Tri-layer Distributed Scheduling for Coastal Integrated Transmission-Distribution-Gas System with Uncertain Typhoons-affected Offshore Wind Power

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## A. Detailed Parameters of the DNs

## 1) Modified IEEE33-bus DN

Bus data of the DN

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Bus | Active load (MW) | Reactive load (MW) | Base voltage magnitude (kV) | Max voltage magnitude  (p.u.) | Min voltage magnitude  (p.u.) |
| 1 | 0 | 0 | 12.66 | 1.1 | 0.9 |
| 2 | 3 | 1.5 | 12.66 | 1.1 | 0.9 |
| 3 | 2.7 | 1 | 12.66 | 1.1 | 0.9 |
| 4 | 3.6 | 2 | 12.66 | 1.1 | 0.9 |
| 5 | 1.8 | 0.75 | 12.66 | 1.1 | 0.9 |
| 6 | 1.8 | 0.5 | 12.66 | 1.1 | 0.9 |
| 7 | 6 | 2.5 | 12.66 | 1.1 | 0.9 |
| 8 | 6 | 2.5 | 12.66 | 1.1 | 0.9 |
| 9 | 1.8 | 0.5 | 12.66 | 1.1 | 0.9 |
| 10 | 1.8 | 0.5 | 12.66 | 1.1 | 0.9 |
| 11 | 1.35 | 0.75 | 12.66 | 1.1 | 0.9 |
| 12 | 1.8 | 0.875 | 12.66 | 1.1 | 0.9 |
| 13 | 1.8 | 0.875 | 12.66 | 1.1 | 0.9 |
| 14 | 3.6 | 2 | 12.66 | 1.1 | 0.9 |
| 15 | 1.8 | 0.25 | 12.66 | 1.1 | 0.9 |
| 16 | 1.8 | 0.5 | 12.66 | 1.1 | 0.9 |
| 17 | 1.8 | 0.5 | 12.66 | 1.1 | 0.9 |
| 18 | 2.7 | 1 | 12.66 | 1.1 | 0.9 |
| 19 | 2.7 | 1 | 12.66 | 1.1 | 0.9 |
| 20 | 2.7 | 1 | 12.66 | 1.1 | 0.9 |
| 21 | 2.7 | 1 | 12.66 | 1.1 | 0.9 |
| 22 | 2.7 | 1 | 12.66 | 1.1 | 0.9 |
| 23 | 2.7 | 1.25 | 12.66 | 1.1 | 0.9 |
| 24 | 12.6 | 5 | 12.66 | 1.1 | 0.9 |
| 25 | 12.6 | 5 | 12.66 | 1.1 | 0.9 |
| 26 | 1.8 | 0.625 | 12.66 | 1.1 | 0.9 |
| 27 | 1.8 | 0.625 | 12.66 | 1.1 | 0.9 |
| 28 | 1.8 | 0.5 | 12.66 | 1.1 | 0.9 |
| 29 | 3.6 | 1.75 | 12.66 | 1.1 | 0.9 |
| 30 | 6 | 10 | 12.66 | 1.1 | 0.9 |
| 31 | 4.5 | 1.75 | 12.66 | 1.1 | 0.9 |
| 32 | 6.3 | 2.5 | 12.66 | 1.1 | 0.9 |
| 33 | 1.8 | 1 | 12.66 | 1.1 | 0.9 |

Line data of the DN

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Line | Form bus | To bus | Resistance (kohms) | Reactance (kohms) |
| 1 | 1 | 2 | 0.00922 | 0.0047 |
| 2 | 2 | 3 | 0.0493 | 0.02511 |
| 3 | 3 | 4 | 0.0366 | 0.01864 |
| 4 | 4 | 5 | 0.03811 | 0.01941 |
| 5 | 5 | 6 | 0.0819 | 0.0707 |
| 6 | 6 | 7 | 0.01872 | 0.06188 |
| 7 | 7 | 8 | 0.17114 | 0.12351 |
| 8 | 8 | 9 | 0.103 | 0.074 |
| 9 | 9 | 10 | 0.1044 | 0.074 |
| 10 | 10 | 11 | 0.01966 | 0.0065 |
| 11 | 11 | 12 | 0.03744 | 0.01238 |
| 12 | 12 | 13 | 0.1468 | 0.1155 |
| 13 | 13 | 14 | 0.05416 | 0.07129 |
| 14 | 14 | 15 | 0.0591 | 0.0526 |
| 15 | 15 | 16 | 0.07463 | 0.0545 |
| 16 | 16 | 17 | 0.1289 | 0.1721 |
| 17 | 17 | 18 | 0.0732 | 0.0574 |
| 18 | 2 | 19 | 0.0164 | 0.01565 |
| 19 | 19 | 20 | 0.15042 | 0.13554 |
| 20 | 20 | 21 | 0.04095 | 0.04784 |
| 21 | 21 | 22 | 0.07089 | 0.09373 |
| 22 | 3 | 23 | 0.04512 | 0.03083 |
| 23 | 23 | 24 | 0.0898 | 0.07091 |
| 24 | 24 | 25 | 0.0896 | 0.07011 |
| 25 | 6 | 26 | 0.0203 | 0.01034 |
| 26 | 26 | 27 | 0.02842 | 0.01447 |
| 27 | 27 | 28 | 0.1059 | 0.09337 |
| 28 | 28 | 29 | 0.08042 | 0.07006 |
| 29 | 29 | 30 | 0.05075 | 0.02585 |
| 30 | 30 | 31 | 0.09744 | 0.0963 |
| 31 | 31 | 32 | 0.03105 | 0.03619 |
| 32 | 32 | 33 | 0.0341 | 0.05302 |

Units data of the DN

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Unit | Bus | Max active power output (MW) | Max reactive power output (MVar) | Min active power output (MW) | Min reactive power output (MVar) |
| DG1 | 18 | 20 | 60 | 0 | 14 |
| DG2 | 22 | 18 | 40 | 0 | 10 |
| GT1 | 10 | 15 | 35 | 0 | 6 |
| GT2 | 33 | 12 | 25 | 0 | 4 |
| P2G | 15 | 5 | —— | 0 | —— |
| BS1 | 14 | 6 | —— | 0 | —— |

1:The maximum capacity of BS is 15 MWh.

Cost coefficient of the DN

|  |  |  |
| --- | --- | --- |
| Unit | First-order cost coefficient ($/MWh) | Constant cost coefficient ($/MWh) |
| DG1 | 50 | 20 |
| DG2 | 55 | 20 |
| GT1 | 40 | 15 |
| GT2 | 45 | 15 |
| P2G | 10 | —— |
| BS1 | 5 | —— |

1:The cost coefficient of discharging a BS is 80% of the cost of charging it.

Power Load curve for 24 periods

|  |  |
| --- | --- |
| Scheduling period (15 mins) | Load factor (p.u.) |
| 1 | 0.9810 |
| 2 | 0.9387 |
| 3 | 0.9664 |
| 4 | 0.9944 |
| 5 | 1.0000 |
| 6 | 0.9484 |
| 7 | 0.9145 |
| 8 | 0.9126 |
| 9 | 0.9407 |
| 10 | 0.9255 |
| 11 | 0.9414 |
| 12 | 0.9161 |
| 13 | 0.9685 |
| 14 | 0.9794 |
| 15 | 0.9706 |
| 16 | 0.9512 |
| 17 | 0.9442 |
| 18 | 0.9260 |
| 19 | 0.9385 |
| 20 | 0.9720 |
| 21 | 0.9527 |
| 22 | 0.9080 |
| 23 | 0.8967 |
| 24 | 0.9172 |

## B. Detailed Parameters of the GNs

## 1) Modified 20-node radial GN

Bus data of the GN

|  |  |  |  |
| --- | --- | --- | --- |
| Bus | Max pressure (bar) | Min pressure (bar) | Gas load factor (p.u.) |
| 1 | 77 | 0 | 0 |
| 2 | 77 | 0 | 0.0625 |
| 3 | 80 | 30 | 0 |
| 4 | 80 | 0 | 0.0625 |
| 5 | 77 | 0 | 0 |
| 6 | 80 | 30 | 0 |
| 7 | 80 | 30 | 0.0625 |
| 8 | 66.2 | 0 | 0.0625 |
| 9 | 66.2 | 0 | 0.0625 |
| 10 | 66.2 | 30 | 0.0625 |
| 11 | 66.2 | 0 | 0.0625 |
| 12 | 66.2 | 0 | 0.0625 |
| 13 | 66.2 | 0 | 0.0625 |
| 14 | 66.2 | 0 | 0.0625 |
| 15 | 66.2 | 0 | 0.0625 |
| 16 | 66.2 | 0 | 0.0625 |
| 17 | 66.2 | 0 | 0.0625 |
| 18 | 80 | 0 | 0.0625 |
| 19 | 66.2 | 0 | 0.0625 |
| 20 | 66.2 | 25 | 0.0625 |

Pipe data of the DN

|  |  |  |  |
| --- | --- | --- | --- |
| Pipe | Form node | To node | C*k-n* |
| 1 | 1 | 2 | 0.07 |
| 2 | 2 | 3 | 0.404 |
| 3 | 3 | 4 | 0.39 |
| 4 | 5 | 6 | 0.1 |
| 5 | 6 | 7 | 0.15 |
| 6 | 7 | 4 | 0.22 |
| 7 | 4 | 14 | 0.66 |
| 8 | 8 | 9 | 0.26 |
| 9 | 9 | 10 | 0.81 |
| 10 | 10 | 11 | 0.45 |
| 11 | 11 | 12 | 0.86 |
| 12 | 12 | 13 | 0.91 |
| 13 | 13 | 14 | 0.26 |
| 14 | 14 | 15 | 0.63 |
| 15 | 15 | 16 | 0.45 |
| 16 | 11 | 17 | 0.05 |
| 17 | 17 | 18 | 0.006 |
| 18 | 18 | 19 | 0.002 |
| 19 | 19 | 20 | 0.03 |
| 20 | 1 | 2 | 0.07 |

Units data of the DN

|  |  |  |  |
| --- | --- | --- | --- |
| Unit | Max gas output (Mm3) | Min gas output (Mm3) | Cost coefficient ($/Mm3) |
| GS1 | 0.9 | 1.7391 | 85000 |
| GS2 | 0 | 1.26 | 85000 |
| GS3 | 0 | 0.72 | 85000 |
| GS4 | 1 | 2.3018 | 62000 |

Gas Load curve for 24 periods

|  |  |
| --- | --- |
| Scheduling period (15 mins) | Load factor (Mm3) |
| 1 | 0.0545 |
| 2 | 0.0520 |
| 3 | 0.0502 |
| 4 | 0.0508 |
| 5 | 0.0538 |
| 6 | 0.0582 |
| 7 | 0.0577 |
| 8 | 0.0613 |
| 9 | 0.0627 |
| 10 | 0.0630 |
| 11 | 0.0621 |
| 12 | 0.0620 |
| 13 | 0.0610 |
| 14 | 0.0585 |
| 15 | 0.0590 |
| 16 | 0.0601 |
| 17 | 0.0615 |
| 18 | 0.0630 |
| 19 | 0.0656 |
| 20 | 0.0672 |
| 21 | 0.0665 |
| 22 | 0.0654 |
| 23 | 0.0615 |
| 24 | 0.0570 |

## C. Parameters of typhoon

## 1) Forecast Parameters of 2024 super typhoon Kong-rey

Forecast typhoon Parameters for 24 periods1

|  |  |  |  |
| --- | --- | --- | --- |
| Scheduling period (15 mins) | Longitude (°E) | latitude (°N) | Center pressure (kPa) |
| 1 | 119.885 | 24.45 | 980 |
| 2 | 119.89 | 24.5 | 980 |
| 3 | 119.895 | 24.55 | 980 |
| 4 | 119.9 | 24.6 | 980 |
| 5 | 119.905 | 24.675 | 980.5 |
| 6 | 119.91 | 24.75 | 981 |
| 7 | 119.915 | 24.825 | 981.5 |
| 8 | 119.92 | 24.9 | 982 |
| 9 | 119.94 | 24.95 | 982 |
| 10 | 119.96 | 25 | 982 |
| 11 | 119.98 | 25.05 | 982 |
| 12 | 120 | 25.1 | 982 |
| 13 | 120.055 | 25.225 | 982 |
| 14 | 120.11 | 25.35 | 982 |
| 15 | 120.165 | 25.475 | 982 |
| 16 | 120.22 | 25.6 | 982 |
| 17 | 120.2975 | 25.675 | 982.75 |
| 18 | 120.375 | 25.75 | 983.5 |
| 19 | 120.4525 | 25.825 | 984.25 |
| 20 | 120.53 | 25.9 | 985 |
| 21 | 120.5525 | 25.975 | 985 |
| 22 | 120.575 | 26.05 | 985 |
| 23 | 120.5975 | 26.125 | 985 |
| 24 | 120.62 | 26.2 | 985 |

1:Data from the National Meteorological Centre of China [Online]. Available: http://typhoon.nmc.cn/web.html

## 2) Forecast Parameters of 2020 hurricane Isaias

Forecast typhoon Parameters for 24 periods2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scheduling period (15 mins) | Longitude (°W) | | latitude (°N) | Center pressure (kPa) |
| 1 | 79.7 | | 31.195 | 990 |
| 2 | 79.675 | | 31.275 | 990 |
| 3 | 79.65 | | 31.355 | 990 |
| 4 | 79.625 | 31.435 | | 990.5 |
| 5 | 79.595 | 31.5 | | 988.5 |
| 6 | 79.575 | 31.55 | | 988.5 |
| 7 | 79.55 | 31.605 | | 988.5 |
| 8 | 79.525 | 31.65 | | 988 |
| 9 | 79.5 | 31.7 | | 987.75 |
| 10 | 79.475 | 31.75 | | 987.75 |
| 11 | 79.455 | 31.82 | | 987.5 |
| 12 | 79.435 | 31.88 | | 987.5 |
| 13 | 79.405 | 31.935 | | 985.5 |
| 14 | 79.375 | 31.985 | | 985 |
| 15 | 79.345 | 32.035 | | 985 |
| 16 | 79.31 | 32.085 | | 985 |
| 17 | 79.275 | 32.16 | | 985 |
| 18 | 79.24 | 32.25 | | 985.5 |
| 19 | 79.205 | 32.335 | | 985.25 |
| 20 | 79.17 | 32.425 | | 985 |
| 21 | 79.175 | 32.535 | | 983.25 |
| 22 | 79.185 | 32.645 | | 984.5 |
| 23 | 79.195 | 32.75 | | 985.25 |
| 24 | 79.205 | 32.865 | | 986.75 |

2:Data from the U.S. National Oceanic and Atmospheric Administration [Online]. Available: https://www.coast.noaa.gov/hurricanes