The Appendix of “Deciding Sharing Mode for Multi-microgrid System Considering Risk and Coordination Cost”

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*Abstract—*This material presents some related contents in the paper “Deciding Sharing Mode for Multi-microgrid System Considering Risk and Coordination Cost”.

1) Nomenclature

|  |  |  |
| --- | --- | --- |
| *Indices* | | |
| *i*, *j* | Index of MGs. |
| *t* | Index of time periods. |
| *k* | Index of power sharing modes. |
| *α*, *β* | Index of risk evaluation criterions. |
| *ω* | Index of decision-making factors. |
| *Sets* |  |
| *N* | Set of MGs. |
| *T* | Set of time periods. |
| *Parameters* |  |
| *k*BT*/k*WT*/k*PV | Operating cost coefficient of BT, WT and PV. |
| *b* | Equivalent emission factor per unit corresponding to the purchasing power from grid. |
|  | Emission price. |
| / | Buying/selling price of power from/to grid. |
| // / | Initial/remaining/maximum/minimum capacity of battery. |
| / | Maximum charge/discharge power of battery. |
|  | Maximum exchanged power with grid. |
|  | Maximum exchanged power between MGs*.* |
| / | Total power supply/demand at *t*-th time period. |
| / | Lower/upper bound of biding price of MG *i*. |
| / | Lower/upper bound of biding power of MG *i*. |
|  | Coordination coefficients of three sharing modes. |
| *Variables* |  |
| *P*BT*/P*WT*/P*PV | Power of BT, WT and PV. |
| / | Buying/selling power of MG *i* from/to grid at *t*-th time period. |
| / | Power supply/demand of MG *i* at *t*-th time period. |
|  | Load demand of MG *i* at *t*-th time period. |
|  | Battery capacity of MG *i* at *t*-th time period. |
| / | Charge/discharge power of MG *i* at *t*-th time period. |
| / | Battery charge/discharge state of MG *i* at *t*-th time period. |
| / | State of buying/selling power from/to grid of MG *i* at *t*-th time period*.* |
| / | Buying/selling power of MG *i* from/to other MGs at *t*-th time period. |
| / | State of buying/selling power from/to other MGs of MG *i* at *t*-th time period*.* |
|  | Supply-demand ratio. |
| / | Buying/selling price of power from/to other MGs. |
| / | Actual buying/selling power of MG *i* from/to other MGs at *t*-th time period. |
| / | Actual buying/selling power of MG *i* from/to grid at *t*-th time period. |
|  | Bidding price of MG *i* at *t*-th time period. |
|  | Bidding price of MG *i* at *t*-th time period. |
|  | Exchanged power contribution of MG *i*. |
|  | Exchanged power of MG *i* at *t*-th time period. |

2) Simplified fuzzy analytic hierarchy process (FAHP):

The fundamental scale for the pairwise rating is shown in Table Ⅰ.

TABLE Ⅰ

THE FUNDAMENTAL SCALES ON A SCALE OF 0.1 – 0.9

|  |  |  |  |
| --- | --- | --- | --- |
| Scale | Meaning | Scale | Meaning |
| 0.1 | Overwhelmingly Less important | 0.6 | Moderately More important |
| 0.2 | Very strongly Less important | 0.7 | Strongly More important |
| 0.3 | Strongly Less important | 0.8 | Very strongly More important |
| 0.4 | Moderately Less important | 0.9 | Overwhelmingly More important |
| 0.5 | Equally important |  |  |
| Note: If *aαβ* is the judgment value when *α* is compared to *β*. Then *aαβ* = 1/*aαβ* is the judgment value when *β* is compared to *α*. | | | |

The pairwise comparison matrix *A* (element *aαβ*) in the criterion level is expressed as follows.

 (1)

Where *aαβ* is often expressed as a triple (*lαβ*, *mαβ*, *uαβ*) and *mαβ*, *lαβ*, *uαβ* are the mean, the lower and the upper bounds, respectively.

The fuzzy matrix *M* (element *mαβ*) is as follows.

 (2)

Using the following form to transform *M* into the fuzzy consistent matrix *M*1 (element *mαβ*,1).

 (3)

 (4)

Here *n*=3 is the dimension of matrix *A*.

Perform the consistency checking by using the following expressions.

 (5)

 (6)

Whereandare the consistency index.

Using the following form to transform matrix *A* into the non-fuzzy matrix *M*2 (element *mαβ*,2).

 (7)

The weight of criterion *α* can be calculated with the following equation.

 (8)

Finally, convert the weights into scores by the following expression.

 (9)

Here *w*+ and *w*- are the maximum and average weight respectively; *c* and *d* are constants. Take the value of *c* as 80 and the value of *d* as 20, thus the value of *Wα*ranges from 0 to 100.

3) Anti-entropy weight method

The expression of matrix *X* (element *xωk*) is as follows.

 (10)

The expression to convert matrix *X* to normalized matrix *Y* (element *yωk*) is as follows.

 (11)

Whereandare the largest value and the smallest value, respectively, in the *ω*-th row of matrix *X*.

The anti-entropy *Ek* of the evaluation object *k* is expressed as follows.

 (12)

 (13)

Where *pωk* is the weight of *yωk* in *k*-th column.

The weight *θk* of evaluation object *k* and the score *Zω* of factor *ω* can be calculated by the following expressions.

 (14)

 (15)

Here *m*=3 is the number of decision-making factors.

Then, the weight *gω* of factor *ω* can be obtained as follows.

 (16)

Finally the vector of the objective weight is obtained as follows.

 (17)

4) Base data and forecast curves

The parameters of battery are presented in Table Ⅱ. The forecast curves about renewable energy outputs and load power are shown in Fig. 1.

TABLE Ⅱ

Battery Parameters

|  |  |  |
| --- | --- | --- |
| Charge/Discharge Efficiency | Maximum Charge/ Discharge power | Maximum Capacity |
| 0.75 | 100 | 360 |
| Minimum Capacity | Initial Capacity | Self-discharge Rate |
| 80 | 80 | 0.02 |



(a) The forecast curves of industrial MGs and load demand



(b) The forecast curves of commercial MGs and load demand



(c) The forecast curves of residential MGs and load demand

Fig. 1. The forecast curves about renewable energy output and load demand.