A Supply and Demand Matching Algorithm for Industry-Park-Level Power System Considering Multiple Timeframe Outputs of Distributed Generators

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Abstract. In this paper, a supply and demand matching algorithm for industry park level energy systems is proposed. The algorithm can provide the configuration scheme of distributed generators installed capacity in line with the given load demand. Comprehensively considering the output characteristics of distributed sources such as wind and photovoltaic generators in different timeframes, the outputs of distributed generators are classified into several typical modes, and the installed capacity of distributed generator is matched in line with the representative output mode and the load demand curve so as to realize the balance of energy supply and demand in the industry park. The energy storage device is used to balance the energy due to the asynchronism of the distributed generator output and the load demand. The capacity requirements of the battery under various installed capacities of distributed generators are provided. The proposed algorithm is programmed in MATLAB and verified by the actual data of an industry park in northeast China. The results show that the proposed algorithm can comprehensively consider the output characteristics of distributed generator in different time ranges, and provide reasonable matching schemes of energy supply.

1. Introduction

The power supply-demand matching is one of important steps in the planning of power system in industry park. Be different with the conventional power balance study in distribution planning, the power output characteristics of renewable distributed generators, which are going to be installed in industry park, should be fully considered [1-5]. The interaction of customers is simulated by multi-agent systems, then an day-ahead power supply-demand matching method is given in [6]. The hybrid system which contains solar, wind and bio-mass resources is discussed in [7], an optimization methodology is presented with the aim of minimum life cycle cost. The matching strategy is addressed with purpose of minimizing the social cost in [8]. The component sizing and optimal scheduling method for integrated power system is described in [9]. The matching between renewable generators and load is presented for building energy system in [10]. The optimal capacity calculation formula of distributed PV grid connected is derived on the basis of characteristics of distributed photovoltaic (PV) power [11].The document [12] proposes a supply and demand matching method for power systems in
remote areas, and the average output curve of distributed generators is used to match the average load demand.

In this paper, based on the fact that the output curves of different distributed power types may be different in timeframes, the representative output modes of wind power and PV power in different timeframes are classified, and different output modes are used to match the load demand respectively. The proposed algorithm is programmed in MATLAB, and actual data is employed to verify the proposed algorithm. The results show that the proposed algorithm can fully consider the time difference of outputs of different distributed power types and provide the power supply matching scheme of the industry park.

The rest of the paper is organized as follows: the second section is dedicated to the power output of distributed generators and matching algorithm principle. In the third section, actual data is inputted to the algorithm and the matching scheme of an actual industry park is developed. The fourth part gives the conclusions.

2. Algorithm

The power system of industry park is shown in figure 1. The power demand is equivalent to a load, power supply side consists of distributed wind, PV generators and battery. The park distribution network is connected with the external public power grid. When it is running in usual, the park does not need electricity from the public grid, but it can feed power into the public grid. In case of emergency, such as distributed generators failure, power is obtained from the public grid to ensure normal power supply in the park. The battery is mainly used to solve the difference between the power of the distributed generators and the load demand, so that the excess power generated by the wind and PV generators can be stored in the battery, and stored energy will be used at load peaks to ensure the sustainability of the system.

**Figure 1. Schematic diagram of power system of industry park**

Although power load forecast is very important in power system planning, it is not the focus of this paper. Assuming that the hourly power load curve of the industry park is known, the output of wind and PV generators are calculated as follows:

The active power of wind generator $P_{WG}$ is related to the wind velocity $v_{actual}$, and is calculated in the following formula:

$$P_{WG} = \begin{cases} 
0, & v_{actual} < v_{ci}, v \geq v_{co} \\
(P_{N_{WG}} \times \frac{v_{actual} - v_{ci}}{v_{N} - v_{ci}}), & v_{ci} \leq v_{actual} < v_{N} \\
P_{N_{WG}}, & v_{N} \leq v_{actual} < v_{co} 
\end{cases}$$

(1)

in formula (1), $P_{N_{WG}}$ is rated active power of wind generator, $v_{N}$ is wind turbine nominal wind velocity, $v_{ci}$ is wind turbine cut-in wind velocity, $v_{co}$ is wind turbine cut-out wind velocity.
Active power of distributed PV generator $P_{PV}$ is related to solar radiation $SR_{\text{actual}}$, the relations are shown below:

$$P_{PV} = \begin{cases} P_{N-PV} \frac{SR_{\text{actual}}}{SR_p} & SR_{\text{actual}} < SR_p \\ P_{N-PV} & SR_{\text{actual}} > SR_p \end{cases}$$

(2)

in formula (2), $P_{N-PV}$ is rated active power of PV generator, $SR_{\text{actual}}$ is actual solar radiation; $SR_p$ is solar radiation in the case of which PV generators work at peak power.

The flow chart of the proposed algorithm is shown in figure 2.

**Assumptions:**
1. The distributed generators are installed with purpose of supplying power load in industry, not selling power to utility;
2. For the priority of renewable energy dispatch, the utility accepts the feed-in power whenever there is abundant power output in industry park.

**Inputs:**
1. The representative hourly wind speeds in a year;
2. The representative hourly solar radiation in a year;
3. The forecast hourly load curve of industry park;

The power outs of wind and PV generators are calculated.

The power output modes of renewable generators are classified through combination of wind and PV representative output curves.

With increment of $\delta kW$ of wind generator, the corresponding capacity of PV generators are calculated with the criterion $\Delta P^j \neq 0$.

The matching schemes of power supply and demand is given, and the battery capacity is decided by the balance of energy in a day.

The final matching schemes are selected as the ones which can satisfy power demand under all output modes of distributed generators.

**Figure 2:** Flow chart of the proposed algorithm

In figure 2, $\Delta P^j_i$ is the sum of $\Delta P^j_k(i)$, which is the difference of power between renewable generators and load demand, and is calculated in formula (3).

$$\Delta P_k^j = \sum_{i=1}^{24} \Delta P^j_k(i) = \sum_{i=1}^{24} \left[ P_{\text{we}}^j(i) + P_{\text{pv}}^j(i) - P_L(i) \right]$$

(3)

Where, $i$ represents hours, the unit is $h$,
$j$ is the output model of renewable energy,
$k$ stands for wind generator installed capacity of $k \times \delta kW$,
$P_L(i)$ is power load at time $i$.

Assuming under $j$ output mode, unbalanced quantity of energy at time $i$ is $\Delta E_k^j(i)$, which can be calculated as follows:

$$\Delta E_k^j(i) = \sum_{m=1}^{i} \Delta P_k^j(m)$$

(4)
Where, $\Delta E(i)$ is in kWh.

Under $j$ output mode, the capacity of battery $B^j_k$ is selected in line with the following formula:

$$B^j_k = \max(\Delta E(i)) - \min(\Delta E(i))$$ (5)

On the basis of determining the PV installed capacity in each output mode, the final PV installed capacity should be able to meet the load requirements under all output modes. Thereafter, the battery capacity corresponding to the final PV installed capacity is the finally selected battery capacity.

3. Case Study

An industry park in northeast China is selected as real-field study case. The predicted peak load of the industry park is 18 MW and hourly load curve is shown in figure.3.

![Figure 3: Hourly load curve of industry park](image)

Based on the cluster analysis of the measured wind speed and solar radiation data of the industry park, the representative wind speed and solar radiation curves can be obtained as shown in figure.4.

![Figure 4: Wind speed and solar radiation curve of industry park](image)

According to the above wind speed and the PV output curves, seven representative distributed generators can be determined as shown in table 1.

| Output mode | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-------------|---|---|---|---|---|---|---|
| Month       | Jan., Dec. | Sep. | Jul., Aug. | Feb., Oct., Nov. | Jun. | Mar., Apr. | May |
| Season      | Winter | Autumn | Summer | Winter | Summer | Winter | Spring |

Table 1. The time periods corresponding to output modes of renewable generators
Assuming that due to the space limitation of industry park, 3–10 wind turbines with 600kW rated power capacity can be installed. The proposed algorithm is coded in MATLAB software. The calculated PV installation capacities of 3–10 wind generators under 7 output modes are shown in the table 2.

| Output mode | 1.8 | 2.4 | 3  | 3.6 | 4.2 | 4.8 | 5.4 | 6   |
|-------------|-----|-----|----|-----|-----|-----|-----|-----|
| 1           | 883.9 | 869.0 | 854.0 | 839.1 | 824.1 | 809.2 | 794.3 | 779.4 |
| 2           | 427.0 | 419.8 | 412.6 | 405.4 | 398.2 | 391.0 | 383.7 | 376.5 |
| 3           | 263.7 | 259.3 | 254.8 | 250.3 | 245.9 | 241.4 | 237.0 | 232.5 |
| 4           | 815.6 | 778.0 | 740.2 | 702.5 | 665.0 | 627.1 | 589.5 | 551.8 |
| 5           | 243.3 | 232.1 | 220.8 | 209.6 | 198.3 | 187.1 | 175.9 | 164.6 |
| 6           | 866.6 | 845.9 | 825.2 | 804.5 | 783.7 | 763.0 | 742.3 | 721.6 |
| 7           | 418.7 | 408.7 | 398.7 | 388.6 | 378.6 | 368.6 | 358.6 | 348.6 |

It can be seen from table 2 that PV installed capacities under the same wind generator capacity are different among seven output modes, especially the difference of the required PV generator capacity in winter and summer is more than 3 times.

The final matching schemes of PV and battery installation capacities are selected as shown in table 3.

| Output mode | 1.8 | 2.4 | 3  | 3.6 | 4.2 | 4.8 | 5.4 | 6   |
|-------------|-----|-----|----|-----|-----|-----|-----|-----|
| 1           | 883.9 | 869.0 | 854.0 | 839.1 | 824.1 | 809.2 | 794.3 | 779.4 |
| 2           | 427.0 | 419.8 | 412.6 | 405.4 | 398.2 | 391.0 | 383.7 | 376.5 |
| 3           | 263.7 | 259.3 | 254.8 | 250.3 | 245.9 | 241.4 | 237.0 | 232.5 |
| 4           | 815.6 | 778.0 | 740.2 | 702.5 | 665.0 | 627.1 | 589.5 | 551.8 |
| 5           | 243.3 | 232.1 | 220.8 | 209.6 | 198.3 | 187.1 | 175.9 | 164.6 |
| 6           | 866.6 | 845.9 | 825.2 | 804.5 | 783.7 | 763.0 | 742.3 | 721.6 |
| 7           | 418.7 | 408.7 | 398.7 | 388.6 | 378.6 | 368.6 | 358.6 | 348.6 |

### 4. Conclusions

In this paper, a power supply and demand matching algorithm for industry park power system is proposed. Considering the output characteristics of distributed generators in different timeframes, the installed capacities of wind and PV generators are decided for matching load requirements. The main conclusions are as follows:

1. The proposed algorithm can synthetically consider the output characteristics of distributed renewable sources in different timeframes of one year to ensure that the calculated supply scheme can meet the load demand at all time.
2. The proposed algorithm can provide the corresponding matching capacity of PV and battery for different installed capacities of wind generators, in order to ensure the demand of power load in the park.
3. From the calculation of real-field data of an industry park in northeast China, the results show that the corresponding PV installed capacities with same wind generators are different under different output modes, especially in winter and summer, the required PV installed capacity may vary by more than 3 times.
4. For an industry park in northeast China, the corresponding matching schemes of PV and battery capacity under 1.8–6MW wind generators are provided, which verifies the scientificity and feasibility of the proposed algorithm.

At next step, economic comparison and calculation of different energy matching schemes will be carried out in line with the typical cost of wind generator, PV and battery.

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