Multi-source Geographic Information Data Fitting for Transmission Line Design

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Abstract. Geographic information data is the basis of power transmission line design. The topography and topography of the survey area and the distribution of trees, houses, roads, rivers and other features directly affect the route direction of the line. How to quickly and efficiently acquire large-scale and high-precision geographic information data has always been the focus of power transmission line design research. This paper presents a method of fitting aerial survey data, satellite images, geographic contour lines and other multi-source geographic information data. It can be used to determine and optimize the route plan in the feasibility study and preliminary design stage to improve the work efficiency.

1. Background
Three-dimensional design of transmission lines is an integrated application of geographic information system, three-dimensional modeling technology, digital collaborative design technology and digital design results transfer technology. The three-dimensional virtual display and information integration of transmission lines can be realized, and the aims of improving design quality, promoting design technology progress, constructing a digital power grid and serving the whole life cycle process management can be achieved[1].

Different from substation design, line design is closely related to the geographical environment of the transmission channel. At the same time, the route selection and optimization of transmission lines, channel cleaning, land acquisition and relocation, environmental assessment and water conservation, crossing and treatment of unfavorable geological sections are closely related to the refinement of geographic information data. Therefore, the construction of a high-precision engineering geographic information system that follows the three-dimensional design standard of the State Grid Corporation is the foundation and key factor that restricts the orderly development of the three-dimensional design of transmission lines.

2. Main Sources of Geographic Information Data
2.1 Satellite images
Satellite images are the general designation of satellite remote sensing images, which are remote sensing images obtained by observing the earth's land surface through earth observation remote sensing instruments loaded on artificial satellites. Satellite images have the advantages of strong macro, wide coverage, multi-temporal, and low acquisition cost. However, the satellite images image has low
resolution, low elevation accuracy and uncertain timeliness, which can only meet the design requirements in the feasibility study stage of transmission lines.

2.2 Aerial photograph

Most of the Aerial photograph based on the project site image data captured from low altitude by small unmanned aerial vehicles equipped with high-definition cameras. According to the different combination of flight and shooting methods, aerial photography data can be divided into orthographic images and oblique photography. Orthographic images are similar to satellite images in imaging principle, but with higher resolution and clearer ground object response. Tilt photography is to form real three-dimensional image data by mounting multiple sensors on the same platform and simultaneously acquiring images from five different angles such as one vertical angle, four inclinations, etc., with a measurement accuracy of ±20cm. The disadvantage of aerial photography lies in its high acquisition cost and small coverage.

2.3 Digital Topographic Map

Mainly refers to the contour data downloaded from the third-party websites such as the historical survey results of the area and the water injection. Its advantages are high precision and wide coverage. However, these data are often acquired over a long period of time, mostly based on the results of the second or even the first survey of China's land, up to 30 years ago, with poor timeliness and only topographic data but no image data.

3. Multi-source Geographic Information Data Integration

Integrating satellite images data, aerial photography images, digital topographic maps and other multi-source geographic information data, and making an engineering geographic information system with high image resolution, accurate elevation data, wide coverage, strong timeliness and relatively low acquisition cost. This will become a powerful support platform for three-dimensional design of transmission line engineering.

| Projects          | Satellite images | Digital Topographic Map | Digital Topographic Map |
|-------------------|------------------|-------------------------|-------------------------|
| Image resolution  | Up to 0.5m       | 5cm                     | None                    |
| Elevation accuracy| 10~30m           | 10cm                    | 5cm                     |
| Timeliness        | Up to half a year| Real time               | Years to decades        |
| Acquisition cost  | Low              | High                    | Low                     |

According to the characteristics of geographic information data, the data integration principle of engineering geographic information system is determined. (1) Strip aerial image data are used for important sections of transmission line routes, such as important crossing and crowded sections of line corridors. (2) satellite images data are selected for plain areas with little elevation change. (3) For mountainous and hilly areas where surface attachments have not changed much for many years, satellite images and digital topographic maps are used to combine data.

4. Establishment of Engineering Geographic Information Platform

Taking a 220kV transmission project as an example, the length of this project is about 26km. Topographic classification of the whole line: hills 35%;The plain is 65%. The line needs to cross expressway and the South-to-North Water Transfer River, and the crossing section length adopting the combination mode of resistance-straight-resistance tower is about 1.6km. According to the characteristics of the project, the whole line will be divided into 3 parts, and geographic information data will be obtained by different methods. (1) satellite images is used as data source for plain sections with sparse surface attachments. (2) in hilly region, satellite images and digital topographic map are used as data sources. (3) For the plain section and river-crossing section with dense surface
attachments, aerial survey data are used in this section because the accuracy of geographic information data directly affects whether the route scheme can be established.

### 4.1 Technology roadmap

![Technology roadmap diagram](image)

**Figure 1. Technology roadmap**

### 4.2 Data fitting

The principle of data fitting is similar to that of generating three-dimensional digital images from DEM superimposed orthophoto images. Firstly, the collected digital topographic map data are transformed into TIN triangular model, and then the TIN triangular model is transformed into high-precision DEM. The DEM and Orthophoto Image are superimposed by coordinate correction to generate high-precision satellite images, as shown in Figure 2.

![Satellite images and Digital Contour Fitting](image)

**Figure 2. Satellite images and Digital Contour Fitting**

### 4.3 Acquisition and Processing of Aerial Photographic Data

In the key section where the line crosses expressway, the accuracy of geographic information data is required to be high. Multi-rotor unmanned aerial vehicle is used to obtain aerial survey data. In addition, the route design is carried out by comprehensively considering the performance of instruments and equipment, topography, terrain, elevation difference, camera area shape, navigation height, heading overlap, lateral overlap and navigation coordination, etc. According to the requirements of route design parameters and operation specifications, the crowded section and important crossing section of the route corridor are flown to generate strip-shaped three-dimensional image maps. The design range is 4.1km, the flight band width is 300m, the course overlap is 80%, and
the side overlap is 60%. The plane accuracy is 0.15m and the elevation accuracy is 0.3m, as shown in Table 2, and the strip aerial photography data is shown in Figure 3.

| Detection Point Number | DeviationΔ X[m] | DeviationΔ Y[m] | DeviationΔ Z[m] |
|------------------------|-----------------|-----------------|-----------------|
| 1                      | 0.04            | -0.14           | -0.26           |
| 2                      | -0.16           | 0.20            | -0.39           |
| 3                      | -0.16           | -0.02           | 0.43            |
| 4                      | 0.11            | -0.17           | -0.14           |
| 5                      | 0.12            | 0.19            | -0.07           |
| Medium error           | ±0.126          | ±0.158          | ±0.293          |

Figure 3. Striped aerial photography (top: digital topographic map, below: orthophoto)

4.4 Multi-source Data Integration

Multi-source geographic information data need to be calibrated to the same coordinate system through seven parameters to realize superposition. Therefore, this paper unifies the multi-source data such as high-precision satellite images, aerial photography images and ordinary satellite images into CGS2000 coordinate system and 1985 national elevation, and integrates them into a three-dimensional design platform to form a multi-source geographic information data platform. As shown in Figure 4.

Figure 4. Multi-source geographic information data integration

5. Application Effect Evaluation

Multi-source geographic information data has the characteristics of accuracy and diversity of resolution. Selecting different data sources according to the needs of different line segments is a relatively efficient way to obtain geographic information data.
As shown in fig. 5, tilt photography data obtained by unmanned aerial vehicle aerial photography can restore the topography and geomorphology of the project site with high precision, as well as the ground feature information such as houses and buildings, and can carry out accurate spatial measurement in the three-dimensional design platform. At the same time, it can also count the amount of deforestation and house demolition within the corridor. For the key areas such as high speed, South-to-North Water Transfer River, the accuracy of geographic information data directly affects whether the cross-river scheme can be established.

![Figure 5. Aerial data application (Top: Terrain display in the hilly section, below: Statistics of trees cut across the forest)](image)

For the hilly areas of this project, the ground objects such as houses and roads are sparsely distributed, and the crossing of power line communication lines is rare. Using the satellite images and the high-precision satellite images data fitted by digital contour lines, the tower ranking work can be supported. Compared with the acquisition cost of aerial photography data, the method is low in cost, is not limited by the width of the aerial belt, and can better support path optimization work.

6. Conclusions

Three-dimensional design of power grid and three-dimensional information management of power grid are the main development trends of current power survey and design. How to obtain high-precision geographic information data in a large scale and efficiently has been the main research direction in the field of three-dimensional design of power transmission lines. Based on the characteristics of multi-source geographic information data, this paper chooses different data acquisition methods according to the section: (1) In the key section such as the express way, South-to-North Water Transfer River, aerial survey is used to acquire aerial photography data. (2) Overlay digital topographic map with satellite images is selected for hilly areas, ground features and areas with few crossing lines. (3) Select satellite images in plain areas. Through the way of
multi-source integration, the real scene modeling of the line corridor is completed. It is proved that this method has the advantages of economy and rationality, and the data precision can meet the depth requirements in the feasibility study and preliminary design stage of the line.

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