Supplementary material

**I. Modified IEEE 14-node system**

A. Data of wind farm and power grid

1) Bus data

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Bus** |  |  |  |  |  |  |  |  |
| 1 | 0 | 0 | 0 | 0 | 1.060 | 0 | 1.060 | 0.940 |
| 2 | 21.70 | 12.70 | 0 | 0 | 1.045 | -4.980 | 1.060 | 0.940 |
| 3 | 94.20 | 19.00 | 0 | 0 | 1.010 | -12.72 | 1.060 | 0.940 |
| 4 | 47.80 | -3.900 | 0 | 0 | 1.019 | -10.33 | 1.060 | 0.940 |
| 5 | 7.600 | 1.600 | 0 | 0 | 1.020 | -8.780 | 1.060 | 0.940 |
| 6 | 11.20 | 7.500 | 0 | 0 | 1.050 | -14.22 | 1.060 | 0.940 |
| 7 | 0 | 0 | 0 | 0 | 1.062 | -13.37 | 1.060 | 0.940 |
| 8 | 0 | 0 | 0 | 0 | 1.050 | -13.36 | 1.060 | 0.940 |
| 9 | 29.50 | 16.60 | 0 | 0.19 | 1.056 | -14.94 | 1.060 | 0.940 |
| 10 | 9.000 | 5.800 | 0 | 0 | 1.051 | -15.10 | 1.060 | 0.940 |
| 11 | 3.50 | 1.800 | 0 | 0 | 1.057 | -14.79 | 1.060 | 0.940 |
| 12 | 6.100 | 1.600 | 0 | 0 | 1.055 | -15.07 | 1.060 | 0.940 |
| 13 | 13.50 | 5.800 | 0 | 0 | 1.050 | -15.16 | 1.060 | 0.940 |
| 14 | 14.90 | 5.000 | 0 | 0 | 1.036 | -16.04 | 1.060 | 0.940 |

2) Branch data

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **From**  **bus** | **To**  **bus** |  |  |  |  | **Ratio** |
| 1 | 2 | 0.0194 | 0.0592 | 0.0528 | 170 | 1 |
| 2 | 3 | 0.0470 | 0.1980 | 0.0438 | 80 | 1 |
| 2 | 4 | 0.0581 | 0.1763 | 0.0340 | 90 | 1 |
| 2 | 5 | 0.0570 | 0.1739 | 0.0346 | 75 | 1 |
| 3 | 4 | 0.0670 | 0.1710 | 0.0128 | 90 | 1 |
| 4 | 5 | 0.0134 | 0.0421 | 0.0000 | 70 | 1 |
| 4 | 7 | 0.0000 | 0.2091 | 0.0000 | 80 | 0.978 |
| 4 | 9 | 0.0000 | 0.5562 | 0.0000 | 60 | 0.969 |
| 5 | 6 | 0.0000 | 0.2520 | 0.0000 | 70 | 0.932 |
| 6 | 11 | 0.0950 | 0.1989 | 0.0000 | 50 | 1 |
| 6 | 12 | 0.1229 | 0.2558 | 0.0000 | 60 | 1 |
| 6 | 13 | 0.0662 | 0.1303 | 0.0000 | 60 | 1 |
| 7 | 8 | 0.0000 | 0.1762 | 0.0000 | 60 | 1 |
| 7 | 9 | 0.0000 | 0.1100 | 0.0000 | 60 | 1 |
| 9 | 10 | 0.0318 | 0.0845 | 0.0000 | 60 | 1 |
| 9 | 14 | 0.1271 | 0.2704 | 0.0000 | 50 | 1 |
| (Continued table) | | | | | | |
| 10 | 11 | 0.0821 | 0.1921 | 0.0000 | 40 | 1 |
| 12 | 13 | 0.2209 | 0.1999 | 0.0000 | 40 | 1 |
| 13 | 14 | 0.1709 | 0.3480 | 0.0000 | 40 | 1 |

3) Generator data

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Bus** |  |  |  |  |  |  |  |
| 1 | 232.4 | -16.90 | 332.4 | 0 | 10 | 0 | 1.060 |
| 2 | 40.00 | 42.40 | 140.0 | 0 | 50 | -40 | 1.045 |
| 3 | 0.000 | 23.40 | 100.0 | 0 | 40 | 0 | 1.010 |
| 6 | 0.000 | 12.20 | 100.0 | 0 | 24 | -6 | 1.070 |
| 8 | 0.000 | 17.40 | 100.0 | 0 | 24 | -6 | 1.090 |

4) Wind farm data

|  |  |  |  |
| --- | --- | --- | --- |
| **Bus** |  |  | **Type** |
| 13 | 51 | 0 | PMSG |

5) Static var generator (reactive power compensation equipment)

|  |  |  |  |
| --- | --- | --- | --- |
| **Bus** |  |  | **Type** |
| 13 | 20 | -20 | SVG |

6) Historical wind active power at 24 hours

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Hour** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|  | 0.0500 | 0.8000 | 0.4897 | 0.3395 | 0.9516 | 0.9203 | 0.0527 | 0.7379 |
| **Hour** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
|  | 0.2691 | 0.4228 | 0.5479 | 0.9427 | 0.4177 | 0.9831 | 0.3015 | 0.7011 |
| **Hour** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
|  | 0.6663 | 0.5391 | 0.6981 | 0.6665 | 0.1781 | 0.1280 | 0.9991 | 0.1711 |

7) Load power at 24 hours



B. Data of different wind generation penetration levels (Percentage of wind power = PWP)

1) Wind generation penetration level 20%

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Hour** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| PWP | 0.95% | 16.68% | 9.62% | 7.01% | 19.88% | 17.95% | 1.08% | 14.96% |
| **Hour** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| PWP | 5.40% | 7.69% | 10.69% | 18.28% | 7.81% | 19.65% | 5.80% | 13.95% |
| **Hour** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| PWP | 13.16% | 9.98% | 15.29% | 14.02% | 3.64% | 2.38% | 18.59% | 3.61% |

2) Wind generation penetration level 30%

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Hour** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| PWP | 1.45% | 25.51% | 14.71% | 10.73% | 30.41% | 27.45% | 1.65% | 22.88% |
| **Hour** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| PWP | 8.27% | 11.77% | 16.34% | 27.96% | 11.95% | 30.06% | 8.86% | 21.33% |
| **Hour** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| PWP | 20.13% | 15.26% | 23.39% | 21.45% | 5.57% | 3.64% | 28.43% | 5.53% |

3) Wind generation penetration level 40%

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Hour** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| PWP | 1.67% | 29.44% | 16.97% | 12.38% | 35.09% | 31.67% | 1.91% | 26.40% |
| **Hour** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| PWP | 9.54% | 13.58% | 18.86% | 32.26% | 13.79% | 34.68% | 10.23% | 24.61% |
| **Hour** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| PWP | 23.23% | 17.61% | 26.98% | 24.75% | 6.42% | 4.20% | 32.81% | 6.38% |

**II. A real-sized power system in China (183 nodes)**

A. data of wind farm and power grid

1) Wind farm data

|  |  |  |  |
| --- | --- | --- | --- |
| **Bus** |  |  | **Type** |
| 69 | 1215 | 0 | PMSG |

2) Static var generator (reactive power compensation equipment)

|  |  |  |  |
| --- | --- | --- | --- |
| **Bus** |  |  | **Type** |
| 69 | 250 | -250 | SVG |

3) Historical wind active power at 24 hours

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Hour** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|  | 0.2455 | 0.1937 | 0.0909 | 0.3684 | 0.0078 | 0.6027 | 0.4789 | 0.3081 |
| **Hour** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
|  | 0.2455 | 0.1937 | 0.0909 | 0.3684 | 0.0078 | 0.6027 | 0.4789 | 0.3081 |
| **Hour** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
|  | 0.6265 | 0.1813 | 0.1230 | 0.5800 | 0.3285 | 0.2682 | 0.5502 | 0.1805 |

4) System summary

Buses: 183

Generators: 33; total gen capacity: 29535MW, -21701.0Mvar to 25398.4Mvar

Loads: 140, 6295.2MW, 3324.0Mvar in total

Shunts: 6, -16.2Mvar in total

Branches: 308

Transformers: 308

Please contact the author if you need the detailed system data.

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