

Table S1. Optimal cluster number of demand response resources.

| Categories of demand response re- sources | Day-ahead re- ducible loads | | | Day-ahead tran- sferable loads | | | Intraday re- ducible loads | | | Real-time directed load controls | | |
|--|--------------------------------|---|---|-----------------------------------|---|---|-------------------------------|---|---|-------------------------------------|----|----|
| Number of the distribution area | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| Optimal number of clusters | 5 | 5 | 8 | 6 | 5 | 6 | 7 | 7 | 6 | 15 | 14 | 14 |

Table S2. Clustering results of day-ahead type reducible loads.

| Number of the distribu- tion area | Number of the cluster | Time to enter the distribution network t_1 | Time to leave the distributi- on network t_2 | The expected response time t_0 | Maximum reducible power(kW) | Amount of resources |
|---|--------------------------|--|--|--|-----------------------------------|------------------------|
| 1 | 1 | 7:21 | 17:06 | 10:05 | 1.26 | 16 |
| | 2 | 8:42 | 17:08 | 13:28 | 1.23 | 25 |
| | 3 | 10:34 | 19:57 | 14:52 | 1.15 | 22 |
| | 4 | 9:51 | 18:52 | 13:54 | 1.03 | 18 |
| | 5 | 11:05 | 21:42 | 15:46 | 1.57 | 19 |
| 2 | 1 | 8:06 | 16:42 | 13:52 | 1.35 | 27 |
| | 2 | 10:37 | 18:42 | 14:08 | 1.04 | 16 |
| | 3 | 15:24 | 23:58 | 14:37 | 1.21 | 9 |
| | 4 | 9:42 | 18:44 | 15:02 | 1.27 | 23 |
| | 5 | 11:38 | 20:36 | 16:42 | 1.08 | 25 |
| 3 | 1 | 5:24 | 14:37 | 9:37 | 1.09 | 14 |
| | 2 | 7:38 | 15:54 | 10:32 | 1.52 | 8 |
| | 3 | 10:23 | 20:49 | 15:02 | 1.21 | 19 |
| | 4 | 8:28 | 17:43 | 16:21 | 1.17 | 15 |
| | 5 | 11:29 | 20:45 | 15:23 | 1.22 | 13 |
| | 6 | 9:37 | 19:24 | 10:14 | 1.26 | 18 |
| | 7 | 10:03 | 19:02 | 15:47 | 1.13 | 6 |
| | 8 | 9:47 | 18:53 | 10:58 | 1.38 | 7 |

Table S3. Clustering results of day-ahead type transferable loads.

| Number of the distribu- tion area | Number of the cluster | Time to enter The distribu- tion network t_1 | The durati- on in the distributio- n network Δt | Time to leave the distribution network t_3 | The ex- pected re- sponse time t_0 | Maximum reducible power(kW) | Amount of resources |
|---|-----------------------------|---|---|---|---|-----------------------------------|------------------------|
| 1 | 1 | 6:32 | 3:23 | 18:55 | 8:22 | 1.73 | 14 |
| | 2 | 8:12 | 3:05 | 20:56 | 9:03 | 1.61 | 17 |
| | 3 | 9:45 | 4:22 | 17:22 | 11:10 | 1.98 | 15 |
| | 4 | 10:43 | 4:05 | 17:52 | 11:55 | 1.77 | 25 |
| | 5 | 17:05 | 3:03 | 23:51 | 18:22 | 1.65 | 16 |
| | 6 | 17:51 | 4:56 | 23:58 | 20:00 | 1.85 | 13 |

| | | | | | | | |
|---|---|-------|------|-------|-------|------|----|
| 2 | 1 | 5:22 | 3:19 | 16:37 | 8:22 | 1.92 | 23 |
| | 2 | 6:38 | 2:55 | 18:25 | 8:03 | 1.78 | 16 |
| | 3 | 17:08 | 3:35 | 23:55 | 19:32 | 1.56 | 28 |
| | 4 | 11:45 | 2:59 | 22:52 | 13:18 | 1.88 | 13 |
| | 5 | 17:38 | 3:01 | 23:58 | 20:03 | 1.69 | 20 |
| 3 | 1 | 18:02 | 3:49 | 24:00 | 21:12 | 1.59 | 13 |
| | 2 | 5:52 | 3:02 | 17:48 | 8:11 | 1.87 | 17 |
| | 3 | 10:24 | 2:29 | 21:19 | 12:13 | 1.94 | 20 |
| | 4 | 16:52 | 3:06 | 23:51 | 18:55 | 1.99 | 28 |
| | 5 | 17:03 | 4:16 | 23:59 | 21:02 | 1.54 | 14 |
| | 6 | 17:29 | 3:29 | 23:57 | 19:23 | 1.83 | 8 |

Table S4. Clustering results of intraday type reducible loads.

| Number of the distribution area | Number of the cluster | Time to enter the distribution on network t_1 | Time to leave the distribution on network t_2 | The expected response time t_0 | Maximum reducible power(kW) | Amount of resources |
|---------------------------------|-----------------------|---|---|----------------------------------|-----------------------------|---------------------|
| 1 | 1 | 10:47 | 14:32 | 13:41 | 0.88 | 9 |
| | 2 | 11:46 | 15:19 | 12:07 | 0.73 | 18 |
| | 3 | 7:13 | 10:15 | 9:45 | 0.64 | 24 |
| | 4 | 1:57 | 5:16 | 3:21 | 0.92 | 13 |
| | 5 | 16:34 | 18:47 | 16:44 | 0.85 | 16 |
| | 6 | 18:48 | 22:27 | 21:32 | 0.77 | 13 |
| | 7 | 3:10 | 7:55 | 6:23 | 0.69 | 7 |
| 2 | 1 | 6:12 | 10:27 | 9:21 | 0.72 | 18 |
| | 2 | 10:35 | 14:33 | 11:08 | 0.83 | 13 |
| | 3 | 13:21 | 15:47 | 14:17 | 0.95 | 7 |
| | 4 | 9:14 | 13:03 | 10:42 | 0.78 | 10 |
| | 5 | 2:05 | 6:48 | 5:21 | 0.67 | 17 |
| | 6 | 19:21 | 23:45 | 21:21 | 0.88 | 10 |
| | 7 | 18:08 | 21:49 | 20:38 | 0.9 | 25 |
| 3 | 1 | 4:15 | 9:03 | 5:15 | 0.9 | 15 |
| | 2 | 7:25 | 12:24 | 9:14 | 0.87 | 12 |
| | 3 | 11:24 | 14:32 | 14:05 | 0.84 | 23 |
| | 4 | 16:43 | 21:41 | 17:01 | 0.73 | 20 |
| | 5 | 20:05 | 23:00 | 21:21 | 0.78 | 13 |
| | 6 | 6:33 | 10:03 | 10:00 | 0.8 | 17 |

Table S5. Clustering results of real-time type directly controlled loads.

| Number of the distribution area | Number of the cluster | Time to enter the distribution on network t_1 | Time to leave the distribution on network t_2 | The expected response time t_0 | Maximum regulatory power(kW) | Amount of resources |
|---------------------------------|-----------------------|---|---|----------------------------------|------------------------------|---------------------|
|---------------------------------|-----------------------|---|---|----------------------------------|------------------------------|---------------------|

| | | | | | | |
|---|----|-------|-------|-------|------|----|
| 1 | 1 | 11:31 | 13:22 | 12:45 | 0.45 | 5 |
| | 2 | 15:22 | 17:58 | 16:22 | 0.39 | 6 |
| | 3 | 2:03 | 4:48 | 3:07 | 0.44 | 5 |
| | 4 | 5:41 | 7:35 | 6:18 | 0.55 | 8 |
| | 5 | 20:25 | 22:38 | 21:03 | 0.54 | 4 |
| | 6 | 7:00 | 9:55 | 8:02 | 0.51 | 6 |
| | 7 | 16:27 | 18:46 | 17:35 | 0.63 | 7 |
| | 8 | 21:13 | 23:44 | 21:56 | 0.53 | 6 |
| | 9 | 6:16 | 8:25 | 7:15 | 0.66 | 5 |
| | 10 | 6:45 | 8:03 | 7:42 | 0.47 | 6 |
| | 11 | 5:44 | 7:34 | 6:15 | 0.53 | 14 |
| | 12 | 9:14 | 11:28 | 10:09 | 0.60 | 8 |
| | 13 | 10:24 | 12:57 | 10:58 | 0.48 | 5 |
| | 14 | 6:33 | 7:59 | 7:32 | 0.65 | 4 |
| | 15 | 5:42 | 7:38 | 7:13 | 0.75 | 11 |
| 2 | 1 | 7:08 | 9:37 | 8:21 | 0.63 | 6 |
| | 2 | 10:54 | 13:28 | 11:56 | 0.47 | 5 |
| | 3 | 17:13 | 18:58 | 18:25 | 0.55 | 8 |
| | 4 | 17:59 | 19:08 | 18:53 | 0.59 | 5 |
| | 5 | 18:27 | 20:41 | 20:07 | 0.43 | 10 |
| | 6 | 20:43 | 23:41 | 22:43 | 0.67 | 7 |
| | 7 | 2:22 | 4:35 | 2:55 | 0.5 | 5 |
| | 8 | 0:13 | 3:02 | 2:08 | 0.52 | 7 |
| | 9 | 9:01 | 11:23 | 10:16 | 0.42 | 5 |
| | 10 | 10:11 | 12:48 | 10:55 | 0.48 | 4 |
| | 11 | 16:25 | 18:43 | 17:33 | 0.71 | 8 |
| | 12 | 3:44 | 5:57 | 4:02 | 0.62 | 13 |
| | 13 | 16:55 | 19:24 | 18:22 | 0.66 | 8 |
| | 14 | 8:44 | 9:51 | 9:05 | 0.38 | 9 |
| 3 | 1 | 6:14 | 9:11 | 7:36 | 0.48 | 9 |
| | 2 | 7:15 | 9:57 | 8:34 | 0.57 | 7 |
| | 3 | 11:27 | 13:48 | 11:56 | 0.62 | 5 |
| | 4 | 12:32 | 15:13 | 13:42 | 0.54 | 7 |
| | 5 | 17:38 | 18:58 | 17:58 | 0.43 | 4 |
| | 6 | 18:29 | 20:34 | 19:53 | 0.68 | 11 |
| | 7 | 20:46 | 23:39 | 22:19 | 0.6 | 5 |
| | 8 | 2:12 | 4:53 | 3:01 | 0.4 | 6 |
| | 9 | 4:23 | 6:55 | 4:56 | 0.56 | 7 |
| | 10 | 10:13 | 12:49 | 11:34 | 0.67 | 10 |
| | 11 | 5:44 | 7:15 | 6:27 | 0.44 | 6 |
| | 12 | 15:55 | 18:43 | 17:22 | 0.58 | 7 |
| | 13 | 6:11 | 8:38 | 7:06 | 0.7 | 12 |

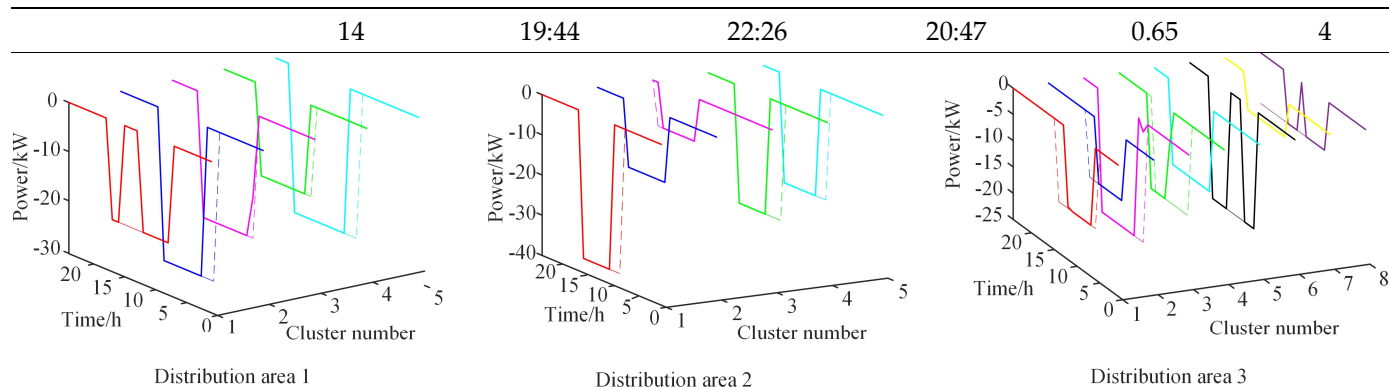


Figure S1. Optimal results of day-ahead type reducible loads in the day-ahead stage.

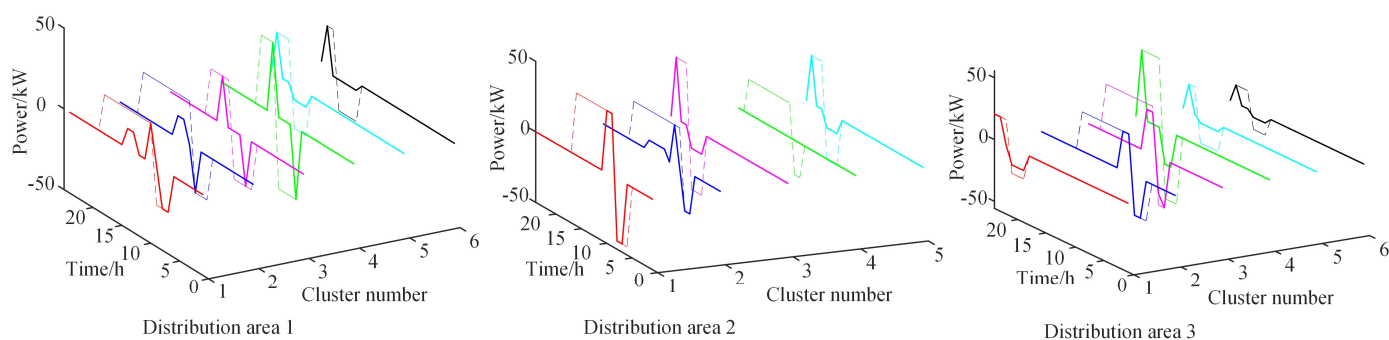


Figure S2. Optimal results of day-ahead type transferable loads in the day-ahead stage.

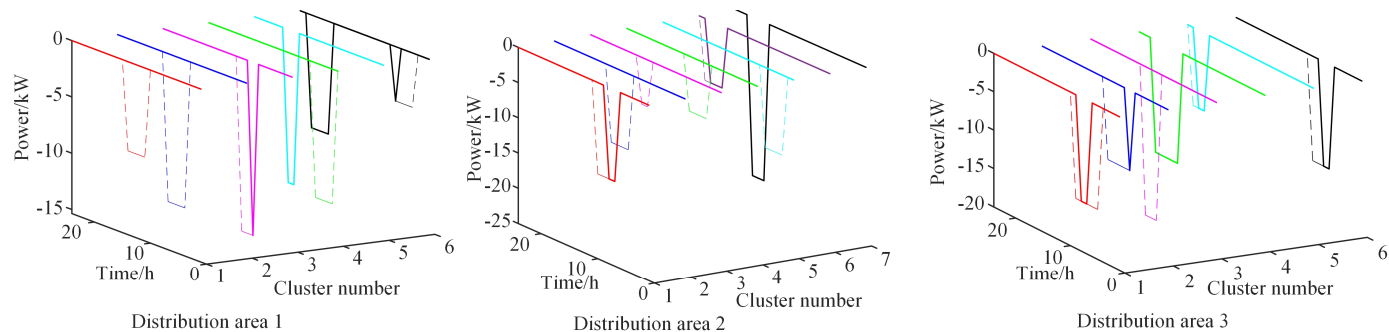


Figure S3. Optimal results of intraday type reducible loads in the day-ahead stage.

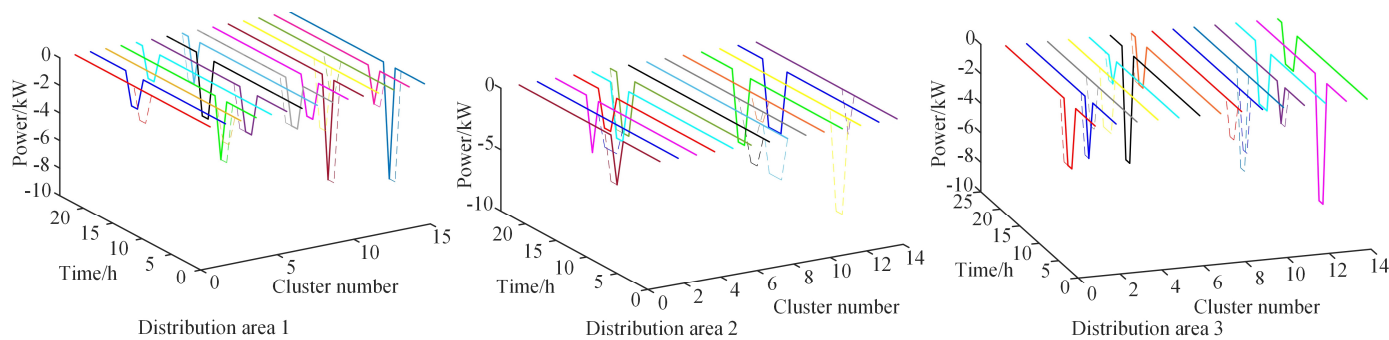


Figure S4. Optimal results of real-time type directly controlled load controls in the day-ahead stage.

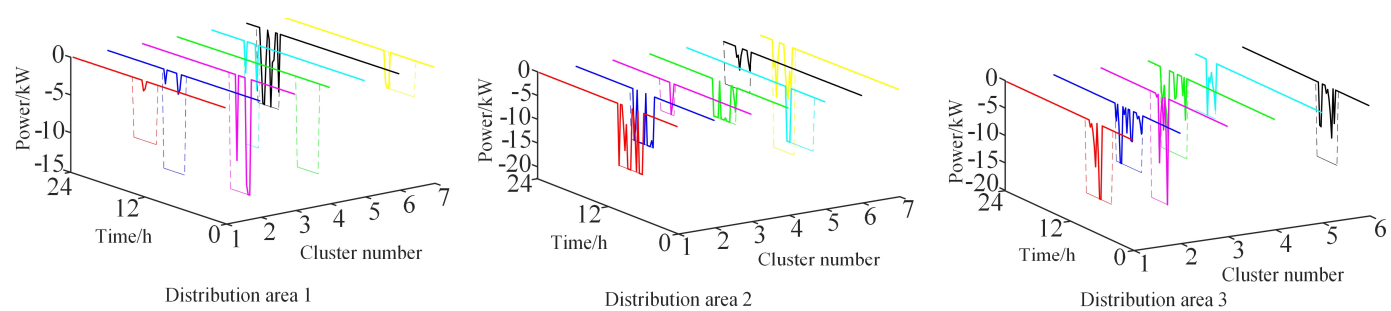


Figure S5. Optimal results of intraday type reducible loads in the intraday stage.