the optimization process. A steady state voltage stability index has been used to assess the stability at each node. A 33-node distribution network has been used for the simulation. Illustrative mesh plots were given in this paper to show the impacts of DGs locations and sizes on the voltage stability and power losses. The proposed algorithm has been used in different scenarios to show the effect of the type and the number of DGs integration on the distributed network. The location, size and type of DGs significantly affect the voltage stability and the power losses. The algorithm proposed in this paper can find a compromise between different objective functions providing useful information for optimal DGs integration.

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## 8. Appendix

| Line # | Node *i* | Node *j* | R (Ω) | X (Ω) | Load at node *j* P (kw) | Load at node *j* Q (kvar) | Line # | Node *i* | Node *j* | R (Ω) | X (Ω) | Load at node *i* P (kw) | Load at node *i* Q (kw) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 0.0922 | 0.047 | 100 | 60 | 20 | 20 | 21 | 0.4095 | 0.4784 | 90 | 40 |
| 2 | 2 | 3 | 0.493 | 0.2512 | 90 | 40 | 21 | 21 | 22 | 0.7089 | 0.9373 | 90 | 40 |
| 3 | 3 | 4 | 0.3661 | 0.1864 | 120 | 80 | 22 | 3 | 23 | 0.4512 | 0.3084 | 90 | 50 |
| 4 | 4 | 5 | 0.3811 | 0.1941 | 60 | 30 | 23 | 24 | 25 | 0.8980 | 0.7091 | 420 | 200 |
| 5 | 5 | 6 | 0.8190 | 0.7070 | 60 | 20 | 24 | 24 | 25 | 0.8980 | 0.7071 | 420 | 200 |
| 6 | 6 | 7 | 0.1872 | 0.6188 | 200 | 100 | 25 | 6 | 26 | 0.2031 | 0.1034 | 60 | 25 |
| 7 | 7 | 8 | 0.7115 | 0.2351 | 200 | 100 | 26 | 26 | 27 | 0.2842 | 0.1474 | 60 | 25 |
| 8 | 8 | 9 | 1.0299 | 0.7400 | 60 | 20 | 27 | 27 | 28 | 1.0589 | 0.9338 | 60 | 20 |
| 9 | 9 | 10 | 1.044 | 0.7400 | 60 | 20 | 28 | 28 | 29 | 0.8043 | 0.7006 | 120 | 70 |
| 10 | 10 | 11 | 0.1967 | 0.0651 | 45 | 30 | 29 | 29 | 30 | .5074 | 0.2585 | 200 | 100 |
| 11 | 11 | 12 | 0.3744 | 0.1298 | 60 | 35 | 30 | 30 | 31 | 0.9745 | 0.9629 | 150 | 70 |
| 12 | 12 | 13 | 1.4680 | 1.1549 | 60 | 35 | 31 | 31 | 32 | 0.3105 | 0.3619 | 210 | 100 |
| 13 | 13 | 14 | 0.5416 | 0.7129 | 120 | 80 | 32 | 32 | 33 | 0.3411 | 0.5302 | 60 | 40 |
| 14 | 14 | 15 | 0.5909 | 0.5260 | 60 | 10 | - | - | - | - | - | - | - |
| 15 | 15 | 16 | 0.7462 | 0.5449 | 60 | 20 | - | - | - | - | - | - | - |
| 16 | 16 | 17 | 1.2889 | 1.7210 | 60 | 20 | - | - | - | - | - | - | - |
| 17 | 17 | 18 | 0.7320 | 0.5739 | 90 | 40 | - | - | - | - | - | - | - |
| 18 | 2 | 19 | 0.1640 | 0.1565 | 90 | 40 | - | - | - | - | - | - | - |
| 19 | 19 | 20 | 1.5042 | 1.3555 | 90 | 40 | - | - | - | - | - | - | - |

Table 2. System data of 12 buses and 11 branches system

| Branch no. | Sending end | Receiving end | R (ohms) | X (ohms) | Load at node *i* PL (kW) | Load at node *i* QL (kVAR) |
|---|---|---|---|---|---|---|
| | | | | | 0 | 0 |
| 1 | 1 | 2 | 1.093 | 0.455 | 60 | 60 |
| 2 | 2 | 3 | 1.184 | 0.494 | 40 | 30 |
| 3 | 3 | 4 | 2.095 | 0.873 | 55 | 55 |
| 4 | 4 | 5 | 3.188 | 1.329 | 30 | 30 |
| 5 | 5 | 6 | 1.093 | 0.455 | 20 | 15 |
| 6 | 6 | 7 | 1.002 | 0.417 | 55 | 55 |
| 7 | 7 | 8 | 4.403 | 1.215 | 45 | 45 |
| 8 | 8 | 9 | 5.642 | 1.597 | 40 | 40 |
| 9 | 9 | 10 | 2.89 | 0.818 | 35 | 30 |
| 10 | 10 | 11 | 1.514 | 0.428 | 40 | 30 |
| 11 | 11 | 12 | 1.238 | 0.351 | 15 | 15 |

Table 3. System data for modified 119-bus distribution network

| Line # | Node *i* | Node *j* | R (Ω) | X (Ω) | Load at node *j* | | Line # | Node *i* | Node *j* | R (Ω) | X (Ω) | Load at node *i* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | P (kw) | Q (kvar) | | | | | | P (kw) | Q (kw) |
| 1 | 1 | 2 | 0.036 | 0.01296 | 101.14 | 0.12 | 60 | 60 | 61 | 0.207 | 0.0747 | 90.758 | 0.69 |
| 2 | 2 | 3 | 0.033 | 0.01188 | 11.292 | 0.11 | 61 | 61 | 62 | 0.247 | 0.8922 | 47.7 | 0.823 |
| 3 | 2 | 4 | 0.045 | 0.0162 | 21.845 | 0.15 | 62 | 31 | 63 | 0.187 | 0.261 | 369.7 | 0.623 |
| 4 | 4 | 5 | 0.015 | 0.054 | 63.602 | 0.05 | 63 | 63 | 64 | 0.133 | 0.099 | 321.64 | 0.443 |
| 5 | 5 | 6 | 0.015 | 0.054 | 68.604 | 0.05 | 64 | 64 | 65 | 0.070 | 0.044 | 150.64 | 0.223 |
| 6 | 6 | 7 | 0.015 | 0.0125 | 61.725 | 0.05 | 65 | 1 | 66 | 0.028 | 0.0418 | 463.74 | 0.093 |
| 7 | 7 | 8 | 0.018 | 0.014 | 11.503 | 0.06 | 66 | 66 | 67 | 0.117 | 0.2016 | 52.006 | 0.39 |
| 8 | 8 | 9 | 0.021 | 0.063 | 51.073 | 0.07 | 67 | 67 | 68 | 0.255 | 0.0918 | 100.34 | 0.85 |
| 9 | 2 | 10 | 0.166 | 0.1344 | 106.77 | 0.553 | 68 | 68 | 69 | 0.21 | 0.0759 | 193.5 | 0.7 |
| 10 | 10 | 11 | 0.112 | 0.0789 | 75.99 | 0.373 | 69 | 69 | 70 | 0.383 | 0.138 | 26.713 | 1.277 |
| 11 | 11 | 12 | 0.187 | 0.313 | 18.687 | 0.623 | 70 | 70 | 71 | 0.504 | 0.3303 | 25.257 | 1.68 |
| 12 | 12 | 13 | 0.142 | 0.1512 | 23.22 | 0.473 | 71 | 71 | 72 | 0.4 | 0.1461 | 38.713 | 1.353 |
| 13 | 13 | 14 | 0.18 | 0.118 | 117.5 | 0.6 | 72 | 72 | 73 | 0.962 | 0.761 | 395.14 | 3.207 |
| 14 | 14 | 15 | 0.15 | 0.045 | 28.79 | 0.5 | 73 | 73 | 74 | 0.165 | 0.06 | 239.74 | 0.55 |
| 15 | 15 | 16 | 0.16 | 0.18 | 26.45 | 0.533 | 74 | 74 | 75 | 0.303 | 0.1092 | 84.363 | 1.01 |
| 16 | 16 | 17 | 0.157 | 0.171 | 25.23 | 0.523 | 75 | 75 | 76 | 0.303 | 0.1092 | 22.482 | 1.01 |
| 17 | 11 | 18 | 0.218 | 0.285 | 11.906 | 0.727 | 76 | 76 | 77 | 0.206 | 0.144 | 1614.775 | 110.687 |
| 18 | 18 | 19 | 0.118 | 0.185 | 78.523 | 0.393 | 77 | 77 | 78 | 0.233 | 0.084 | 129.817 | 110.777 |
| 19 | 19 | 20 | 0.16 | 0.196 | 351.4 | 0.533 | 78 | 78 | 79 | 0.591 | 0.1773 | 1122.43 | 111.97 |
| 20 | 20 | 21 | 0.12 | 0.189 | 164.2 | 0.4 | 79 | 79 | 80 | 0.126 | 0.0453 | 145.37 | 110.42 |
| 21 | 21 | 22 | 0.12 | 0.0789 | 54.594 | 0.4 | 80 | 67 | 81 | 0.559 | 0.3687 | 223.22 | 1.863 |
| 22 | 22 | 23 | 1.41 | 0.723 | 39.65 | 4.7 | 81 | 81 | 82 | 0.186 | 0.1227 | 162.47 | 0.62 |
| 23 | 23 | 24 | 0.293 | 0.1348 | 95.178 | 0.977 | 82 | 82 | 83 | 0.186 | 0.1227 | 437.92 | 0.62 |
| 24 | 24 | 25 | 0.133 | 0.104 | 150.22 | 0.443 | 83 | 83 | 84 | 0.26 | 0.139 | 183.03 | 0.867 |
| 25 | 25 | 26 | 0.178 | 0.134 | 24.62 | 0.593 | 84 | 84 | 85 | 0.154 | 0.148 | 183.03 | 0.513 |
| 26 | 26 | 27 | 0.178 | 0.134 | 24.62 | 0.593 | 85 | 85 | 86 | 0.23 | 0.128 | 119.29 | 0.767 |
| 27 | 27 | 28 | 0.1866 | 0.127 | 53.336 | 0.622 | 86 | 86 | 87 | 0.252 | 0.106 | 27.96 | 0.84 |
| 28 | 4 | 29 | 0.015 | 0.0296 | 522.62 | 0.05 | 87 | 87 | 88 | 0.18 | 0.148 | 26.515 | 0.6 |
| 29 | 29 | 30 | 0.012 | 0.0276 | 59.117 | 0.04 | 88 | 82 | 89 | 0.16 | 0.182 | 257.16 | 0.533 |
| 30 | 30 | 31 | 0.12 | 0.2766 | 99.554 | 0.4 | 89 | 89 | 90 | 0.2 | 0.23 | 20.6 | 0.667 |
| 31 | 31 | 32 | 0.21 | 0.243 | 318.5 | 0.7 | 90 | 90 | 91 | 0.16 | 0.393 | 11.806 | 0.533 |
| 32 | 32 | 33 | 0.12 | 0.054 | 456.14 | 0.4 | 91 | 91 | 92 | 0.16 | 0.393 | 11.806 | 0.533 |
| 33 | 33 | 34 | 0.178 | 0.234 | 136.79 | 0.593 | 92 | 68 | 93 | 0.669 | 0.2412 | 42.96 | 2.23 |
| 34 | 34 | 35 | 0.178 | 0.234 | 83.302 | 0.593 | 93 | 93 | 94 | 0.266 | 0.1227 | 34.93 | 0.887 |
| 35 | 35 | 36 | 0.154 | 0.162 | 93.082 | 0.513 | 94 | 94 | 95 | 0.266 | 0.1227 | 66.79 | 0.887 |
| 36 | 36 | 37 | 0.21 | 0.1383 | 42.361 | 0.7 | 95 | 95 | 96 | 0.266 | 0.1227 | 81.748 | 0.887 |
| 37 | 37 | 38 | 0.12 | 0.0789 | 51.653 | 0.4 | 96 | 96 | 97 | 0.266 | 0.1227 | 66.526 | 0.887 |
| 38 | 38 | 39 | 0.15 | 0.0987 | 57.965 | 0.5 | 97 | 97 | 98 | 0.233 | 0.115 | 15.96 | 0.777 |
| 39 | 39 | 40 | 0.15 | 0.0987 | 1205.1 | 0.5 | 98 | 98 | 99 | 0.496 | 0.138 | 60.48 | 1.653 |
| 40 | 40 | 41 | 0.24 | 0.1581 | 146.66 | 0.8 | 99 | 95 | 100 | 0.196 | 0.18 | 224.85 | 0.653 |
| 41 | 41 | 42 | 0.12 | 0.0789 | 56.608 | 0.4 | 100 | 100 | 101 | 0.196 | 0.18 | 367.42 | 0.653 |
| 42 | 42 | 43 | 0.405 | 0.1458 | 40.184 | 1.35 | 101 | 101 | 102 | 0.1866 | 0.122 | 11.7 | 0.622 |
| 43 | 43 | 44 | 0.405 | 0.1458 | 283.41 | 1.35 | 102 | 102 | 103 | 0.0746 | 0.318 | 30.392 | 0.249 |
| 44 | 44 | 45 | 0.405 | 0.1458 | 283.41 | 1.35 | 103 | 103 | 104 | 0.0746 | 0.318 | 30.392 | 0.249 |
| 45 | 30 | 46 | 0.33 | 0.194 | 55.134 | 1.1 | 104 | 1 | 105 | 0.0625 | 0.0265 | 47.572 | 0.208 |
| 46 | 46 | 47 | 0.31 | 0.194 | 38.998 | 1.033 | 105 | 105 | 106 | 0.1501 | 0.234 | 350.3 | 0.5 |
| 47 | 47 | 48 | 0.13 | 0.194 | 342.6 | 0.433 | 106 | 106 | 107 | 0.1347 | 0.0888 | 449.29 | 0.449 |
| 48 | 48 | 49 | 0.28 | 0.15 | 278.56 | 0.933 | 107 | 107 | 108 | 0.2307 | 0.1203 | 168.46 | 0.769 |
| 49 | 49 | 50 | 1.18 | 0.85 | 240.24 | 3.933 | 108 | 108 | 109 | 0.447 | 0.1608 | 134.25 | 1.49 |
| 50 | 50 | 51 | 0.42 | 0.2436 | 66.562 | 1.4 | 109 | 109 | 110 | 0.1632 | 0.0588 | 66.024 | 0.544 |
| 51 | 51 | 52 | 0.27 | 0.0972 | 39.76 | 0.9 | 110 | 110 | 111 | 0.33 | 0.099 | 83.647 | 1.1 |
| 52 | 52 | 53 | 0.339 | 0.1221 | 31.964 | 1.13 | 111 | 111 | 112 | 0.156 | 0.0561 | 419.34 | 0.52 |
| 53 | 53 | 54 | 0.27 | 0.1779 | 20.758 | 0.9 | 112 | 112 | 113 | 0.3819 | 0.1374 | 135.88 | 1.273 |
| 54 | 30 | 55 | 0.391 | 0.141 | 26.86 | 1.303 | 113 | 113 | 114 | 0.1626 | 0.0585 | 387.21 | 0.542 |
| 55 | 55 | 56 | 0.406 | 0.1461 | 88.38 | 1.353 | 114 | 114 | 115 | 0.3819 | 0.1374 | 173.46 | 1.273 |
| 56 | 56 | 57 | 0.406 | 0.1461 | 55.436 | 1.353 | 115 | 115 | 116 | 0.2445 | 0.0879 | 898.55 | 0.815 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 | 57 | 58 | 0.706 | 0.5461 | 332.4 | 2.353 | 116 | 116 | 117 | 0.2088 | 0.0753 | 215.37 | 0.696 |
| 58 | 58 | 59 | 0.338 | 0.1218 | 16.83 | 1.127 | 117 | 117 | 118 | 0.2301 | 0.0828 | 40.97 | 0.767 |
| 59 | 59 | 60 | 0.338 | 6 | 49.156 | 1.127 | 118 | 105 | 119 | 0.6102 | 0.2196 | 192.9 | 2.034 |

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