STUDY AND APPLICATION OF DECISION-MAKING SUPPORT SYSTEM FOR URBAN DISTRIBUTION NETWORK PLANNING OF SHANGHAI

Saiyi WANG, Jianmin WANG, Yinong LI
Urban Power Supply Company, SMEPC, Shanghai 200080, China
E-MAIL: saiyiwang@163.com

ABSTRACT

Combining the daily operations of the utilities, the latest computer technology and the professional technology of distribution network planning, a practical GIS (Geographical Information System) based computer decision-making support system with eight sub systems for urban power distribution network planning is introduced. The models and functions of the system are described. This system has been successfully applied in some real urban power networks. The results show that it cannot only optimize the planning results of urban power distribution network considering many complicated factors, but also reduce the work of computation, analysis and graphic drawing.

INTRODUCTION

Urban distribution network planning is a complicated systematic project, which will deal with a large-scale data, many uncertainties and inaccurate factors, as well as many fields involved. The planners not only need to collect many data about the history of urban development, but also need a in-depth study of the situation of urban planning and have a comprehensive understanding of the urban planning and it's development in the future. The computer-assisted decision-making system has become a essential tools to modern urban power network planning (see in [1], [2]).

At present, some major domestic and foreign commercial software of power system planning and design is PSASP (China Electric Power Research Institute), BPA (American Electric Power Banville), PSS/E (American PTI company), ETAP (U.S. company ETAP), PSAPAC (U.S. companies EPRI), NEPLAN (Switzerland's BCP)[3], DigSilent (Germany's DigSilent), ARENE (Electric company of France), NETOMAC (Siemens AG, Germany)[4] and so on. Although the software provide computing simulation-related analysis tools, but they are not directly involved in planning and designing for urban power network, and most of them do not have the complete functions of planning, and do not have the functions of GIS (Geographic Information System).

At present, in Shanghai Municipal Electric Power Company and its subordinate units, transmission and distribution production management systems of GIS-based (referred to as PMS) have been successful applied as routine work platform of scheduling, planning, operating technology, engineering departments, each department achieves the maintenance of information in a timely manner, information and real-time monitoring of real-time and real-time feedback to ensure that the power-house of information between the departments of communication and efficient coordination. In this paper, using PMS supports as the platform, targeted studies of the planning of the present analysis, load forecasting, substation location and sizing, network planning, and other key technologies involved in the distribution network have been done to achieve the PMS-based practical use of urban distribution network planning decision support system. The practical application of the system in planning works in Urban Power Supply Company, SMEPC, shows that it can optimize the outcome of network planning, at the same time, it can greatly reduce the planner's workload and have high scientific and practical levels.

STRUCTURE OF SYSTEM

The structure of system with four-layers is as shown in Fig.1, including data-layer, platform-layer, application-layer and performance-layer. The data-layer is made up with the graphics library and attributes database, stored in Oracle, and been called for by the platform layer; platform layer loads the underlying graphics services through ARC SDE spatial data engine, connects to read Attribute data through the common data connectivity interface (ADO), and covers all the graphics systems and data query features of the Conventional GIS system; application-layer is designed specifically for business planning, calls algorithms of planning theory through a standard interface to achieve the all planning functions; performance-level is designed for different applications and different scenes role in planning to provide regional power network planning, network planning district planning, querying of the results of the planning, and other functions.

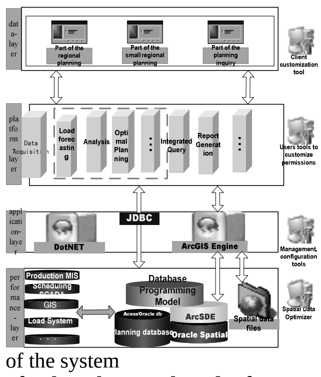

Fig. 1 Structure of the system

The design of the hierarchical framework with the separation of data-storage and data viewing, the separation of algorithm and interface has abandoned the traditional process-oriented and the design business and data integration, is more suitable for object-oriented development to ensure the security and stability to the system , and can facilitate a system upgrade smoothly at the same time.

FUNCTIONS OF SYSTEM

The core functions of the planning system is to assist the completion of planning, the process to complete planning using the developed system is the shown in Fig.2.

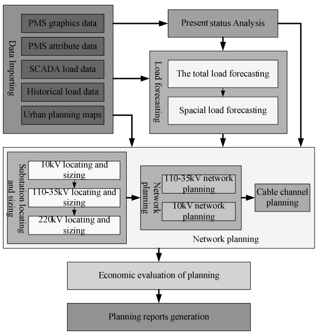

Fig. 2 Flow chart of the system

Data importing

The import module of the basis data includes the import of PMS graphics data, PMS attributes data, SCADA load data, history power load data, the Town Planning map of the goal year and so on for the widespread data-quality issues of the existing GIS system, this module also provides a tool for rules-based data validation of topology to address the lack of data and the validity of analysis under the condition of some errors (see in [5]).

Compared to the module of traditional software that must input the data manually , the development of this module can address the issue of data sources of planning system better, can liberate a large number of workers from the tedious data collection and verification work, and more focus on of Power System Planning.

Present status analysis

The module includes five parts, that are power flow computing tools, high-voltage network analysis and assessment tools, medium voltage network analysis and assessment tools, reports and charts display tools, analysis of the status quo and assessment summed up.

Compared to the simple analysis of the total level for the distribution network in traditional conditions that lacks of supporting tools, the modules builds an analysis hierarchy system for urban distribution network evaluation[6] to provide quantitative support data from various angles, so as to provide better technology to raise the level of decision-making and efficient use of funds.

Load forecasting

As opposed to those forecasting algorithm softwares which is only focus on the traditional models, this module is more focused on the practicality of function prediction, in addition to its own built-in modules of the large number of configurable forecasting model.

For part of the total, the module has a variety of forecasting methods of management, according to various forecasts, the environment and the characteristics of data to choose the optimum configuration of the combination forecasting model, to be completed by hierarchical (sub-voltage level), area (sub-administrative region, sub-branches, sub-link, the sub-block) and different calibers' load forecasting, preliminary achieved the forecast results checking each other and the linkage adjusting. In addition, in the level of total load forecast, considering actual situation of power supply in Urban Power Supply Company, SMEPC, the module achieves a preliminary accounting of load forecast factor of function, with business expansion inquire and temperature substance, which laid a good foundation for further refinement and day-to-day convert.

For the special one, this module achieved long-term saturated forecast by planning power supply block which is based on the index method, and according the rules to achieve mutual verification between long-term power supply block and short-term function block, get the development of the region's load curve in any space year by year, provide basic data for the following substation locating and sizing, network planning and cable channel planning.

Substation locating and sizing

On the basis of city planning spatial distribution load forecast, the module using the computer to determine the substation location and its capacity to be built in target year and the years in the middle automatically to meet the needs of the future development of the load, at the same time to meet the investment and Minimum operating costs, optimize the site will automatically calculate the power of substation, as well as the scope of the main transformer load levels. Compared to traditional planning software, the module expands the content of locating and sizing including, 10kV substation, 110-35kV substation and 220kV substation locating and sizing. Additionally, this module includes single-stage object year locating and sizing and the middle years from the present year to the objective year.

Network planning

Compared to traditional software which mainly rely on the planning of the manual mode, based on the geographic planning street to the shortest path, the scope of power supply which is calculated by the substation locating &sizing module, using power supply substation and substation load as the start and termination nodes, this module achieved network roads automatically along the street.

For 10kV medium voltage network, this module provides the automatic layout of the path from a 110-35kV substation to a switch-station as well as to a series of switch-station.

For 110-35kV high-voltage network, this module provides the automatic layout of the path from the 220kV substation to 110-35kV substations. Considering the feature urban network in Shanghai, this module achieved multi-power sources optimization between power points and load points, as well as manual function for the ring in and ring out path editing.

Cable channel planning

After the automatic network cabling, consider access substance, based on the result of the 110-35kV and 10kV network planning, this module achieved the geographical distribution planning along the street toward channel. For characteristics of channel, providing the detailed planning results of main channel, sub-channel, the substation exit routes, the small channel and achieve the path through the channel by the geography along the main street.

Economic evaluation of planning

Keep all of the individual project involved in the whole planning project as a whole, use the initial investment and operating costs as inputs, use income from electricity sales as output, all-round and dynamic financial guideline of planning project can be given quantitatively in the consideration of the time value of investment, thereby provide base on economic decision-making for utilities' long-term management.

APPLICATION CASE

In application, Hudong Power Supply Branch, Urban Power Supply Company, SMEPC was taken as an experiment unit, the planning was accomplished completely supporting with the system.

First, in the system, 2006 was taken as the present year, 2030 as the prospective objective year, and 2010 as the present planning objective year. Do perspective plan of the planning area as the flow in Fig.2. Due to the limited space, the following part will briefly introduce the main planning results by this system from load forecasting, network planning and cable trench planning, etc..

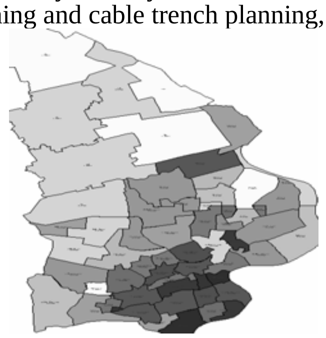

Fig. 3 Example for small area load forecasting results

Load Forecasting

Fig.3 shows the example for load forecasting results of the objective year. Different color depth represents different load density area in the figure. The deeper the color is, the bigger the load density is. And this kind of area should be mainly concerned in the planning. Annual load density development diagram from the first year to the objective year is needed in planning, to provide basic information for substation and network transitional planning.

Substation Locating and Sizing

Tab.1 gives partial result of 110kV substation location.

Tab. 1 Partial result of 110kV substation location

Substation	Voltage(kV)	Capacity (MVA)	Main transformer number	Capacity expansion(MVA)	Runing time (year)	Capacity expanding time (year)
Ningguo	110	80	2	40	1996	2008
Changbai	110	80	2	40	2006	2008
Xinpingliang	110	80	2	40	2007	2010
NewGH3	110	80	2	40	2011	2014

This table gives the building time and extension time of the planned substations and extended substations, laying a good foundation for scheduling project orders.

Network Planning

Fig.4 and Fig.5 respectively give the results of 10kV distribution network planning and 110kV distribution network planning along geographical trend.

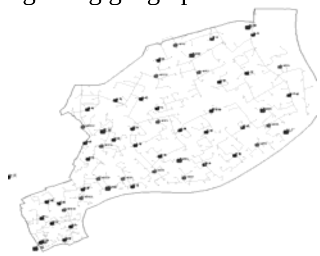

Fig. 4 Example for the result of 10 kV network planning

As the setting goal of full cabling reconstruction of the planning area by the objective year, Fig.4 is the automatic routing result of 10kV network, along geographical trend, from 110kV substation to 10kV switch-stations. According to *Some Technical Principles of Shanghai Power Grid*, 10kV switch-station configures two power sources. According to power sources and geography conditions, the system flexibly determines whether the two power sources come from the same 110kV or 35kV substation，or two different 110kV or 35kV substations.

Fig.5 is the automatic routing result of 110kV network, along geographical trend, from 220kV substation outgoing line to 110kV substation incoming line. According to *Some Technical Principles of Shanghai Power Grid*, prospective and newly-built substations are all standardly configured as 3 main transformers, and configures 3 power sources. According to power sources and geography conditions, and ring-in-and-ring-out results manually interfered by experts, the system flexibly determines directions of the power sources by regulations.

Fig. 5 Example for the result of 110-35 kV network planning

Cable channel Planning

Fig.6 gives the geographical route to the results of planning. The Image is the target year channel planning. According to the nature of the channel, set the 110kV cable to be the main channel, as the thick solid line shown in the image; the road to the inside of cell is areola channel, as the thin real line shown in above Image; the rest are sub-channels, as the dotted line shown in the Image above. In accordance with the principle of the main channel must be a unimpeded access the system has ensured the main road along geographical route into a network link.

Fig. 6 Example for the result of cable trench planning

Economic evaluation of planning

Based on the model of engineered economics cash flow, put all the involved single project into a whole planning, take the fees of new build and reconstruct substations (including the 220kV substation, 110V substation and 10kV switching station), and the fees of new build cable (including 10kV cable, 35kV and 110kV cables Cable), and also the cost of new equipment operating as inputs, and take the income from electricity sales as output, also consider the time value of money, we have calculate the dynamic financial indicators of the project plans into the table below.

The results showed on above table, suggests that the planning of the programming is viability in economic consideration.

Tab. 2 Example for the economic evaluation result of the planning

item	unit	amount
static invest	10,000$	77097.27
dynamic invest	10,000$	94786.03
reserve funds for price discrepancy	10,000$	15504.88
interests in construction period	10,000$	2183.87
IRR of capital fund	%	15.32
IRR of total invest	%	9.13

CONCLUSION

The decision-making system for planning mentioned in this paper is in accordance with the guiding ideology of "best use of existing resources, and in close integration with power companies' daily operational planning". This system, form architecture design to the overall planning of specific business functions are designed to take full account of the power companies' planning business features, also has used the advanced computer technology and distribution network planning expertise. This system has characteristics as follows:

1) Build a unified GIS-based platform for network planning. The full-featured platform covers all the planning stage, not only provide a set of daily work of the platform for the Planner, but also provide a platform on information access related to the outcome of the planning for the provide staff , at the same time provide a information collection and display platform for relevant research.
2) Achieve interface with PMS, SCADA, and some systems based on the information, also provide urban planning and manual data maintenance interface, fully integrated the basis of information planning , liberating a large number of workers from the tedious data collection and data verification work, try for the realization of planning and information-based planning of day-to-day basis in the preparation of the data.
3) Use a series of advanced professional theories, models and algorithms, in conjunction with the characteristics of a variety of practical methods in Shanghai power grid studied ,to ensure that the planning system more scientific and practical for day-to-day planning and meticulous planning.
4) Has PMS-style interface, and provides the planning process control, use a variety of available interactive visualization technology, easy to operate, and facilitate man-machine cooperation planning.
5) The system uses a tiered architecture design, secure, reliable, and easy to software upgrades.

In short, this paper covers 3 years of research results from the system design. Planning application on the basis of information access interface, verification of information, planning to implementation process, planning to show results in areas such as sharing a comprehensive research and exploration, and The key modules have been targeted research and practical realizes, information based planning, day-to-day planning and meticulous planning lay a good foundation for the ongoing reunification SMEPC Planning Information System accumulation.

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BIOGRAPHIES

Saiyi WANG was born in Ningbo, Zhejiang Province of P.R. China, on January 30, 1978. He received his Ph.D. in electrical engineering in Tianjin University. His research interests include power network planning and he is now working in Urban Power Supply Company, SMEPC, SGCC.