Research On Auxiliary Decision-making Technology In the Early Stage of Power Network Base On Multi-plan Integration

Mengxuan Liu1*, Zihe Zhang1, Shunxian Zhang1, Xiaoliang Zhang1 and Yixing Yin2

1 State Grid Tianjin Construction Company, Tianjin, 300000, China
2 Information Department Beijing Celix Spatial Technology, Beijing, 100000, China
*Corresponding author’s e-mail: 15900286430@163.com

Abstract. Under the current national comprehensive promotion and deployment of "building territorial spatial planning system and supervise its implementation" background, power network planning and construction must be based on the "multi-plan integration", in line with the requirements of territorial spatial planning. This paper puts forward the construction scheme of the "early stage of power network auxiliary decision-making tool basing on multi-plan integration". This tool is based on GIS technology to realize the intelligence, visualization and refinement of substation site and network path selection, which can solve the problem that at present, the grid planning is not coordinated, and inconsistent with other planning, and help improve the efficiency of power network planning and construction.

1. Introduction
With the rapid development of national society and economy, the power industry has been making continuous progress, and the overall construction level of the power grid has been steadily improved. However, the contradiction between the planning of the power grid and the territorial spatial planning has become increasingly prominent in the early stage work of power grid construction. At present, power grid planning cannot be fully integrated into local spatial planning, which leads to incoordination and difficulty in connection between power grid planning and other plans, resulting in serious waste of resources. With more and more scarce land and space resources, it is more difficult to select substation site and implement power network planning.

Based on the above situation, using GIS technology to incorporate the standard and spatial control of territorial spatial planning and power network planning into an auxiliary decision-making tool in the early stage of the grid technology has important research significance and application value. In this way, the intelligent, visual and refined substation site selection and line path planning can be realized, which can greatly reduce the workload and work omissions in the early stage, improve the quality, efficiency and predictability of the early stage work, improve the efficiency of the early stage work, and ensure the safety, reliability and economy of the future power grid.
2. Research Review at Home and Abroad

2.1. Research on auxiliary decision-making technology based on GIS in the early stage of power network

2.1.1. Research abroad
Due to the development and accumulation of GIS open source community for many years and the monopoly of ArcGIS and other mainstream commercial GIS products in the market, the development of GIS technology in foreign countries has been in a leading position. There are many applications of GIS in the early stage of power grid technology decision-making.

For example, GIS technology and digital elevation model are used to analyze potential hydropower resources and assist decision analysis for the site selection of hydropower stations [1]. Use geographic information system to establish wind generator site selection decision support system [2]; Using GIS technology and weighted linear combination method, a scheme for selecting nuclear power plant site is proposed [3]. The spatial analysis capability of GIS is utilized to develop electrification planning and power strategy [4].

2.1.2. Domestic research
China has a vast territory and a large population. With the development of social economy, the demand for electricity is increasing day by day. Power planning needs more and more support and assistance from information technology and Geo-Spatial Technology. There are also numerous researches on the auxiliary decision-making method of GIS of early stage of power planning in China, such as improving the flexibility and advancement of power planning adjustment by using the interaction and intuition of GIS. The information management of power grid based on GIS can realize the organic combination of power grid information management and geographic information system. Intelligent substation planning method is proposed, and GIS software technology is used to realize it and provide strong support for macro decision-making of power grid [5].

2.2. Summary
Based on the domestic and foreign studies, it can be found that in the research of spatial planning, most of the domestic and foreign studies are from the perspective of macro strategy, spatial regulation, compilation technology, etc., and less consideration is given to the connection between space planning and electric power planning, space contradiction, and compilation coordination.

In the research on the auxiliary decision-making technology in the early stage of power grid based on GIS, foreign researches mainly focus on the analysis or problem solving of specific indicators such as site selection, potential calculation and economic benefit calculation. Although the domestic research has considered the compilation of electric power planning, it lacks the research of the overall arrangement and compilation method under the framework system of territorial spatial planning.

3. Influencing Factors of Substation Site Selection and Line Path Selection
In this paper, the spatial control requirements of territorial spatial planning and the impact or requirements of nature reserves, oil and gas pipelines, water conservancy facilities, transportation, communication and other sensitive information related facilities on substation site selection and route selection are summarized. The results are as follows:

3.1. Control elements of territorial spatial planning
- Substation location should try to avoid the ecological protection red line
- Substation location should try to avoid the permanent basic farmland protection red line
- Substation location should be within the limits of urban development
3.2. Nature reserves, cultural relics, mineral resources

- The site should be located away from the protected natural areas and cultural sites and not overlie the mineral resources. Otherwise, the site should obtain the written consent of the relevant authorities[6].

3.3. Inflammable and explosive facilities

- The minimum safety distance between substation and buried pipeline is required to be 10m for 35kV and below, 15m for 110kV and 30m for 220kV and above[7].
- The minimum fireproof distance between substation and petrochemical enterprise is 25m[8].
- The minimum safe distance between outdoor transformer substation, gas station and various equipment in the gas station is 9m~32m below 35kV and 12.5m~45m above 35kV.

3.4. Traffic facilities

- The safe distance between substation site selection and surrounding railway lines shall be maintained:
  - For railway on bridges, the distance between walls of more than 35kV substation and railway requisition lines should be ≥50m
  - For railway on the subgrade, the distance between the walls of 35kV substation and the railway requisition line is considered as ≥50m, and the distance between the walls of more than 110kV substation and the railway requisition line is considered as ≥100m
  - When the rail surface of the railway is higher than the ground of the substation and the elevation difference exceeds 5m, the distance between the enclosure walls of more than 35kV substation and the railway land acquisition line shall be considered as ≥200m

Substation site selection should be close to the highway. On the basis of not destroying the integrity of the road network, limited conditions such as turning radius, transport height and road carrying capacity of the transport road should be considered.

3.5. Communication facilities

- The high voltage power line should not pass through the satellite earth station site, and the high voltage power line above 35kV should be more than 100m from the satellite earth station site.
- With the navigation receiving antenna as the center, there shall not be 1000kV or above AC UHV overhead power lines within a radius of 250m.
- With the VHF directional antenna as the center, there should be no 110kV or higher power transmission lines within the radius of 700m; There should be no high voltage transmission lines of 35kV and above within 500m.
- The permissible distance between the directional beacon antenna and the overhead low voltage power line and overhead high voltage transmission line below 110kV is 150m, and the allowable distance between the antenna and the overhead high voltage transmission line above 110kV is 500m.

3.6. Geological hazards

- The site should have appropriate geological and topographic conditions, and avoid the undesirable geological structures such as landslides, debris flows, subsidence areas and seismic fault zones.

3.7. Residential construction

- When the distribution substation is located outside the residential building, the distance between the outside of the distribution substation and the external wall of the residential building should meet the requirements of fire prevention, noise prevention and electromagnetic radiation protection, and the distribution substation should avoid the horizontal line of sight of the main window
of the household. Considering the particularity of residential buildings, it is suggested that the distance between the outer part of outdoor substation and the outer wall of residential buildings should not be less than 20m, because the electromagnetic field intensity at 20m (within the spectrum range of 0.1MHz ~ 30MHz) outside the 10/0.4kV transformer is generally less than 10V/m, which is within the safe range.

3.8. Water source
- There should be reliable sources of water for production and domestic use near the site.

4. Construction Scheme of the Tool

4.1. Development architecture design
The overall architecture of this tool is divided into five layers: basic data support layer, map service layer, algorithmic logic layer, security layer and user interaction layer.

4.1.1. Basic data support layer
Using relational database to provide data management for basic data, and use MDB, GDB, SDE to provide data source service for spatial data. The underlying data support layer is the data base of the entire tool that supports access up to the map service and direct access to the application.

4.1.2. Map service layer
This layer manages all the background map service configuration files, as well as the connection and invocation parameters of the MapWorld service. Automatic invocation and visualization of map services.

4.1.3. Algorithmic logic layer
Completing the core algorithmic such as spatial analysis, substation site selection and route planning.

4.1.4. Security layer
Protecting the tools and data security, carry out identity verification, anti-SQL injection attack, permission check and other authentication when the user accesses.

4.1.5. Interface Layer
A Windows-based application that runs on a client computer and provides a user interface.

4.2. Core function design
Auxiliary decision-making tool in the early stage of power network basing on multi-plan integration mainly have three core functions: spatial query, line selection rule management and site selection analysis.

4.2.1. Spatial query
This tool can realize the visualization of relevant influencing factors of substation and route location selection, such as ecological protection red line, permanent basic farmland protection red line and other planning control lines, water system, traffic, communication and other data, and can quickly query the spatial planning and control elements of the target area.

4.2.2. Site selection rule management
The tool allows you to add new layers of space control elements and new site selection control rules according to the actual situation.
4.2.3. Location analysis
Based on various spatial control elements and spatial control rules integrated with multiple plans, this tool makes comprehensive superposition analysis, assists in substation and network location selection, calculates location conflict, and visualizes the analysis results to users by means of diagrams and tables.

4.3. Core auxiliary decision-making logic
The core auxiliary decision-making logic of this tool is to determine whether substation location area or line path design breaches any kinds of spatial regulation or sensitive facilities construction requirements by spatial analyzing and computing the space superposition of network planning data and different site selection influence factors data which were determined by the "multi-plan integration" such as ecological red line permanent basic farmland and urban development boundary etc; If true it shall visually mark and display the conflict area, calculate the conflict area or conflict length with various spatial control elements, and automatically generate the corresponding site selection adjustment.

The GIS spatial analysis algorithms used in this tool mainly include superposition analysis algorithm, buffer analysis algorithm and neighbor analysis algorithm. The superposition analysis algorithm includes intersection analysis and erasing analysis, which are used to analyze the location relationship between substation site selection area and space control area; The combined application of buffer analysis algorithm and superposition analysis algorithm is used to analyze the distance relation between substation site selection area or network path and adjacent sensitive facilities; The nearest neighbor analysis algorithm is used to analyze and calculate the shortest distance between different elements. In this tool, it is applicable to calculate the distance between substation site selection area, highway, water pipeline and other essential elements, and assist in the decision-making and selection of the optimal scheme in multiple compliance schemes. The core auxiliary decision-making logic process diagram is shown as Figure 2.
5. Case Description

5.1. Case description
After the completion of the tool construction, it is applied to the site selection of 220kV substation in Daliang Town, Wuqing District, Tianjin and the path selection of 220kV input line.

This case preselected three locations as substation site alternatives, through tool site analysis to determine the optimal scheme. After determining the substation site scheme, two network paths are preselected as alternative path selection schemes, and the line path selection scheme is finally determined through the tool site selection analysis.

5.2. Practice Process

5.2.1. Substation site selection
(1) Data preparation: the data of 220kV substation site alternative in CAD format is converted to SHP format, and the data is determined to use CGCS2000 coordinate system.

(2) Data loading of substation site alternatives: the SHP surface data is loaded into the ArcMap software and the layer is left in the edit state.

(3) Site selection rules: check the ecological protection red line, permanent basic farmland protection red line, urban development boundary, navigation communication antenna and other site selection factors to analyze, and fill in the substation voltage 220kV.

(4) Site selection analysis: click the icon of site selection analysis, and the tool will automatically analyze the alternatives one by one according to the site selection analysis model and visualize the analysis results.

5.2.2. Route selection
(1) Data preparation: Convert the alternative data of CAD format 220kV input line path selection into SHP format, and determine the data to use CGCS2000 coordinate system.

(2) Line path alternative data loading: The SHP line data is loaded into the ArcMap software and the layer is left in the edit state.

(3) Line selection rules: check the ecological protection red line, permanent basic farmland protection red line, urban development boundary, navigation communication antenna and other site selection factors to analyze, and fill in the substation voltage 220kV.
(4) Line analysis: Click the line analysis icon, and the tool will automatically analyze the alternatives one by one according to the line analysis model and visualize the analysis results.

5.3. The practice results

5.3.1. Selection of substation site
The tool shows that among the three alternative site plans, the first site occupies permanent basic farmland, the second site is partly beyond the town development boundary, and the third site does not violate any control rules of the planning control line. The user interface screenshot is as follows:

Figure 3. Influencing factors selection interface

Figure 4. Visual interface of site selection

5.3.2. Route selection
According to the avoidance requirements of communication facilities for power network path selection, the maximum safety construction radius of the tool is 700 meters when the detailed type of communication facilities cannot be determined.

The tool shows that one line of the two alternatives is partly within the 700-meter maximum safety construction radius of the communication antenna of the National Astronomical Observatory Tianjin Navigation and Communication Center Station, and the other line is completely outside the 700-meter maximum safety construction radius. The user interface screenshot is as follows:
Figure 5. Figure of overall architecture

The process of site selection analysis of the whole case is no more than 10 seconds. The system uses GIS to achieve efficient analysis and clear analysis results. At the same time, inconsistent data format and improper operation are avoided, which may lead to low efficiency and improve the accuracy and efficiency of analysis.

6. Conclusion

This research embarks from the practical problems, combined with the historical background of China's territorial space planning, based on "multi-plan integration" and the territorial spatial planning system, coordinate power network planning contradiction, realized the upper and lower planning index transmission by using GIS, realized space control elements of superposition, realized the location of the transformer substation and route planning intelligent key functions such as analysis, planning results visualization display; has obtained good result in practical power network planning and substation site selection, and has important research significance and application value for significantly reducing the workload and omission, improving the quality, predictability and efficiency of the early stage work, and ensuring the safety, reliability and economy of the future power network.

References

[1] Xin Wei, Some Reflections on the Construction of China’s Spatial Planning System in the New Period. Geographical Science Research, 2019. 8(03): 275-284.
[2] Albrechts, L., P. Healey and K.R. Kunzmann, Strategic spatial planning and regional governance in Europe. JOURNAL OF THE AMERICAN PLANNING ASSOCIATION, 2003. 69(2): p. 113-129.
[3] ZHANG Ruyi, ZHANG Xiaorui, HU Yanling, Review of Research and Practice of Spatial Planning Theory Both at Home and Abroad. Journal of Anhui Jianzhu University, 2019. 27(5): 29-35.
[4] LIN Jian, QIAO Zhi-yang, Research on “Multiple Plans Integration” based on the Game Theory. China Land Science, 2017. 31(5).
[5] ZHAO Yanjing, ON THE UNDERLYING INFRASTRUCTURE OF THE SPATIAL PLANNING. City Planning Review, 2019. 43(12): 17-26,36.
[6] ZHANG Xiaodong, HAN Haoying, ZHANG Yunlu, CAI Xinyu and ZHU Sis, Establishment of an important Control Line System for territorial spatial planning. Urban Development Studies, 2020. 27(2): 30-37.
[7] WU Tinghai, A DISCUSSION ON URBAN PLANNING IN SPATIAL PLANNING SYSTEM. City Planning Review, 2019. 43(8): 9-17.
[8] WANG Bei, HUANG Xiaochun, SUN Daosheng, RONG Yilong and HU Tengyun, Thoughts on the Construction of a Quantitative Research Framework System for territorial spatial planning. City Planning Review, 2019(6): 28-36.