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ANALYSIS OF FOREST FIRE SURVEILLANCE & PREWARNING APPLICATION SYSTEM BASED ON POWER GRID GIS

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ABSTRACT

In recent years, with the increasing scale of power grid, more and more transmission lines are built across forests. Due to the global warming climate, tripping outage of transmission lines occurs more frequently so that the operation of power grid and the national economy are threatened. The stability of power grid would face to a big challenge which may be caused by a large-sized forest fire involving several transmission lines. Therefore, it is significant to establish an analysis and application system about forest fire surveillance and prewarning. In this paper, after a sufficient analysis on forest fire mechanism and existing models, a power grid GIS-based analysis & application system of forest fire surveillance and prewarning is designed to meet the requirements on reliability and stability of power grid. Construction ideas, framework and function of the software would be illustrated respectively.

Keywords: Power grid GIS, Forest fire disaster, Surveillance, Prewarning.

1. INTRODUCTION

In recent years, influenced by unusual climate factors such as global warming, high-hazard weather with characteristics of high temperature, low humidity, continuous drought and high-speed wind is getting more frequent. Additionally, due to human factors, forest fire trends to increase. With the development of economy, electric power industry has rapidly developed. The scale of power grid is larger and larger, more and more transmission lines are built across forests. Tripping outages of transmission lines occur more frequently so that the operation of power grid is threatened severely. Thus, forest fire disasters in all regions over the years and their influence on power system should be analyzed comprehensively and thoroughly, and better techniques and management measures on forest fire forecast and warning before disaster, quick positioning during the disaster and self-healing after the disaster should be put forward to protect power system from forest fire, and to avoid a large scale and social impact. The above techniques and management measures are essential in improving power system stability in the forest fire disasters, and can also reduce the power failure and improve reliability of power supply. Thus, with the enhanced robustness, and security and economic operation, power grid could run securely and economically [1].

2. RESEARCH REVIEW

2.1 Forest fire surveillance research review

There are several main methods in forest fire surveillance, such as manual inspection, watchtower observation, patrol plane inspection and surveillance technologies based on satellite remote sensing, wireless sensor and radar which are developed rapidly in recent years. The tunnel vision of traditional surveillance technologies is relatively narrow so that they are easily restricted by natural factors such as weather and landform, and amount of manpower and material resources are needed. What's more, their effect is not good. Therefore, traditional surveillance technologies are gradually replaced by the emerging technologies.

ZigBee technology is a wireless sensor network technology. Compared with other wireless sensor networks, it is not powerful enough. In the early years, it is used in forest fire surveillance system by some scholars. However, other wireless sensor networks are more popular in the study of forest fire surveillance system [2]. Mobile intelligence is used in searching for combustion source in the wireless sensor network by scholars from the University of Washington in the USA [3], and field data are collected and sent by the wireless sensor network with higher precision and less storage space. However, this technology is still in early stage, the internationally standard has not been formed, and its safety and power dissipation can be improved.

With the development of radar technology, radar accesses the realm of forest fire surveillance. Laser radar system which can detect early small forest fire is developed by Portuguese scientists. The system can precisely recognize the forest fire within the scope of 6.5km [4].

For the weather satellite in the forest fire surveillance, it can be used in the early detection of macro forest fire and continuously tracking surveillance of serious forest fire. From the 1980s, satellites have been used in forest fire surveillance by Canadians, meanwhile, information processing, communication transmission and remote sensing surveillance technologies have been applied in the forest fire surveillance and rescue with good results so that the American advanced technology system of forest fire prevention had been finally formed [5].

From 1986, our country has been involved into research in forest fire surveillance based on meteorological satellite data, and has achieved good results. Surveillance area of meteorological satellite is large enough, so that sensors are not needed in the forest. Besides, meteorological parameters in other respects can also be achieved, which is useful for the forest fire pre-warning. However, there are some limitations in this technology: the frequency of satellite going through the surveillance area is limited, full-time surveillance cannot be realized; satellite image resolution is limited; data accuracy is deficient and so on.

With the advance of science technology and research on fire disaster, forest fire surveillance system is developing in respects of digitization, intelligence and network.

2.2 Research status of forest fire pre-warning

It has been nearly one hundred years since the forest fire forecast firstly appeared last century and the concept of forest fire forecast that was proposed by Dubios from USA has been generally accepted. In 1914, Dubios published “Systematic Fire Protection in the California Forest” in US Forest Service Bulletin. The conception of forest ire forecast was mentioned in the paper, and meteorological factors of forest fire forecast was discussed. But Dubios only focused on the general conceptual description, and specific methods of measuring and forecasting were not put forward; meanwhile, sabinai chinensis branches and trunks were used in forest fire forecast by the former Soviets [6].

In 1925, relative air humidity was used in forest fire forecast by J.G.Wright from Canada. Relative humidity of 50% was used as the demarcation line, and there was a probability of forest fire when the relative humidity is below 50%. This method was authorized by Canadian government in 1982.

In the USA, forest fire forecast work dated from 1925, and Gisborne was the main representative. He proposed a method of fire forecast based on multi-factors in the papers published in 1928 and 1936. In 1993, he developed a precise “fire danger meter”, in which the integrate effect of fire danger was described by combing five factors, so that Gisborne became the originator to develop the fire danger meter in the world. In 1972, J.E. Deeming led and made the “National Fire Danger Rating System” (NFDRS) of America published, and further revised in 1978. The USA is the first country that developed the forest fire forecast system which is suitable for the whole nation.

Study on computer simulation of forest fire behavior has been carried out for many years. North Laboratory in the USA began this study earlier, and has reached major achievements. This laboratory has been doing forest fire spread experiments in large scale since the early 1960s, a theoretical model was put forward in 1972, and a large program—BEHAVE was finally established in 1985 to estimate forest fire behavior, decades of study and achievements have significantly influenced the forest fire prevention work both in America and in the whole world. This program was written in FORTRAN. Distribution characteristic parameters of combustibles and the terrain (gradient) and weather (wind speed, humidity, etc.) conditions should be input, and then several values of forest fire characteristics could be computed. Both the regular and the special forest fire behavior can be forecasted by the program, and the rescue scheme and measure can be put forward according to the forest fire condition. This system consists of two parts. The first part is sub-system of combustibles. In this part, users are provided with two software packages, one is NEWMDL, which is for users to build the combustible model suitable for its region; another is TSTMDL, which is used for debugging and modifying after the model is built. The second part is BURN sub-system, which including two software packages named FIRE1and FIRE2. According to combustible models, user can forecast forest fire; compute the area of fire ground based on FIRE1and FIRE2, which provide a reliable method of commanding and decision-making during firefighting. The output parameters include: wind direction & wind speed under conditions of different gradient and slope, forest fire spread velocity, energy released by the fire on unit area, intensity, fire ground’s area & perimeter, maximum velocity of flying fire at different time. The system can also provide the commanders of firefighting consultant services on firefighting strategy and distributions of human and material resources.

In 1986, fire behavior forecast and combustible model—combustion sub-system was published by the USA Forest Service. Rothermel model was used to forecast forest fire, and fire spread simulation is realized. Combined Rothermel model with GIS, the spatial structure of inlaid shrubbery in New Zealand was simulated by Deoigl, M.Deny and so on who pointed out that this model could be a useful tool for forest land management.

Besides, countries and regions such as Canada, Australia and European Community have also done well in forest fire forest system study and application. Some advanced communication and remote sensing devices have been used in the systems put forward by the above countries, and conception of GIS was introduced. For example, the Fire Management Information System (FMIS) used in Ontario of Canada, is based on ARCVIEW developed by ESRI of USA. SALTUS developed by European Community countries has its own GIS expression system, good 3D display and analysis function. Thermodynamics and dynamics are very important in forest fire behavior forecast study. In countries such as the USA, Canada and Australia, lots of indoor and outdoor combustion tests have been carried out to simulate forest fire, to explore the spread law of forest fire, and to find the connection with the environment. An American, Rothermel combined methods of mathematics with physics in forest fire tests, and developed a series of thermodynamic and dynamic models of fire burning and spread, which are the strong theoretical basis for NFDRS of USA. At present, forest fire laboratories specializing in forest fire spread study have been built in both America and Canada, striving to uncover the mechanism of fire burning and spread by physical method.

In the respect of video surveillance, "forest fire camera" has been put forward in Australia, the camera is actually a video surveillance system, by scanning and analyzing the images in surveillance area with software in the system, fire behavior in a range of 1km can be confirmed in time. Real-time surveillance and pre-warning can be realized by video surveillance system, and the system can respond swiftly at the initial stage of forest fire. Meanwhile, the fire danger is analyzed and managed in real-time so to reduce pre-warning time greatly, which is beneficial for the early control of fire danger. Video image information is rich and visible, and the reliability of fire recognition is improved. However, huge data from video surveillance system calls for high standards on disk storage volume and transport bandwidth. In comparison, data of the built-in video surveillance system is smaller, but its algorithm needs to be changed according to the weather condition and routine maintenance is necessary.

In our country, research on forest fire began in 1950s, later than the other countries. Great Khingan forest fires in 1987 was a favorable turn and multi-factor aggregative indicator forest fire forecast method is developed by the weather bureau in Great Khingan, which is based on the comparison between large sample of history fire danger data and meteorological data over the same period. Meanwhile, conception of fuzzy set is introduced, and mathematical model of fire danger rating and forecasting system are studied in depth.

As for research on forest fire forecast and prediction in our country, most of the researches focus on forest fire danger command and dispatch, as well as spread prediction of forest fire. And there isn't any systematic study on forest fire behavior yet. Researchers like Zhu Qijiang and Wang Haihun have made a profitable trial for space spread dynamic simulation of fire ground [7]. Based on forest combustible features from aerospace remote sensing image and gradient & slope information from EDM, a forest fire spread forecast system that is object-oriented was put forward by Yuan Hongyong et al [8]. After the 1980s, significance of GIS and remote sensing technology in the forest fire behavior prediction was realized in our country, GIS technology has been preliminarily used in the forest fire surveillance. In the respect of video surveillance, forest fire surveillance system built by Shanxi province was put into operation in 2007, and up to 2009, 28 fire behaviors had been monitored [9]. Despite that forest fire surveillance and pre-warning have fairly been developed in our country, scientific research capability on forest fire prevention is insufficient, science and technology methods of forest fire precaution and firefighting are not advanced enough. Besides, with fund shortage, investment on forest fire prevention is relatively small, infrastructure of forest fire prevention is not strengthen enough, and ability to control forest fire is not strong enough. To sum up, forest fire management in our country still has a long way to go.

From the above analysis on the domestic and foreign research status, there are still many problems needed to be solved in the research of forest fire forecast and prediction, for example: research achievements both on two-dimensional and three-dimensional graphics are applied at a low level; real-time acquisition of data is hard, etc. Therefore, GIS technology has been used widely around the world since 1990s. Depending on its good 3D display and analysis function, GIS brings a new opportunity in forest fire forecast and prediction, and as well as, GIS combined with the existing forest fire management system, immeasurable economic benefits and social benefits will be created.

3. SYSTEM DESIGN

3.1 System establishment

Forest fire danger surveillance and pre-warning analysis and application system is based on multi-system and multi-type data integration and fusion technique, GIS-based integrated data processing and display technique, information model technique, software development technique, network communication technique, and information security technique. It includes data persistence layer, business logic layer and presentation layer.

Data persistence layer: The persistence data layer provides a good support for data in the system. Construction of the system calls for geospatial information data, fundamental information data, on-line surveillance data, expert knowledge database, and social public data and so on.

Business logic layer: Business logic layer is the core in system construction, computation and analysis of mass information are realized, and all task data is connected. Comprehensive analysis and display of multi-system data are realized. The business logic layer includes two and three-dimensional GIS service, kernel business service, control service and rule engine.

Presentation layer: Based on power grid GIS platform, visual display of all kinds of danger forecast and pre-warning information is realized. Meanwhile, the location and influenced electrical equipment can be quickly positioned on GIS platform.

3.2 Main functions of the system

Forest fire dander surveillance and pre-warning analysis and application system based on power grid GIS includes several function modules and shown in Fig.1.

The main functions of the system are as followings: basic information query, marquee query, buffer area query, statistical analysis, and forest fire recorded information, forest fire danger analysis, forest fire thematic map and forest fire pre-warning management.

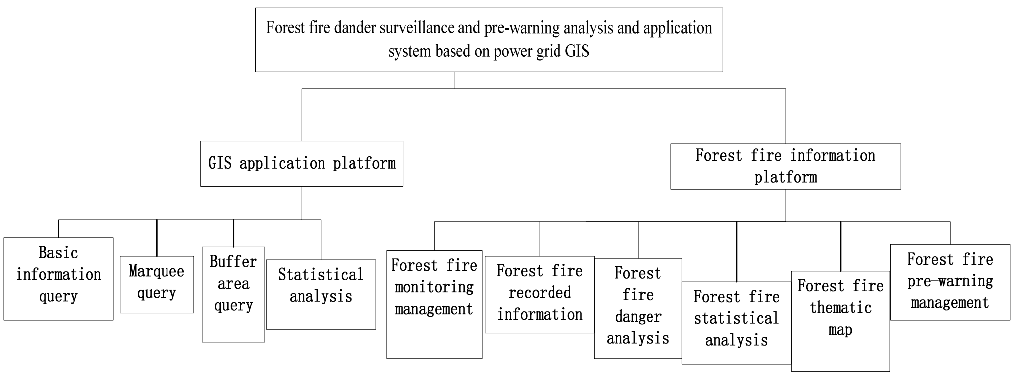

Figure 1. System function structure diagram

3.3.1 GIS basic information query

Based on GIS platform, users can query forest fire information and its location by choosing the city and the time. Spread direction and speed of forest fire, the surrounding area and spread condition of the forest fire in history can be checked by right-clicking the forest fire icon. When checking the forest fire spread condition, power grid GIS coverage can be open to the image part, and geographical environment of the forest fire can be seen in Figure 2.

3.3.2 Marquee query

A use defined area can be designated by marquee query in GIS platform, and forest fire in a certain period in this area can be queried. (Figure 3)

3.3.3 Buffer area query

By power grid resource position and dividing buffer area according to power grid resource, forest fire information of the buffer area can be queried. (Figure 4)

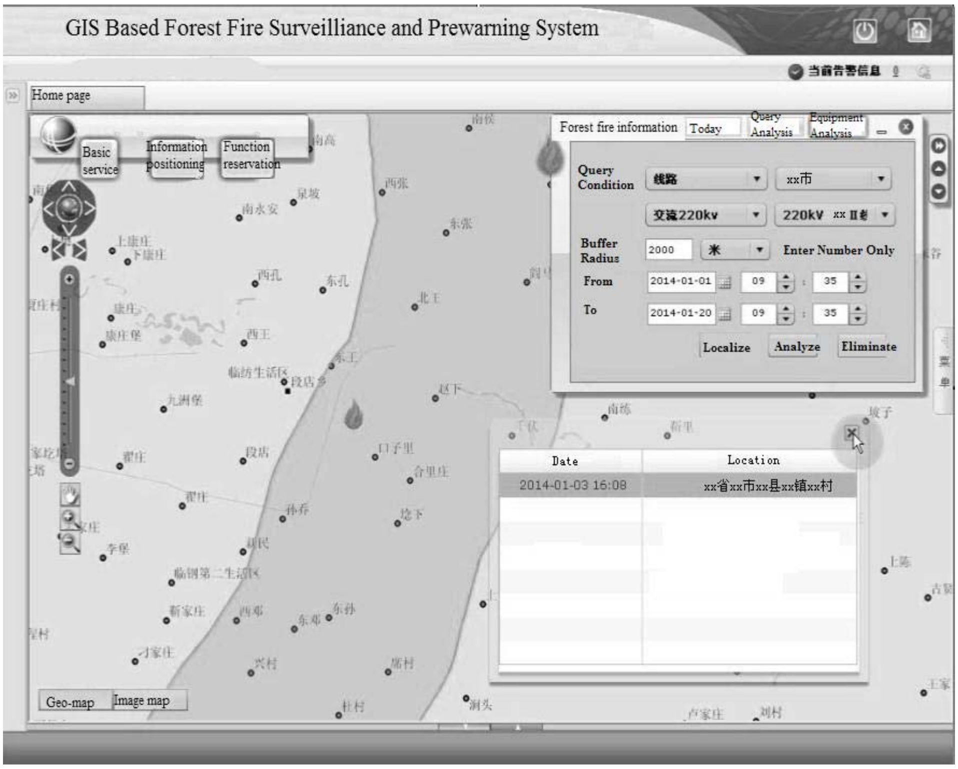

Figure 2. Basic information query

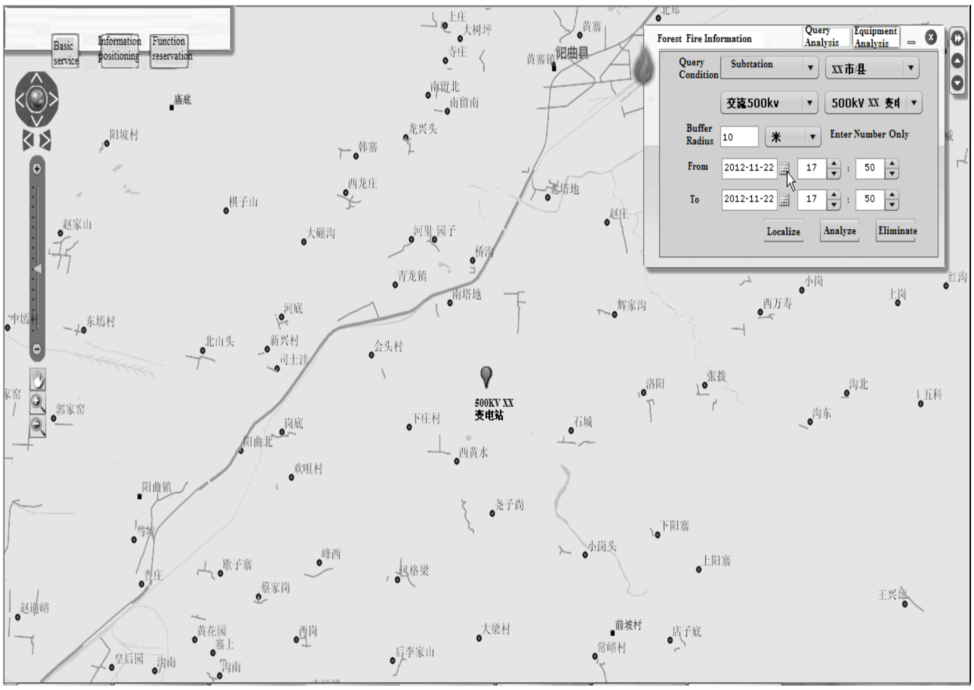

Figure 3. Marquee query

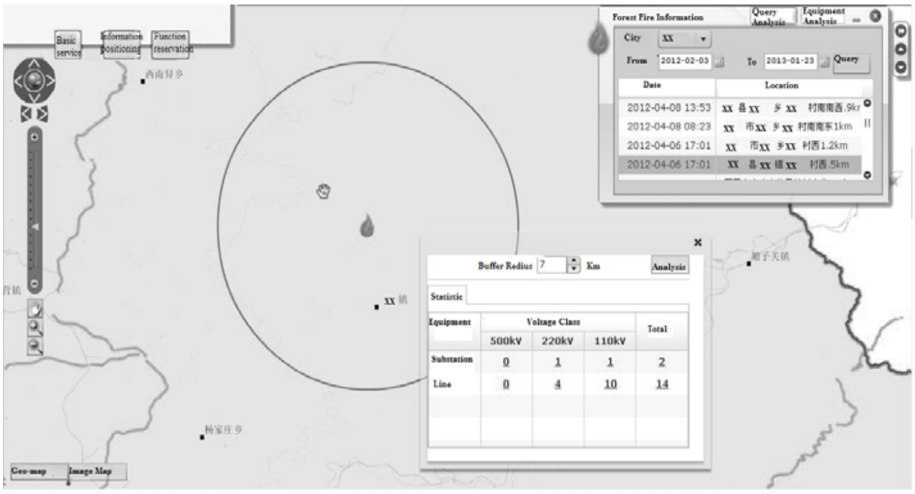

Figure 4. Buffer area query

3.3.4 Statistical analysis on GIS platform

On GIS platform, users do statistics to get the frequency of forest fire. Basic information, tracking pre-warning, forest fire danger and forest fire picture information can be checked by right-clicking the forest fire icon. Analysis on influence of equipment can be also checked by right-clicking the forest fire icon. Meanwhile, important power transmission channels in the near area, high-voltage users, power grid information and distance can be checked, and are shown in highlight. Transmission lines, substations and the towers in the buffer area can be positioned individually according to influenced equipment. Power resource can be retraced by right-clicking tower icon and transformer substations at two ends can be positioned.

3.3.5 Forest fire surveillance management

Both real-time and historical information of forest fire can be checked by the users. Real-time information is the forest fire information for the day. Historical forest fire information can be queried by time, prefecture, place and terrain, and a forest fire list is informed.

3.3.6 Forest fire danger analysis

According to time and prefecture, all the fault information related to forest fire can be checked and positioned.

3.3.7 Forest fire statistical analysis

According to the basic prefecture and time, forest fire times of all prefectures in each period can be statistical analysed by users, the relevant forest fire list can be checked by clicking statistic data (Figure 5).

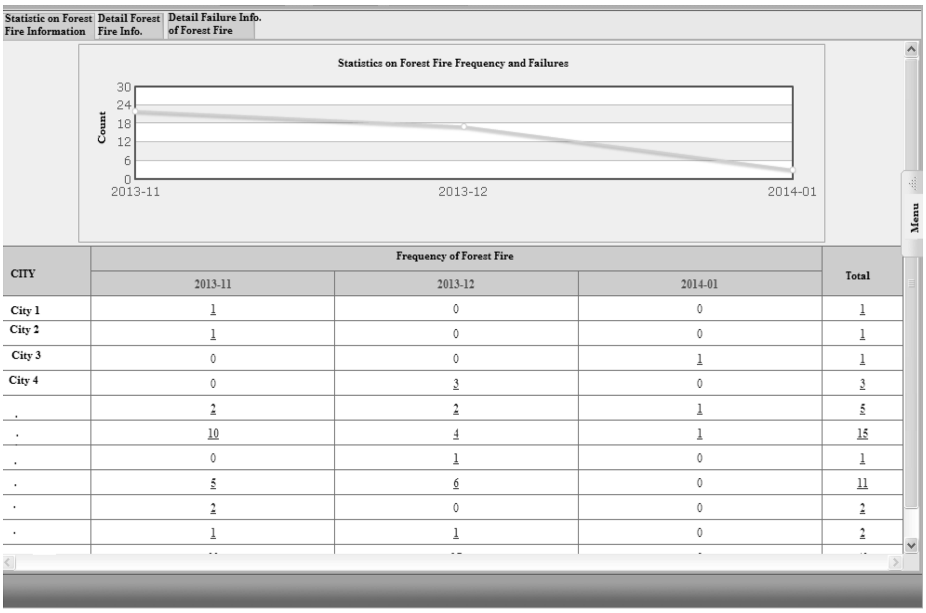

Figure 5. Forest fire statistical analysis

3.3.8 Forest fire thematic map

Fire danger rating distribution map can be checked by users.

3.3.9 Forest fire pre-warning management

In pre-warning management, real-time data is monitored and historical data is analysed, and threshold alarm data is set, once the data exceeds the set value, the person on duty is informed by system windowing.

4. REALIZATION OF SYSTEM

4.1 Power grid geography information management

Served as the most basic information display platform, the system has the basic power grid GIS information and basic operation functions. Besides, it takes FLEX as front display, uses Blaze DS to communicate with forest fire surveillance& pre-warning system too visually display forest fire information on power grid GIS by combining power grid geography information. Meantime, on-line forest fire surveillance system data is analyzed, spatial mathematical model is built, and these data are classified into different groups of data set according to the status message identified by the collected data; with spatial probability statistical analysis, regions that includes most events are extracted in each group, and disaster grade and the influenced area of which is evaluated, the information is dynamically identified and displayed on power grid GIS, thus, information of the disaster area can be dynamically drawn according to the surveillance data.

During the disaster, the disaster scene can be quickly positioned in GIS, and the surrounding meteorological information, environment information and the relevant distribution network information can be checked.

4.2 Forest fire information management platform

Operation condition of power grid is followed by a real-time system, and hidden perils of power system are eliminated quickly. In emergencies or security risks, an alarm is given immediately, warning message is broadcasted by window type as fast as possible, so that the accident can be control or eliminated at beginning by dispatchers, and the following cascading failure is avoided. In the meantime, power grid accident is effectively controlled, recovery time of power accident is shortened, power grid loss can be reduced, decision basis and means are provided, and the ability of power grid to resist the fire disaster accident is improved.

The required data and information are accessed by the system from relevant departments, related indicators involved in all forest fire disaster regions are considered, a disaster region change model based on meteorological factors is built, dynamic change of forest fire disaster regions are followed in time. All the disasters are divided into different disaster pre-warning grades according to their influence on the transmission lines, and relevant workers are informed in time, preparation work against disaster are completed in advance.

4.3 Power grid decision analysis

Based on the existing rule bank, open source rule engine named Drools is used, all the surveillance data is reasoned and judged. Dispatchers, maintainers and leadership of the power grid are provided with auxiliary decisions and opinions.

5. CONCLUSIONS

In this paper, problems faced by power grid forest fire disaster and the relevant existing solution are analyzed, and on this basis, a solution scheme of forest fire disaster based on power grid GIS is proposed, and the demand of power grid dealing with forest fire disaster is met well.

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