9744 | 0.963  |
| b31 | b32 | 0.3105 | 0.3619 |
| b32 | b33 | 0.341  | 0.5302 |