Research on Auxiliary Design System for Rural Power Grids Based on 3D GIS

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***Abstract*—Graphics can not display clearly the surrounding environment of power distribution equipment in the traditional two-dimensional GIS of distribution grids. Aimed at above shortages, this paper proposes an auxiliary design system for rural power grids based on 3D GIS. The system is developed based on component SuperMap to the GIS, the commercial relational database SQLServer 2008 and the object oriented programming language Visual C# in the secondary development. The paper introduce the methods to establish three-dimensional model and attributed database, and analyze the process how to use the existing contours map to produce digital elevation model (DEM). It describes simply the hierarchy structures and flow chart of system development. The system is better able to query data when two dimensions and three dimensions are combined, it can analyze the three-dimensional space, automatically plot the cross-section drawing along any given geo-path of distribution lines, calculate the total length of overhead lines under one weather condition.**

***Index Terms*—rural power grids, 3D GIS, DEM, cross-section drawing**

I. Introduction

With further deepening of the national power grids construction, structure of rural power distribution grids has been complex increasingly; the power users have brought in higher requirements for the electric power quality; consequently, the power distribution grids management and operation has been put forward higher request. How to effectively reduce the construction and maintenance cost of the distribution grids and to improve the level of information management has become an urgent need to solve the problem [1-5]. The traditional management mode could not meet the requirement of the current; the information technology and means have been used to improve management level of power distribution grids; it has become a current very urgent task for the electric power companies to provide considerate and meticulous perfect service [6-9].

Geographic information system (GIS) of distribution grids has become the important component in the power distribution automation and the informationization. With the help of mnemonic symbols of geographic information, distribution lines and the supply and consuming power equipment is shown directly and accurately to realize the function of space database system with topology analysis and offer a variety of means and ways to deal with graphics, text and other information. As a result, it provided more reliable aided decision for the power companies and consumer. Aimed at operation and management of power distribution system, the GIS of distribution power grids is a system software that can describe distribution grid topology, attribute information and real-time data on background map, can integrate many functions such as inquiry statistics, operation and maintenance, analysis management, and so on by using computer technology, communication technology and network technology. The distribution grid management based on GIS is essential support platform to realize smart power grid in the future.

The traditional two-dimensional GIS system has been put into use mass, and function has been improved [10-13], but it isn’t a reflection of reality terrain of the surrounding distribution lines, equipment and facilities, and can’t provide real work environment of lines and equipments of the power distribution grids for inspection tour and maintenance staff. Along with the fast development of computer technology, database technology, image and remote sensing technology, and the more mature three-dimensional geographic information system (3D GIS) made it possible for the development of 3D GIS system of power companies [14-24].

II. 3D GIS Technology

doi:10.4304/jsw.8.3.652-658

The three-dimensional GIS is the need of the development of GIS for many current applications, is a growing high-tech frontier of research field. Compared with two-dimensional GIS, 3D GIS can give more real feeling to the objective world expression, show geographic space object with the three-dimensional modeling technology for the user, it is convenient to three-dimensional spatial query and analyze for 3D object [25].

Different from the two-dimensional GIS, vertical 3th dimension information is simply abstracted into a single attribute value to process. In 3D GIS, spatial object is defined through three coordinates (x, y, z). Increased 3th dimension coordinate make GIS spacial relationship more complex. In 3D GIS system, the research object can be divided into four categories: point, line, surface, body; line included both the plane curve in 2D GIS, and space curve, which uniquely exist in 3D space; the surface included both 2D plane and 3D space curved surface; and the body is unique in the 3D object of study [26].

The core of 3D GIS technology is the spatial database, space query and spatial analysis. The analysis of three-dimensional space is that spatial objects are analyzed, queried in three-dimensional space database, are managed and expressed in 3D patterns. Space analysis is facing users, so it can solve the problems that the users need to solve, and can directly provide decision support for policy makers [27].

III. Establishment of 3D models

A. From the Contours to Digital Elevation Model

Two-dimensional GIS data with three-dimensional attributes can be converted into three-dimension visual images that people accepted easily. Contours map layer is one of the representatives, the contours layer in SuperMap Deskpro is shown in Figure 1.

B. Establishment of 3D Models

Digital elevation model (DEM) usually refer to dataset

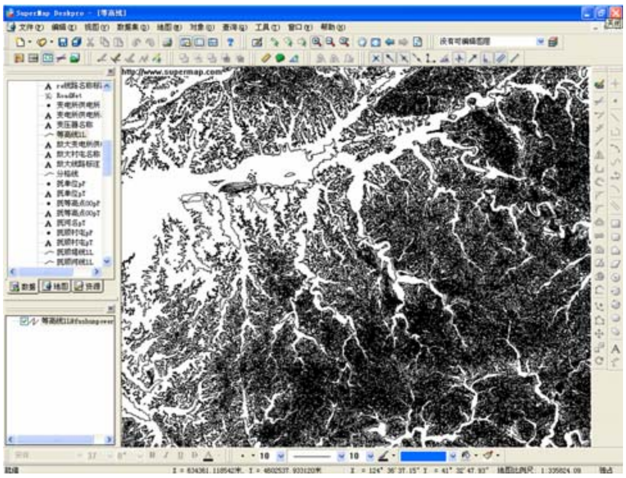

Figure 1. Contours layer to depict terrain

of plane coordinate (x, y) and elevation (z) of regular grid dots on the projection plane (such as Gaussian projection plane), the dataset describe space distribution of terrain features in mathematical theory. Grid interval of DEM adapts to accuracy of the elevation, and forms regular grid series. The interval can be defined by the user, and generally it can be changed with different types of landform.

The conversion from contours to DEM is the process of the 2D contours model to 3D model transformation in order to generate and display three-dimensional terrain maps with realistic sense. In SuperMap Objects, the conversion uses triangulation interpolation algorithm Delaunay, because Delaunay triangle criterion are not easy for the creation of narrow and long triangle with sharp internal angle, which do not make for surface reconstruction, the interface used for the programs is soGridAnalyst.LineToDEM.

C. Establishment of 3D Models

Using the Super3D control in SuperMap Objects, DEM data can be shown in three-dimensional space to see clear hierarchy three-dimensional terrains, as shown in Figure 2. If there was a satellite remote sensing image, after accurate rectification by adding to the three-dimensional model, the realistic three-dimensional terrains can generated easily.

All kinds of attribute information database related to model is established, which is combined with spatial database, to support query for target information in 3D environment. Usually through designing corresponding table structure, the attribute data is stored in relational database, such as Oracle, SQLServer, etc. But a lot of attribute data is often ready-made, which has already existed in the database of the power companies. We can use spatial data engine provided by SuperMap to support many kinds of databases and use seamless integration technology of the multi-source spatial data to support many kind of data formats without conversion in order to realize overlay display, query and analysis between the different formats of data.

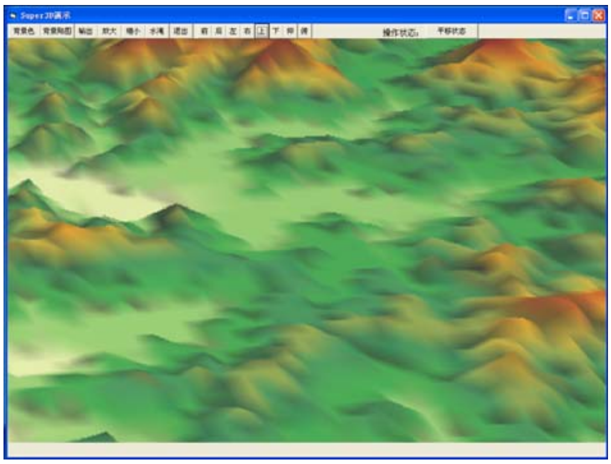

Figure 2. Display of three-dimensional terrain

IV. System development plan

A. Hierarchy Structure of the System

According to the characters of 3D GIS technology and the management need of distribution grids, auxiliary design system for rural power distribution grids combined with 3D geographic information technology, space visualization and space database technology closely link the power grids data to geographic information. It can provide geography position information of power distribution lines and power consumption equipment and other relevant various professional data information stored in the attribute database for departments of rural planning, operation, and management. Therefor, it can lay the foundation for the subsequent advanced application. The system uses multilayer structure model, and the whole applications are divided into the presentation layer, logic layer of function and data service layer, which can separately optimize each layer and greatly improve scalability of program and extensibility of function modules. Hierarchy structure is shown in Figure 3.

(1) Data service layer

Data service layer is logically constituted by the spatial database, attribute database and other database. The spatial database stores data of terrain, including contours layer, the layer of the DEM, satellite images of remote sensing, texture mapping of the model, electronic maps of vector or raster data, and so on. The attribute database stores the geographic information of the distribution lines and power consumption equipments and other parameters data. Other database stores the data of operation and dispatching, and so on.

(2) Logic layer of function

Based on the data provided by the data services layer, the logic layer of function uses database access technology ADO.NET to deal with business process. It mainly completes two-dimensional and three-dimensional simple application, including the system management, equipment management of the lines, inquires and statistics and the analysis of three-dimensional terrain and so on basic functions.

(3) Presentation layer

The presentation layer is contacted directly by users, reflecting the users' requests, so it has a simply and friendly visual interface to easy operate, and there is the strong good affinity. The presentation layer can combine the existing supervisory control and data acquisition (SCADA) of rural power grids and the management information system (MIS) to pass the dynamic real-time data of rural power grids to the users for some advanced application, such as short-term load forecasting of rural power grids, running management, outage management, fault management, analysis of power lines loss and analysis of lightning region, and so on.

Each design layer has more specific limits and certain relative independence, which is facilitate for the system development. To ensure the harmony of the system, the internal of all layers also used good way of component design.

B. Flowchart of Development Design

The system is to achieve the basic function of GIS using tools software SuperMap Objects 2008 about component based GIS, do the integrated further development with popular object-oriented visual programming language Visual C#, and adopt the relational database SQLServer 2008 as database engine. The distribution lines, contours and DEM layer are deal with through using desktop version Deskpro 2008 of SuperMap. Flowchart of program development is shown in Figure 4.

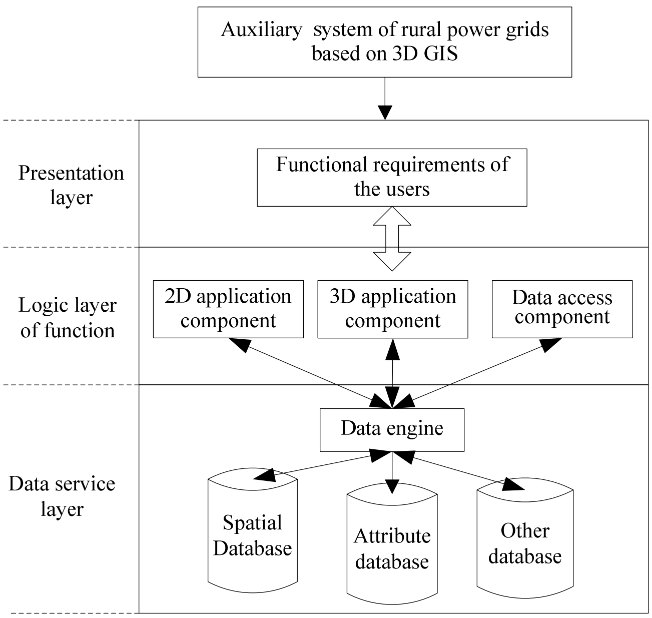

Figure 3. Hierarchy structures of system

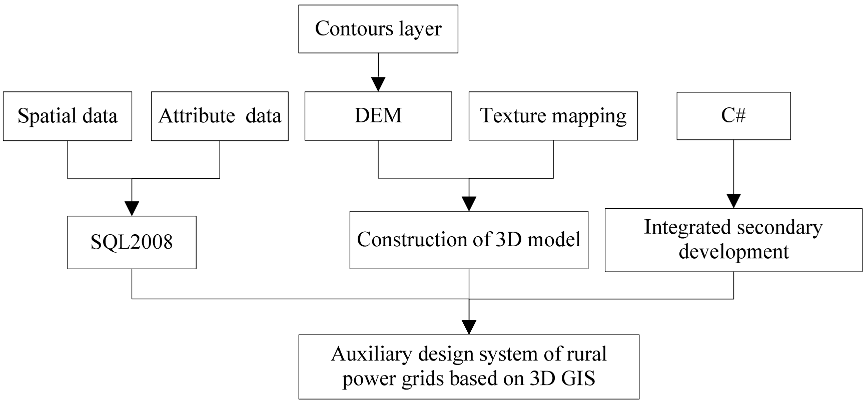

Figure 4. Flowchart of program development

The development of GIS application system that integrate GIS development software with object-oriented visualization development language has become the mainstream, its advantages are very obvious: it can make full use of function of storage, analysis and management of GIS development software for spatial data, and also can give full play to high efficiency and convenient operation of the object-oriented language and help to develop the large software. Application system integrated the advantages of both has not only powerful function of database management but also good appearance, high reliability, easy to transplantation.

C. System Functions

C.A Query function of two-dimension and three-dimension combination

Two-dimensional GIS subsystem is contained in three-dimensional GIS system, so data and can be transfered between three-dimensional and two-dimensional systems, that is by the accurate positioning in the two-dimensional map to realize management and maintenance of the equipments such as pole towers and lines, and so on. In addition, two-dimensional GIS can relize equipment management, data management, outage management, loss analysis of power lines, the calculation of power flow, and so on.

C.B Analysis of three-dimensional terrain

Based on 3D modeling and 3D visualization, three-dimensional analysis can carry out a series of advanced analysis, such as submerged simulation, flight simulation, methods of three-dimensional filling and cutting, mapping and superposition bitmap, and so on.

(1) Browse of submerged simulation

The three-dimensional terrain is simulated through using the DEM of a given region and remote sensing data. Then flood level elevation value is set to judge weather the reigon is submerged or not, in the value below is submerged area. We can simulate the submerged process and calculate the flooded area to generate flood risk map, which can provide a decision-making for flood disaster. With using FloodEnable and Flood methods of SuperMap and Timer control the system can get continuous changed scenes, the effect of submerged simulation is shown in Figure 5.

(2) Browse of flight simulation

Three-dimensional flight of designated route is a senior way of three-dimensional browse, and it can fly in height sky and browse terrain in accordance with specified a route. In SuperMap 3D, positions of the flight routes are determined from points on the geometrical elements, these positions can read from files whose format is XML. The specified files of flight routes need to be loaded and flight elevation need to set before the flight. In the reality playback, the positions of flight are created through interpolation of discrete points that exist in the files of the flight routes. The SuperMap3D provide two interpolation methods: linear interpolation and spline interpolation, it use Fly method to realize such function.

C.C Creation of cross-section drawing along any given geo-path of distribution lines

Begin to draw a polyline along any given geo-path of distribution lines in DEM layer, and then in the program to get the polyline, the other steps are follows:

Step 1: The polyline is divided into many equal parts, interval of equal division is determined from precision of the cross-section drawing. If we hoped get higher precision, the polyline should be divided densely;

Step 2: Vertex coordinates *x* and *y* are successively got from the polyline of equal divisions;

Step 3: The coordinates *x* and *y* can be transformed

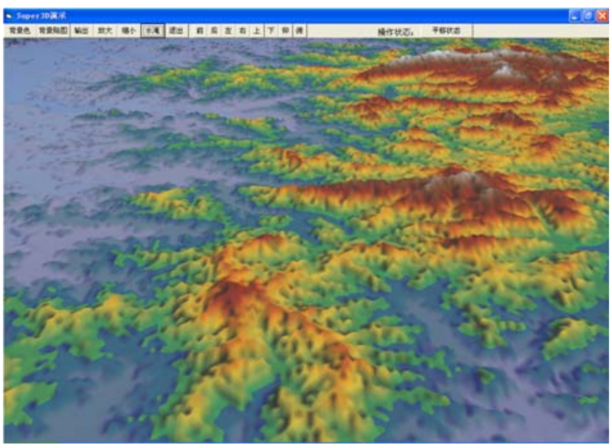

Figure 5. Display of three-dimensional terrain and effect of flood model

into value of row and column for the DEM, and then corresponding elevation can be calculated by soDatasetRaster.Value method.

Step 4: The the series of coordinates x, y, z are added to dataset which is either surface dataset or compound dataset. To here, cross-section curve has drawn. The compound dataset can store text object, can also store curve and other types of objects. The system use compound datasets because we later need add marked text of coordinates and other information to cross-section drawing.

Step 5: To set style of display of cross-section curve, and add it to compound dataset.

Step 6: The vertical and horizontal coordinates, scale text, power line poles, and electric wires can be added to cross-section drawing, and give the corresponding display style.

Flowchart of generation process for cross-section curve is shown in Figure 6; the cross-section drawing with rivers and mountains generated by the system is shown in Figure 7.

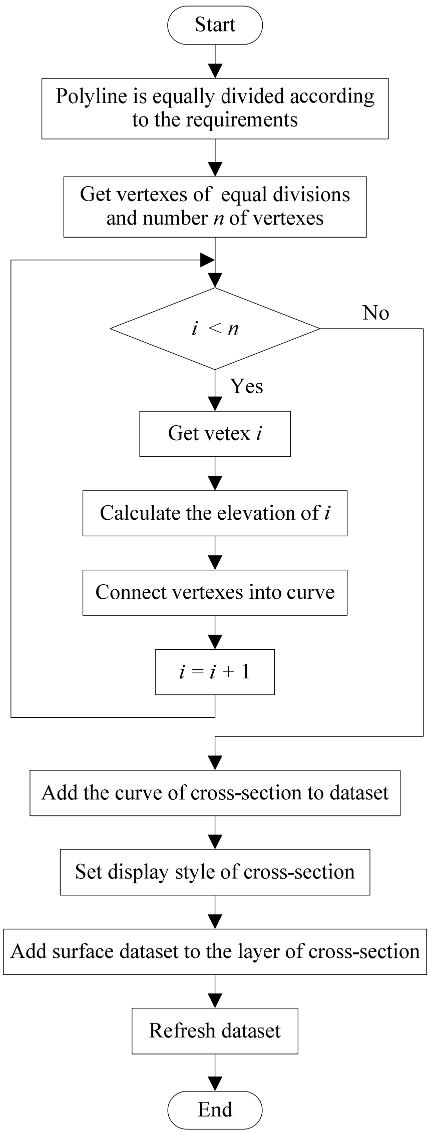

Figure 6. Flowchart of production of section curve

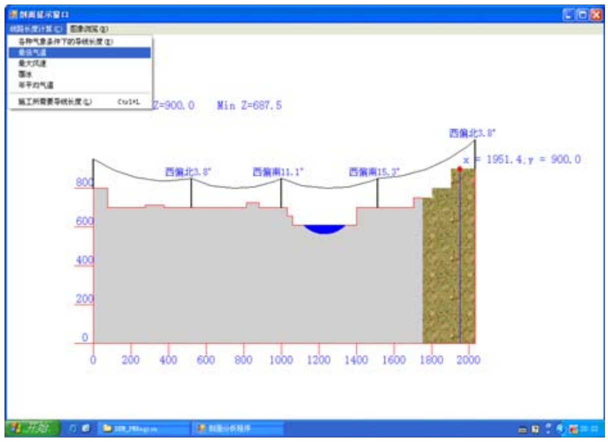

Figure 7. Display window of cross-section with river and mountain

In addition, coordinate of three-dimensional dynamic points and direction of the distribution lines are added to the cross-section drawing. When the overhead lines are over plains, rivers and mountains, different colors and patterns are filled under the cross-section curve for setting up different display styles. Therefore, in the aided design of distribution grids, the terrain cross-section generated according to the actual coordinate is convenient for the design persons to know the local geographic conditions with rivers and mountains without leaving home.

C.D Total length calculation of overhead lines under a weather condition

The wire stress of the overhead line varies with different spans and weather conditions. In order to guarantee the stress of the overhead line in any weather conditions didn't exceed the allowable stress, in the long running, the maximum stress of overhead line equal the allowable stress. Therefore, we need to find out weather condition when the stress reach maximum, namely, control weather conditions we called, and the corresponding allowable stress of the wire is called control stress. There are four control weather conditions: minimum temperature, maximum wind, icing, and the average annual temperature.

To Solve the total length of overhead line under a weather condition is divided into the following a few steps to complete:

First of all, the voltage grade of overhead lines is selected. The system can get changed temperature and wind speed in different typical weather area according to different voltage grade.

Then, selection of wire type is carried out. Different wires have different diameter, calculation section, and the calculating breaking force, calculating quality, expansion coefficient and elastic coefficient, and these parameters provide the foundation for the following calculation of line length.

In the computer-aided design for the distribution lines, the spans are determined with wire pole positions. According to the computer iterative algorithm of control weather conditions [28] the system can judge which weather condition work under the known span of lines, and then get the wire stress value under the current weather condition through a state equation of wire stress.

We can calculate the length of one span of overhead lines by the parabolic equation of wires, accumulate all the spans to compute the total length of the overhead lines under one control weather condition, realization interfaces are shown in Figure 7 and Figure 8.

The total length calculation of overhead lines under a certain weather condition is always very significant, it is convenient for us to construct power overhead lines, and can save a lot of manpower material resources, especially in the mountains, the total length of the wires used have a great discrepancy with the budget because of the great long span, sometimes unequal suspensions, and so on. The calculation results will give builder of the overhead lines a lot of help and reference and save labor costs.

IV. CONCLUSION

According to the technical features and management requirements of the distribution grids, this paper put forward to a development plan and realization method of auxiliary design system for rural power distribution grids based on 3D GIS technology, which combined three-dimensional visualization technology, spatial database technology with GIS technologies of rural power distribution grids. It analyze the hierarchical structure of the system and the methods of 3D models establishment, and describe detailed the flow of the system development and function. Although 3D GIS technology research has made great strides, many theories and application research are still in the stage of exploration, and it needs further improvement. With the further development of 3D data acquisition and analysis techniques, the problems in the auxiliary design system for power distribution grids will further be resolved, auxiliary design system of 3D distribution grids will have more broad application prospects.

ACKNOWLEDGEMENT

This work is support of Science Research and Development Project of Baoding (11ZN027) and Hebei Engineer Research Center of Information Technology for Rural Area.

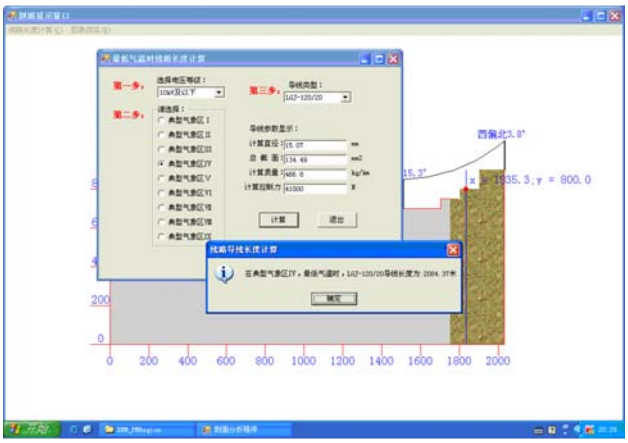

Figure 8. Calculation window of total length of power distribution line

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