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Construction Management Mode of Power Line Engineering in the Era of Big Data

Zheng Qin*

Shanghai Investigation, Design & Research Institute Co., Ltd, Shanghai 200335, China
yz3519@163.com
**corresponding author*

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Abstract: With the arrival of the era of big data (BD for short), the construction management mode of power line engineering is undergoing significant changes. In the traditional mode, the construction of power lines often requires manual monitoring and management, which is inefficient and poses certain safety risks. In the era of BD, advanced technical means and data analysis methods can be applied to achieve automatic monitoring and management of power lines, thereby improving work efficiency and safety. This paper proposes a transmission line fault location algorithm based on BD technology. Through testing and experiments on the algorithm, the accuracy rates of traditional transmission line fault location algorithms for insulators, shock absorbers, and lightning arresters are 86.24%, 87.76%, and 87.17%, respectively. The accuracy rates of transmission line fault location algorithms based on BD technology for various power components are 93.71%, 95.22%, and 94.92%, respectively. This indicates that the fault location accuracy of the transmission line fault location algorithm is higher. The experimental results show that the application of BD technology in power line engineering construction management has achieved certain success. By collecting, storing, and analyzing massive amounts of power line data, it can provide more accurate and comprehensive data support for power enterprises, and help them better achieve the goals of power line engineering construction management.

1. Introduction

Power line engineering construction management refers to the process of comprehensively planning, organizing, coordinating, and controlling power line construction projects. It includes the management of multiple stages of power line construction projects, such as demand analysis, design, construction, and acceptance, to ensure that the project can be smoothly implemented in accordance with predetermined time, cost, and quality requirements.

According to the relevant information, the following scholars' research on power line engineering construction management is listed. Song Guizhu pointed out that the demand for electricity is increasing and the number of electrical equipment is gradually increasing, which poses a challenge to transmission lines. He believes that strengthening the construction technology and management specifications of transmission lines and formulating construction plans and measures based on different landforms and specific circumstances can effectively implement the management of power lines [1]. Yoshikawa Hina believes that partial discharge measurement is of great concern as an insulation diagnosis for power equipment. A detection method with low cost and high sensitivity is needed. He clarified the frequency characteristics of the impedance of ferrite cores and conducted partial discharge measurements using ferrite cores. A new concept of partial discharge detection using power line communication and ferrite magnetic cores is proposed, and the test circuit is constructed and experimentally verified. He also attempted to use the built monitoring system to measure partial discharge to verify the principle of partial discharge detection [2]. Henry Amir pointed out that the development of distribution networks and the increase in power demand have led to the increasing use of distributed power generators, capacitors, and reactor banks. He used network protection methods to research and identify power grids, reviewed the sensitivity of test points that introduced DC reactors, studied network samples, and presented simulation and experimental results [3]. YUNJ B points out that the substation is a key link in the distribution network system, and it is an important interface between the high-voltage transmission system and power users. The stability of its operation has an important impact on the entire power application. He has studied the construction methods of power lines and ultra high winding DC lines, and provided effective suggestions for the design and maintenance of substations [4]. The above research topic has studied power line engineering construction management from multiple directions, which has certain reference value for the research work of this topic. However, the above research directions do not link power line engineering construction management with BD technology, which limits the depth and practicality of further research on this topic.

After consulting the materials, this article found the following research literature on power line engineering construction management and BD technology. Duanchao Li proposed a power grid line loss and power theft prediction system using key technologies of the power BD platform. The system provides integration of line loss calculation, analysis, and visualization. The system can identify potential power theft behaviors through BD mining on abnormal line loss rates in lines and power supply areas, verifying and implementing the application of BD technology in the power industry [5]. Hu Zhuangli pointed out that BD technology is increasingly widely used in modern power systems. He has studied the application of BD technology in rapid image recognition of power transmission towers obtained through large-scale photography by unmanned aerial vehicles. He proposed a method for fast feature embedding using a convolutional neural network convolutional architecture based on fast regions. He conducted deep learning on massive transmission tower images, trained transmission tower models, and generated transmission lines. His research can be used for tree grid modeling of transmission lines, which can replace manual identification of transmission towers and reduce the time required for transmission tower identification and power generation lines [6]. After carefully reading the above article, it can be understood that the research of the above scholars provides a good direction for the research of this topic.

The construction management of power line engineering needs to cover multiple aspects, such as project planning, resource allocation, construction site management, quality control, safety supervision, etc. At the same time, it is also necessary to fully consider factors such as policies and regulations, environmental protection, and social stability to ensure that the project meets relevant standards and requirements, while minimizing the impact on the surrounding environment and social life. This article uses BD technology to optimize the construction process of power lines through transmission line fault location algorithms based on BD technology. Experiments have shown that when the fault distance increases from 500 meters to 3000 meters, the traditional transmission line fault location algorithm increases the positioning time for insulators from 674 ms to 762 ms. The insulator location time of the transmission line fault location algorithm based on BD technology has increased from 621 ms to 654 ms. This indicates that the fault location time speed of the transmission line fault location algorithm based on BD technology is faster. The innovation of this article lies in the use of BD technology to optimize the construction and management process of power lines, improve the accuracy of line fault location, and reduce fault location time.

2. Power Line Engineering Construction Management

2.1. Definition and Process of Power Line Engineering Construction Management

Power line engineering construction management refers to the effective organization and management of the entire process of planning, design, construction, acceptance, commissioning, and subsequent operation and maintenance of transmission and distribution lines [7-8]. The goal of power line project construction management is to ensure that the project construction is completed in accordance with reasonable costs, the best technical requirements, and efficient progress, and to achieve the expected quality objectives. At the same time, attention should be paid to environmental protection and safety factors. The following is the main process of power line engineering construction management.

(1) Project initiation

Project approval is the first step in the entire power line engineering construction management process, providing a legal and targeted basis for the development of power line engineering [9-10]. Determine the necessity, feasibility, and schedule requirements of project construction, develop a preliminary plan, and submit it for approval. During the project initiation stage, the following aspects of work need to be carried out:

Project Feasibility Study: Before determining the construction demand of the power line project, a comprehensive feasibility study on relevant technologies, markets, environment, and other aspects is required to determine whether the project has implementation value.

Preliminary Design Scheme: Evaluate different preliminary design schemes based on project needs and research results, and select the best scheme from them.

Investment estimation: According to the preliminary design scheme, the investment estimation is conducted in combination with local cost factors such as land, labor, materials, etc. This can provide a reference for subsequent funding and bidding.

(2) Preliminary research

Preliminary investigation is the second step in the construction and management process of power line engineering. Its main purpose is to provide necessary data support and scientific basis for the planning and design of power lines through investigation and evaluation of line corridors, geological conditions, and environment. Preliminary research generally includes the following aspects:

Route corridor survey: within the project implementation area, survey the topography and geomorphology of the power line to determine the approximate direction, length, altitude, and other information of the line.

Geological exploration: Based on the situation of the route corridor, geological structure characteristics, stratum thickness, lithology, groundwater level, and other aspects of exploration are conducted to provide reference for subsequent difficulties and construction plans.

Environmental assessment: assess the potential impact of power line engineering construction on the local environment and ecosystem, and propose corresponding preventive and remedial measures.

Research on relevant laws and policies: Understand relevant national and local laws, policies, and standard requirements, ensure project compliance, and provide necessary reference for subsequent planning, design, bidding, and other work.

(3) Scheme design

The main purpose of scheme design is to develop a preliminary design scheme for power lines, modify and improve it, and ultimately complete the preparation of construction drawings. This step directly affects the follow-up work. Through scheme design, the quality, safety, and efficiency of power line engineering construction can be ensured, and the engineering construction objectives can be achieved to the maximum extent. Scheme design generally includes the following aspects:

Preliminary Design: Develop a preliminary design plan based on the results of preliminary research, combined with requirements and technical requirements. The preliminary design plan includes aspects such as line direction, line parameters, tower type, conductor model, and supporting electrical equipment.

Scheme modification: After reviewing the preliminary design scheme, modify the existing problems or areas that need to be optimized to make the scheme more reasonable and scientific.

Perfect design: After the modification of the scheme, it is necessary to further improve the design details, ensure that the scheme meets all requirements and technical requirements, and ultimately form a complete construction drawing.

(4) Construction supervision

The construction supervisor is mainly responsible for supervising and managing the contractor's construction process to ensure that the project is completed in accordance with design specifications and technical standards. Meanwhile, control the construction progress and quality to ensure that the project is completed on time and with good quality. Specifically, construction supervision requires the following aspects of work:

Preparation of construction plan: After the contractor enters the site, the supervision unit needs to communicate with the contractor to jointly formulate a reasonable construction plan.

Construction site management: The supervision unit needs to conduct comprehensive management on the construction site, inspect the conditions of materials, machinery, and construction personnel, and ensure that relevant laws, regulations, and safety production requirements are complied with during the construction process.

Construction quality control: The supervision unit needs to comprehensively control the construction quality to ensure that the project achieves the expected objectives and meets the predetermined quality standards.

(5) Project acceptance

Project acceptance is the last step in the construction management process of power line engineering. Through comprehensive inspection and testing of the project, it is confirmed whether the project meets the design requirements and technical standards. After passing the acceptance, it can be put into operation. Specifically, project acceptance requires the following aspects of work:

Project quality inspection: inspect the quality of various projects of the power line project, including the installation of electrical equipment such as poles, conductors, transformers, grounding lightning protection, transition joints, and other parts.

Engineering function inspection: check the functional performance of the power line engineering, such as the input and output voltage, current, frequency, and other parameters of the transformer.

Project integrity inspection: inspect the integrity of the power line project, including whether the line direction, number and type of poles and towers, and conductor specifications meet the design and requirements.

The process of power line engineering construction management is shown in Figure 1.

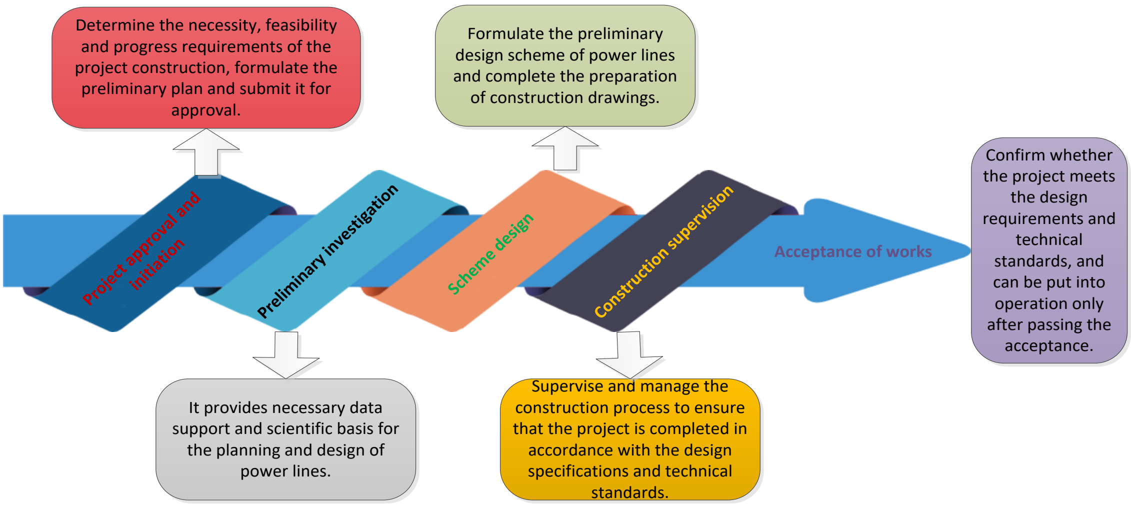

Figure 1: Flow Chart of Power Line Engineering Construction Management

2.2. Application of Big Data Technology in Power Line Construction Management

With the development of modern information technology, BD technology has been widely used in various industries [11-12]. In power line construction management, BD technology can improve work efficiency, reduce costs, and reduce potential risks through automated data collection, analysis, and processing, thereby bringing better economic benefits to power companies. The application of BD technology in power line construction management can include the following aspects:

(1) Route planning

Power line planning refers to systematic research and design in determining the scope of power supply, the demand and location of distribution facilities, and the location of transmission lines and substations [13-14]. BD technology can optimize power line planning in the following aspects:

Data analysis: By collecting various relevant data, including geographic information, meteorological data, electricity consumption data, etc., BD algorithms are used for analysis and mining, such as line load forecasting models based on machine learning models, in order to determine appropriate line planning.

Visual analysis: Visualize data to provide better decision support and communication means. By generating charts and reports on the visualized results, project managers and other relevant personnel can quickly understand the status of power line planning and better formulate work plans and adjustment plans.

(2) Construction process monitoring

Using sensors, cameras, and other equipment to collect data on the construction site, through BD analysis, real-time monitoring of construction progress and quality, timely detection of problems and adjustments to ensure construction progress and quality. BD technology can monitor the construction process of power line construction in the following aspects:

Data collection and storage: The data collected by sensors and cameras are collected and processed, and then stored on the BD platform. These data include construction progress, quality, location of personnel and equipment, and abnormalities.

Real time monitoring: Monitor the status of the construction site in real time through the monitoring system on the BD platform. When construction progress lags behind, abnormal, or dangerous situations occur, the monitoring system would automatically send an alarm message to notify relevant personnel. At the same time, analyzing these data helps to identify bottlenecks in construction and improve construction efficiency.

(3) Resource scheduling

The construction of power lines requires a large number of resources such as personnel, materials, and time. Reasonable optimization of resource scheduling can effectively improve construction efficiency and reduce costs [15]. BD technology can optimize resource scheduling for power line construction in the following aspects:

Resource scheduling strategy: Collect data related to supply chain, inventory, and delivery, analyze various dynamic parameters in real-time, and help determine the optimal resource scheduling strategy. For example, by analyzing personnel turnover and project schedule changes, it is possible to reasonably arrange personnel's working hours and positions.

Intelligent scheduling: Utilize artificial intelligence technology to automatically formulate optimal resource scheduling plans based on different needs and constraints, and quickly respond to changes. For example, when a construction team falls behind schedule or other reasons cause resource waste, the intelligent scheduling system can automatically change the resource allocation plan to ensure optimal utilization of resources.

The application of BD technology in power line construction management is shown in Figure 2.

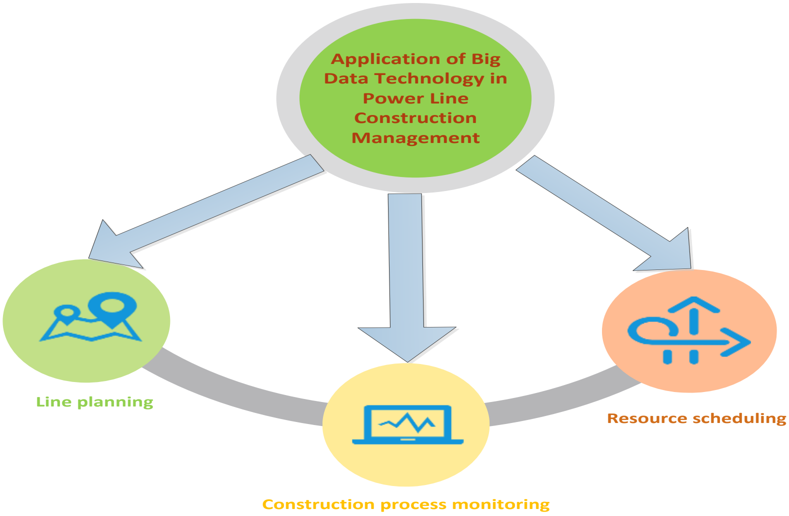

Figure 2: Application diagram of BD technology in power line construction management

3. Transmission Line Fault Location Algorithm Based on Big Data Technology

Traditional fault location methods often require a large amount of human and material investment, which is time-consuming and inefficient. The fault location algorithm based on BD technology can automatically identify fault points and timely repair them by collecting, analyzing, and processing a large amount of line data, thereby improving the accuracy and efficiency of fault location and reducing operation and maintenance costs.

First of all, when locating the line, it is assumed that d is the fault point. M and n refer to both ends of the line. In the single ended traveling wave location method, when the reflected wave caused by the fault point reaches the measurement point m first, the time when the initial traveling wave of the fault reaches the m end is t_{m1}. The time when the reflected wave caused by the fault point reaches the m-end is t_{m2}. Then the fault distance l_{dm} is:

$$l_{dm} = \frac{1}{2}(t_{m2} - t_{m1})v \tag{1}$$

v is the fault traveling wave velocity.

When the reflected wave caused by the opposite bus first reaches the measurement point m, its fault distance l_{dm} is:

$$l_{dm} = l - \frac{1}{2}(t_{m2} - t_{m1})v \tag{2}$$

l is the total length of the transmission line.

In addition, when using the dual terminal traveling wave location method, the time when the initial traveling wave of the fault reaches both ends of the line is t_m and t_n, respectively. At this time, the fault distance l_{dm} is:

$$l_{dm} = \frac{l + (t_m - t_n)v}{2} \tag{3}$$

In the single ended traveling wave positioning method, due to only one side of the measured data, it is impossible to avoid multiple solutions and other issues, resulting in unstable and accurate positioning. The dual terminal traveling wave positioning method utilizes GPS (Global Position System) for time synchronization and achieves accurate positioning through dual terminal communication cooperation, further improving positioning accuracy.

4. Implementation and Testing of Power Line Engineering Construction Management Based on Big Data Technology

After proposing a transmission line fault location algorithm based on BD technology, its performance needs to be tested. Firstly, the accuracy of fault location for each component in the power line is tested. The result data is shown in Table 1.

Table 1: Location accuracy of different algorithms

Power line components	Traditional transmission line fault location algorithm	Fault positioning algorithm for transmission lines based on BD technology
Electrical insulator	86.24%	93.71%
Earthquake hammer	87.76%	95.22%
Lightning protector	87.17%	94.92%

From the experimental data in Table 1, it can be seen that the accuracy rates of traditional transmission line fault location algorithms for insulators, shock absorbers, and lightning arresters are 86.24%, 87.76%, and 87.17%, respectively. The accuracy rates of the transmission line fault location algorithm based on BD technology for insulators, shock absorbers, and lightning arresters are 93.71%, 95.22%, and 94.92%, respectively. Obviously, the transmission line fault location algorithm based on BD technology has a stronger fault location accuracy.

In the construction and management of power lines, in addition to the accuracy of fault location for power lines, the speed of fault location is also an important performance indicator. Therefore, the fault location time of these two algorithms would be studied, and the experimental data is shown in Figure 3.

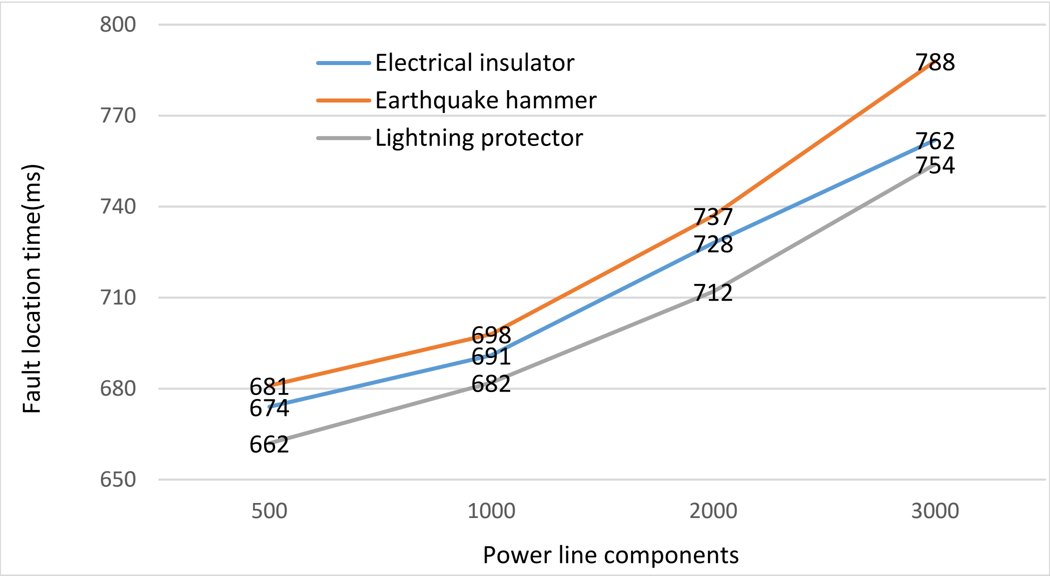

Figure 3 (a): Fault location time of traditional transmission line fault location algorithm

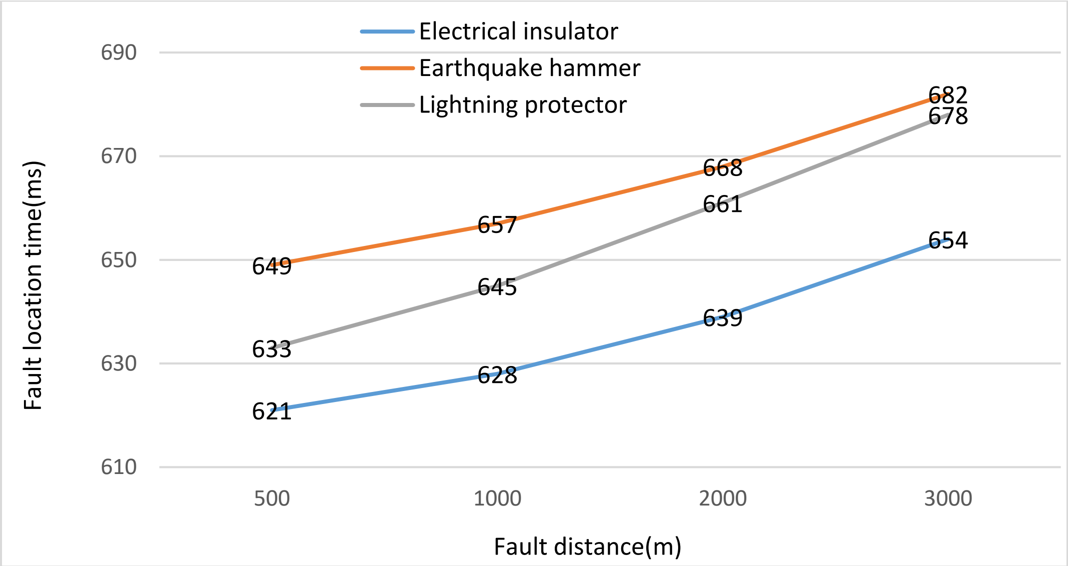

Figure 3 (b): Fault location time of transmission line fault location algorithm based on BD technology

Figure 3: Fault location times for different algorithms

From the data in Figure 3 (a) and Figure 3 (b), it can be seen that when the fault distance increases from 500 meters to 3000 meters, the traditional transmission line fault location algorithm increases the positioning time for insulators from 674 ms to 762 ms. The insulator location time of the transmission line fault location algorithm based on BD technology has increased from 621 ms to 654 ms. The same is true for other power components. Obviously, transmission line fault location algorithms based on BD technology have a faster time speed for fault location.

5. Conclusions

BD technology can achieve real-time monitoring and prediction of power lines, identify potential fault points and promptly handle them. At the same time, data analysis can better grasp the operation of power lines, optimize line layout and design, and reduce power supply costs. In addition, during the construction of power lines, BD technology can also achieve real-time supervision of construction personnel and equipment, improving safety and quality. In short, in the era of BD, the construction and management mode of power line engineering would increasingly tend to be digital, automated, and intelligent, which would bring more opportunities and challenges to the power industry. Experiments have proved that using BD technology can achieve real-time monitoring and analysis of power lines, improve the accuracy of fault location and reduce the time for fault location. However, it should be noted that the location of transmission line faults is usually a complex process that requires consideration of multiple factors, such as weather, terrain, load changes, and other factors. Therefore, in practical applications, it is necessary to continuously optimize and improve algorithms to improve the accuracy and efficiency of fault location.

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