Research on Providing Data and Space Calculation Support for Site Selection of Power Transmission and Transformation Projects

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Abstract. With the acceleration of urban construction, the urban electricity load has increased rapidly, and electricity shortages have also appeared in various places. However, the rapid development of cities has resulted in a shortage of land. The location of substations and the selection of transmission lines are particularly important in planning. In this paper, distributed power transmission and transformation project to optimize network access with locating and sizing problems, establish an annual loss of power as the objective, and consider the output load timing characteristics of multi-period optimal power flow model. Use representative scenes to simulate the situation throughout the year, and give a method for determining scenes and their weights.

Keywords: Transmission and transformation engineering, site selection, environmental protection, data calculation.

1. Introduction
The difficulty of selecting sites for the substation need to take into account the urban planning, environmental protection, military facilities, land resources, aviation, cultural and many other factors, larger work. In recent years, renewable energy generation technology has been rapid development, which has more mature technology power plants, solar power, biomass power generation, hydro power generation. Site selection and capacity determination for the existing distribution network. Selecting a representative case where a scene characterized by year, and the statistical weight values of each scene, according to the wind a timing characteristic, a timing characteristic curve of the light intensity obtained for each scene 0 - wind speed and light intensity levels for each period corresponding to period 24, the establishment of a multi- The optimal model for the planning of power transmission and transformation projects in multiple periods of scenarios [1]. Discuss the introduction of a separate power plants, photovoltaic power generation and the simultaneous introduction of wind, photovoltaic
power generation equipment three cases, the results showed that consider the timing characteristics that will help wind, photovoltaic power generation complementary strengths and improve the utilization of resources.

2. Site selection and capacity model

Incorporated herein represents 0, variables and access capacity distribution of integer variable. Objective function as follows:

$$\text{min } 365 \times \alpha_i \times \sum_{j=1}^{12} \sum_{c=1}^{24} e_{c,i,j}$$

(1)

In the formula: $\alpha_i$ is the weight of the $i$ scene, there are 12 scenes in total, $c_{i,j}$ is the $j$ period in the $i$ scene, and $e_{c,i,j}$ is the power consumption of the $i$ scene in the $j$ period [2].

$$\text{st } P_{g,c,i,j} - P_{r,c,i,j} + w_s \times P_{w,c,i,j} + r_s \times P_{r,c,i,j}$$

$$= \sum_{k=1}^{n_s} P'_{c,i,j} \times Y_{c,i,j} \times \cos(\theta_{c,i,j} + \delta_{c,i,j} - \delta_{c,i,j})$$

$$Q'_{g,c,i,j} - Q_{r,c,i,j}$$

$$= -\sum_{k=1}^{n_s} Q'_{c,i,j} \times Y_{c,i,j} \times \sin(\theta_{c,i,j} + \delta_{c,i,j} - \delta_{c,i,j}) \forall k,s$$

$$b_s \times w_{min} \leq w_s \leq b_s \times w_{max}$$

$$n_s \times r_{min} \leq r_s \leq n_s \times r_{max}$$

(3)

In the formula: $b_s$ and $n_s$ respectively are the 0 and 1 variables representing the installation position of the wind turbine and photovoltaic power supply; $w_s$ and $r_s$ respectively are the integer variables of the number of installation groups; formula (3) expresses the clamping relationship between the two groups of variables; $P'_{g,c,i,j}$ and $Q'_{g,c,i,j}$ are respectively The active and reactive power output of the conventional power supply during the scene period at the node; $P'_{r,c,i,j}$ and $Q'_{r,c,i,j}$ are its active and reactive power loads; $P'_{w,c,i,j}$ and $P'_{r,c,i,j}$ are the actual output of the wind turbine and photovoltaic power supply scenarios during $i$ period $j$ unit, for example, at 1 o'clock on a sunny day in spring The output status of is $P'_{w,c,i,j}$ and $P'_{r,c,i,j}$.

$$V_{\min} \leq V_s \leq V_{\max}$$

(4)

$$\sum_{i=1}^{\xi} w_s \times P_{w} + r_s \times P_{r} \leq \gamma_1 \times \sum_{i=1}^{\xi} P'_{w,c,i,j} + \gamma_2 \times \sum_{i=1}^{\xi} P'_{r,c,i,j}$$

(5)

$$\sum_{i=1}^{\xi} b_s \leq M_b, \sum_{i=1}^{\xi} n_s \leq M_n$$

(6)
Where: $V_{\min}$ is the lower limit of the node voltage, $V_{\max}$ is the upper limit of the node voltage, $P_w$ and $P_{\phi}$ are the rated power of the unit wind turbine and photovoltaic power supply. Equation (5) is the maximum limit of access capacity. It is considered that the total access capacity shall not exceed the sum of $\gamma_1$ times of conventional power output and $\gamma_2$ times of load. In practice, the multiple can be adjusted according to local policy restrictions. In formula (6), $M_B$ and $M_N$ are the maximum limits for the total number of wind turbines and photovoltaic power sources.

### 3. Output model

The relationship between fan output power and wind speed can be approximated by a piecewise function:

$$P_v(V) = \begin{cases} 
0 & (V < V_i) \cup (V > V_o) \\
\frac{P_r}{V_o - V_i} (V - V_i) & (V_i \leq V \leq V_o) \\
P_r & (V < V_i) 
\end{cases}$$

(7)

In the formula: $V_i$ is the cut-in wind speed, $V_o$ is the rated wind speed, $V_c$ is the cut-out wind speed, and $P_r$ is the rated power of the power plant equipment [3]. The actual output of the wind turbine at that moment can be obtained by bringing the wind speed value of each time period in each scene into equation (7).

The output of photovoltaic power supply depends on the actual characteristics of the equipment itself, the intensity of light and the temperature of the surrounding environment. When the light intensity and ambient temperature are known, the actual output power of the photovoltaic power supply can be calculated by formula (8). The formula is as follows:

$$T_y = T_a + s_o \times \left(\frac{N_{OT} - 20}{0.8}\right)$$

$$I_y = s_o \times \left(I_s + K_v \times (T_c - 25)\right)$$

$$V_y = V_o - K_v \times T_y$$

$$P_{\phi_y}(s_o) = FF \times I_y \times V_y$$

$$FF = \frac{V_{MPP} \times I_{MPP}}{V_o \times I_s}$$

Where: $T_a$ is the ambient temperature; $s_o$ is the light intensity in this state; $N_{OT}$ is the rated temperature of the device; $I_s$ is the short-circuit current; $V_o$ is the open-circuit voltage; $K_v$ is the short-circuit current temperature coefficient; $K_v$ is the open-circuit voltage temperature coefficient; $FF$ is The fill factor of the solar cell; $V_{MPP}$ and $I_{MPP}$ are the current and voltage values at the maximum power point of the photovoltaic cell, respectively [4].

### 4. Simulation results

4.1. Calculation example parameters

A 34-node radial microgrid is used to verify the rationality of the algorithm in this paper. 0-33 are node numbers, and L1-L33 are line numbers. The basic data of nodes and lines are shown in Table 1. MT candidate nodes are 3, 7, 12, 16, 19, WG candidate nodes are 9-11, PV candidate nodes are 24, 30, and BS candidate nodes are the collection of WG and PV nodes. The line model is an overhead line.
LGJ-185 with a resistance of 0.17 /km, a reactance of 0.402 /km, and a maximum carrying capacity of 5 300 kVA. The load power factor is 0.9. The unit power transmission and transformation project rated capacity/electricity is 0.1 MW/ h, the unit MT, WG, PV and BS investment costs are respectively 48, 63, 100, 960,000 yuan, and the number of WG and PV nodes to be selected is limited. Both are 12. The genetic algorithm parameters are as follows: the population is 80 individuals, the maximum number of iterations is 400, the crossover rate is 0.99, and the mutation rate is 0.1.

Table 1. Base load and line data

| Node number | Load/ MW | Load type | Line number | Start node | End node | Line length/m |
|-------------|---------|-----------|-------------|------------|----------|---------------|
| 1           | 0.15    | Residents | L1          | 0          | 1        | 50            |
| 2           | 0.136   | Residents | L2          | 1          | 2        | 60            |
| 3           | 0.133   | Residents | L3          | 2          | 3        | 40            |
| 4           | 0.093   | Residents | L4          | 3          | 4        | 50            |
| 5           | 0.162   | Residents | L5          | 3          | 5        | 45            |
| 6           | 0.226   | business  | L6          | 5          | 6        | 35            |
| 7           | 0.2     | business  | L7          | 6          | 7        | 55            |
| 8           | 0.21    | business  | L8          | 7          | 8        | 60            |
| 9           | 0.236   | business  | L9          | 8          | 9        | 35            |
| 10          | 0.202   | business  | L10         | 9          | 10       | 30            |
| 11          | 0.188   | business  | L11         | 10         | 11       | 45            |
| 12          | 0.166   | Residents | L12         | 8          | 12       | 40            |
| 13          | 0.17    | Residents | L13         | 12         | 13       | 55            |
| 14          | 0.155   | Residents | L14         | 12         | 14       | 80            |
| 15          | 0.164   | Residents | L15         | 14         | 15       | 35            |
| 16          | 0.156   | Residents | L16         | 15         | 16       | 30            |
| 17          | 0.13    | Residents | L17         | 16         | 17       | 40            |
| 18          | 0.123   | Residents | L18         | 16         | 18       | 30            |
| 19          | 0.118   | Residents | L19         | 18         | 19       | 25            |
| 20          | 0.098   | Residents | L20         | 19         | 20       | 30            |
| 21          | 0.105   | Residents | L21         | 20         | 21       | 30            |
| 22          | 0.2     | business  | L22         | 19         | 22       | 35            |
| 23          | 0.19    | business  | L23         | 22         | 23       | 35            |
| 24          | 0.196   | business  | L24         | 22         | 24       | 40            |
| 25          | 0.186   | business  | L25         | 24         | 25       | 35            |
| 26          | 0.22    | business  | L26         | 25         | 26       | 30            |
| 27          | 0.211   | business  | L27         | 26         | 27       | 25            |
| 28          | 0.206   | business  | L28         | 27         | 28       | 30            |
| 29          | 0.096   | Residents | L29         | 24         | 29       | 60            |
| 30          | 0.11    | Residents | L30         | 29         | 30       | 45            |
| 31          | 0.083   | Residents | L31         | 30         | 31       | 30            |
| 32          | 0.094   | Residents | L32         | 30         | 32       | 30            |
| 33          | 0.082   | Residents | L33         | 32         | 33       | 30            |

4.2. Consider environmental costs

If the environmental cost is not considered, the planning model is modified to minimize the investment cost, fuel cost and network loss cost of the power transmission and transformation project in the system. The calculation formula is formula (1)-(2), and the constraint conditions are (3)-(6). The planning schemes with and without environmental costs are shown in Table 2 and 3. Figure 7 shows the total number of installations of power transmission and transformation projects in the planning scheme with and without environmental costs. Option 2 does not consider environmental costs and only optimizes transmission and transformation project investment costs, fuel costs, and network loss.
costs. Therefore, the sum of other investment costs excluding environmental protection costs is better than that of Option 1 (Scheme 1 is RMB 15,038,200, and Option 2 is 15.0174 million yuan). While Option 1 optimizes both economy and environmental protection, although the economy is slightly worse than Option 2, it is better than Option 2 overall after considering environmental protection costs. Therefore, the establishment of a planning model that considers environmental costs is of great significance for guiding the site selection and capacity determination of power transmission and transformation projects [5].

Table 2. Planning scheme (1)

| Types of power transmission and transformation projects | Option 1 consider environmental costs | Option 2 does not consider environmental costs |
|--------------------------------------------------------|---------------------------------------|-----------------------------------------------|
| MT 3(9), 7(8), 12(7), 16(9), 19(8)                      | 3(10), 7(9), 12(10), 16(8), 19(10)    |
| WG 9(9), 10(10), 11(9)                                 | 9(5), 10(4), 11(5)                    |
| PV 24(5), 30(5)                                         | 24(5), 30(4)                          |
| BS 9(9), 10(11), 11(9), 24(5), 30(5)                    | 9(5), 10(5), 11(5), 24(5), 30(5)      |

Table 3. Planning scheme cost (1)

| Program                          | Investment cost | Fuel cost | Environmental protection costs | Network loss cost | Total cost |
|----------------------------------|-----------------|-----------|--------------------------------|------------------|------------|
| Option 1 considers environmental costs | 847.6           | 641.71    | 25.57                          | 14.51            | 1529.39    |
| Option 2 does not consider environmental costs | 643.8           | 844.8     | 34.07                          | 13.14            | 1535.81    |

4.3. Consider timing characteristics

In this paper, by simulating the load and timing characteristics of power transmission and transformation projects, a planning scheme that is more in line with the actual operation of the microgrid is obtained (Scheme 1). If the load and the time sequence characteristics of the power transmission and transformation project are not considered, there is no difference between the power transmission and transformation projects in the system, and the output is based on the rated capacity. The planning schemes obtained are shown in Tables 4 and 5. Scheme 3 without considering the timing characteristics, it is better not to install MT. This is not difficult to understand. Although MT saves investment, the fuel cost and environmental protection cost calculated based on the rated output are very high, resulting in the unit MT comprehensive cost even higher than others. Apart from the unit price, there is no difference between WG and PV, so MT with lower unit price is preferred [6].

Table 4. Planning scheme (2)

| Types of power transmission and transformation projects | Option 1 consider environmental costs | Option 2 does not consider environmental costs |
|--------------------------------------------------------|---------------------------------------|-----------------------------------------------|
| MT 3(9), 7(8), 12(7), 16(9)                            | 3(10), 7(9), 12(10), 16(8), 19(10)    |
| WG 9(9), 10(10), 11(9)                                 | 9(12), 10(12), 11(12)                |
| PV 24(5), 30(5)                                         | 24(6), 30(6)                          |
| BS 9(9), 10(11), 11(9), 24(5)                          | 9(12), 10(12), 11(12), 24(6), 30(6)  |
Table 5. Planning scheme cost (2)

| Program | Investment cost | Fuel cost | Environmental protection cost | Network loss cost | Total cost |
|---------|-----------------|----------|-------------------------------|------------------|------------|
| Option 1 consider timing characteristics | 847.6 | 641.71 | 25.57 | 14.51 | 1529.39 |
| Option 3 does not consider timing characteristics | 807.6 | 0 | 0 | 13.73 | 821.33 |

From the planning results, it is not difficult to see that PV is currently expensive and has limited output time, so it is not suitable for large-scale use in micro-grids; MT has the least investment and controllable output. It is currently an indispensable type of power transmission and transformation project in micro-grids. However, as the number of MT installations increases, fuel costs and environmental compensation costs will also increase [7]. Therefore, the number of MT installations is not the better. It needs to be optimized together with other types of power transmission and transformation projects such as WG to reduce fuel costs and environmental compensation. The compensation cost is controlled within a reasonable range, so that the total cost is optimal.

5. Conclusion
In view of the obvious timing characteristics of load and power transmission and transformation project output under certain conditions, this paper proposes a multi-objective location and capacity model and solution method for transmission and transformation projects based on timing characteristics. The simulation results show the following points: 1. The time series characteristics of the output and load of the transmission and transformation project have a great influence on the location and capacity of the transmission and transformation project; 2. The whole process simulation considering the time sequence will bring the planning result closer It is practical and conducive to truly reflect the economic and technical indicators of the distribution network; 3. Due to the strong complementarity of solar and wind energy, the wind and solar combined power generation system makes up for the resource defects of power plants and independent photovoltaic power generation systems in terms of resources.

References
[1] Mokgonyana, L., Zhang, J., Li, H., & Hu, Y. Optimal location and capacity planning for distributed generation with independent power production and self-generation. Applied Energy, 188(FEB.15) (2017) 140-150.
[2] Liu, W., Niu, S., & Xu, H. Optimal planning of battery energy storage considering reliability benefit and operation strategy in active distribution system. Journal of Modern Power Systems & Clean Energy, 5(2) (2017) 177-186.
[3] Schoch-Spana, M., Selck, F. W., & Goldberg, L. A. A national survey on health department capacity for community engagement in emergency preparedness. Journal of Public Health Management and Practice, 21(2) (2015) 196-207.
[4] Li, C., Gao, S., Zhang, J., Zhao, L., & Wang, L. Moisture effect on soil humus characteristics in a laboratory incubation experiment. Soil & Water Research, 11(1) (2016) 37-43.
[5] Helistoe, N., Kiviluoma, J., Holttinen, H., Lara, J. D., & Hoe, B. M. Including operational aspects in the planning of power systems with large amounts of variable generation: a review of modeling approaches. Wiley Interdisciplinary Reviews: Energy and Environment, 8(5) (2019) 1-34.
[6] Manabe, Y., Toji, K., Hosoda, S., Hara, R., & Oomura, T. Cooperative control and required
capacity evaluation of multiple energy storage systems and biogas generation installed with renewable energy generation. Ieej Transactions on Power & Energy, 135(6) (2015) 362-371.

[7] Sfikas, E. E., Katsigiannis, Y. A., & Georgilakis, P. S. Simultaneous capacity optimization of distributed generation and storage in medium voltage microgrids. International Journal of Electrical Power & Energy Systems, 67(5) (2015) 101-113.