Dynamic increasing the Capacity of Transmission Line Based on the Kylin Operating System

Wei Li, Zhiwei Feng, Jing Zhou, Kehe Wu, and Jing Teng

School of Control and Computer Engineering, North China Electric Power University, Beijing, China
liwei@ncepu.edu.cn

Abstract. Transmission of electric power has traditionally been limited by the conductor thermal capacity statically defined of a transmission line. However, based on real-time measurement and analysis of environmental data and transmission line characteristics, the capacity of transmission line can be greatly increased. Consequently, a monitoring system is designed and implemented to dynamic increase the transmission capacity. The system is executed on the Kylin operating system to promote its application in the electric power system. Based on the J2EE^{TM} platform, the monitoring system realizes a series of functions, such as real-time data collection, calculating and analysis, automatic storage of relevant parameters, transmission capacity prediction, etc. The monitoring system provides a reliable hardware and software platform for supervising and scheduling the grid. The effectiveness of the system is evaluated by its successful application in a grid data supervision system.

Keywords: Transmission line; Transmission capacity;J2EE^{TM} platform; Kylin operating system

1 Introduction

With the sustained growth of economy and electricity load in recent years, traditional transmission of electric power, which has been limited by the rated conductor thermal capacity, cannot satisfy the power demands now. However, the construction of new transmission systems necessitates enormous investments in terms of time and capital[1, 2].Therefore, it is significant to improve the transmission capacity based on the existing transmission lines. In fact, the transmission capacity not only depended on the conductor temperature, but also related to the weather conditions, namely the ambient temperature, the sunshine intensity, and the wind velocity, etc. According to the current technical specification[3], the rated ampacity of a transmission line is defined based on the maximum allowed conductor temperature of 70°C, while under the "worst case" of predetermined climatic conditions - a quite high ambient temperature 40°C, a fairly low wind speed 0.5 m/s, and an extremely strong sunshine intensity 1000 W/m^2. This definition guarantees safe operation during the lifetime of transmission line.

However, the rated ampacity is a very conservative theoretical value due to the extreme climatic preconditions. In fact, the practical ampacity could be much higher than the rated ampacity. In another word, a potential ampacity exists between the predetermined ampacity and the practical allowed one. Therefore, we propose a dynamic capacity-increasing approach to make full use of the potential ampacity, while guaranteeing the operation security of the transmission line.

In view of the current operation code of transmission line, and the technical specification of real-time supervision of electrical power system, a monitoring system is designed and implemented to dynamic increase the capacity of transmission line. The monitoring system is a Web application platform based on the Java™ 2 Enterprise Edition (J2EE™) distributed multi-layer application framework, using the Kylin operating system (OS) to enhance information security. The Kylin OS is a landmark achievement of the National High-Tech Research and Development Program of China (863 Program), which eliminates the monopoly of foreign OS and provides a reliable protection for Chinese information systems. The heterogeneity of the J2EE™ platform ensures the feasibility of running different operating systems on the server end and the client end, respectively. For example, the server end uses the Kylin OS for the reason of information security, whereas the client ends can still employ their original Windows® or other OSs. In conclusion, the monitoring system provides a reliable hardware and software platform for real-time supervising and scheduling the electrical grid.

In the following sections, we will first elaborate the principle of dynamic increasing the transmission capacity. Then the main functions and the architecture of the system is introduced. After that, the implementation of the system in the real world is evaluated in the section 3. Finally, we conclude and give some prospectives of the work.

2 Dynamic Transmission Capacity-increase

Given the real-time data collected by the monitoring system, including the meteorological parameters, the conductor temperature, the current ampacity, etc, the theoretical maximum ampacity and the potential one are calculated. The calculation is based on the mathematical model defined in the power industry standard DL / T 5092-1999 "technical code for 110~500kV overhead transmission line" [3]. The formula is shown as follows:

$$I = \sqrt{\frac{9.92(T-t)(vD)^{0.485} + \pi\varepsilon DS[(T+273)^4 + (t+273)^4 - \alpha J_s D]}{R}} \quad (1)$$

where I denotes the ampacity of the transmission line, with the unit of ampere. T is the surface temperature of the line, with the unit of °C. Similarly, t is the ambient temperature, °C. v is the wind speed that is perpendicular to the line, m/s. D is the cable diameter, m. S is the Stefan - Boltzmann constant, whose value is 5.67×10^{-8} W/m^2. ε is the surface radiation coefficient of transmission line, which takes the value in the interval [0.23, 0.43]for bright new line; Whereas for old lines or the ones painted with black preservative, ε is in the interval [0.9, 0.95]. α is the surface endothermic coefficient of line. Similarly, the value of it is [0.35, 0.46] for bright new lines, and [0.9, 0.95] for old ones or lines painted with black preservative. J_s is the sunshine intensity,which takes the value of 1000W/m^2 in shiny days, and when the sunlight is perpendicular to the line. R is the ac resistance of the line, Ω/m. As have been mentioned above, the rated ampacity of a transmission line is traditionally defined using fixed values for the parameters in the equation (1). However, in the proposed monitoring system,

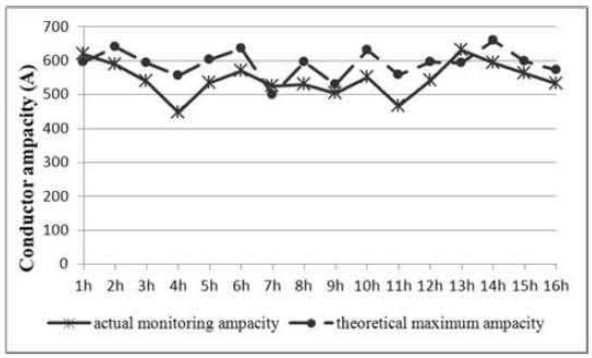

Fig. 1. Ampacity comparison diagram

we use the real-time data in the place of the fixed values to calculate the maximum allowed ampacity, which is therefore much more flexible and adaptable to the practical situation. In addition, the actual ampacity of the transmission line is real-time supervised by the system. As shown in Fig. 1, the theoretical maximum allowed ampacity is denoted by the dashed line, and the actual monitoring ampacity is demonstrated by the solid line, where their temporal values corresponding to each time point are denoted by dot and cross, respectively. The difference between the theoretical maximum ampacity and the actual monitoring one is thus the potential ampacity. Therefore, users can realize how much the transmission ampacity can be improved, while guaranteeing safe operation of the transmission line. According to our calculation, if the transmission line runs at the theoretical ampacity, we can improve the transmission capacity to more than 4 million kW $\cdot$ h in a year, which consists of 10% of its total original capacity.

3 System Design

3.1 System Architecture

The proposed monitoring system provides a platform to dynamically increase capacity, which consists of two parts, the hardware and the software. The hardware part is composed of a small meteorological station, and the sensors that are responsible of monitoring the temperature, the tension and the sag of the transmission line. The software part is based on the Brower/Server (B/S) structure, which adopts the popular J2EE™ platform to ensure the heterogeneity of the system.

Hardware And OS Platform The sensors are directly mounted on the transmission lines, which continuously detect and transfer the monitoring data to the remote data server. Therefore, the meteorological data, and the temperature, tension and sag of transmission lines around the monitoring points are collected in real time.

Since the security requirement of the electrical grid data is quite high, we choose the domestic Kylin OS as the operation platform for the monitoring software. It is also one of the innovation points of the proposed system, which realizes the application of the Kylin OS in power systems and guarantees the system information security as well.

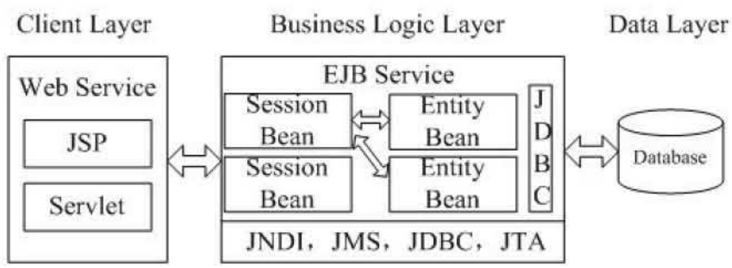

Fig. 2. Software architecture diagram

Software Architecture Design The software part of the system uses the J2EE™ platform, which adopts a reasonable and popular three-layer architecture. As shown in Fig. 2, the system is divided into the client layer, the logic layer and the data layer. The data layer adopts the Oracle® 10g Database, which mainly stores the real-time monitoring data and their upper and lower bounds. It is also responsible of transferring data to the other two layers, such as the real-time calculations of ampacity, the historical data and the related data tables, etc. Besides providing the raw data, the data layer stores the course data submitted or processed by the logic and the client layer as well.

The logic layer packages the process control logic and the operation codes of the system, which is in favor of the reusability and the scalability of the system. In this layer, the Enterprise JavaBeans™ (EJB™) component is the core of the system, which realizes the system operation logic. It receives the query from the client layer, then retrieves the corresponding original data from the database and processes it, finally the processed data is sent back to the users. Furthermore, the EJB™ container provides complex system services, such as transaction, life cycle, state management, multi-threading, and resource storage pool etc. Therefore, it is not necessary for the developers to program these basic but tedious system services. On the contrary, they can be much more concentrated on the operation logic. As a result, we have realized and packaged several specific function modules for the monitoring system in order to dynamically increase the transmission ampacity.

The client layer mainly consists of Java Server Page(JSP)pages, which is the interface between the system and users. In the client layer, users can inspect the functions completed by the logic layer. They can also interactive with the logic layer by input various parameters. For example, users can choose distinct monitoring station and different monitoring time; then, the logic layer generates the graphic data corresponding to these inputs; finally, the query result is returned back to the client layer, and displayed on the current page.

3.2 System Fuction

With respect to the system function, the proposed monitoring system is divided into seven modules: data collection and storage; conductor parameter management; dynamic capacity calculation; real-time display of the meteorological data, the conductor temperature and the ampacity; false alarms; historical data analysis; and statistical report. The function modules of the system are shown in Fig. 3.

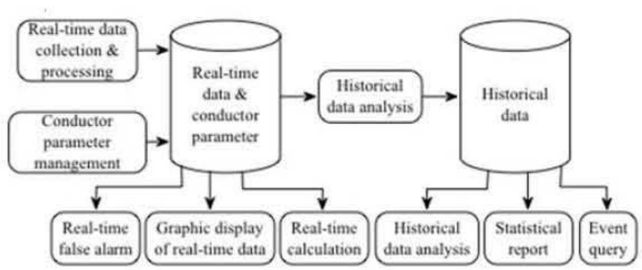

Fig. 3. Function module diagram of the system

Data Collection And Storage There are two types of system monitoring data: real-time data and historical data. The database for real-time data stores only the daily data, which accelerates its data retrieval as a result. It also provides a caching mechanism for the data analysis and the historical data storage. The storage of the historical data prepares the source for any potential query. In fact, the database server and Web server of the system provide real-time data recording. In addition, the using of the advanced data storage strategy dynamically stores the collected data according to time stamp[5].

Conductor Parameter Management The conductor parameters and the information of the transmission lines and the towers are managed centralized in the system, in order to provide users with rapid, accurate responses. In addition, the conductor parameter management module achieves relevant configuration of the conductor.

Real-time Data Display And Analysis Specifically, the real-time data we discussed here include the meteorological data and the operation state of the transmission line, in which the meteorological data consists of the wind speed, the wind direction, the ambient temperature, the environment humidity and other data; the operation state of the line is composed of its temperature, sag, tension etc. The data display module uses several different forms, such as tables, charts, curves etc. to directly illustrate the monitoring result to the end users on Web pages.

The data analysis module is undoubtedly one of the key functions of the system, which provides real-time data query and analysis services to users. The results of query and analysis can be saved to Word, Excel or plain text format. By comparing, analyzing and researching the historical data, we can explore the transition principle or tendency of the transmission ampacity. Therefore, reasonable estimates and predictions on the ampacity of transmission line can be made. It consists not only the foundation of reliable and economic operation of the power system, but also plays an important part in the technical support for the power system.

4 System Implementation

4.1 Configuration

We employ the J2EE™ platform as the environment of system development. The Apache Tomcat and the JBoss® work as the web server and the application server, respectively. The Oracle® 10g acts as the database server of the data layer, and the JDBC driver of Microsoft® is used as the interface of database-driven. The Eclipse 3.2 is chosen as the development tools.

4.2 Operation Results

Real-time Monitoring The information needs to be real-time monitored including the SCADA current, the ambient temperature, the conductor temperature, the environment humidity, the wind speed and the wind direction, as shown in Fig. 4.

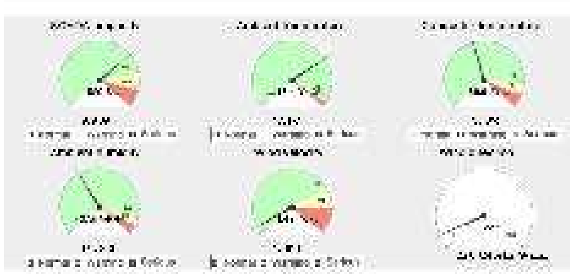

Fig. 4. Real-time monitoring diagram

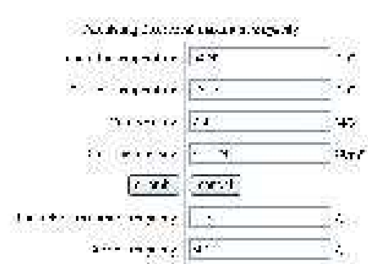

Fig. 5. Real-time monitoring diagram

Theoretial Ampacity Calculation In fact, the system also allows users to calculate the theoretical ampacity by themselves, using the mathematical model described in the section 2. As shown in Fig. 5, users can manually submit the required parameters to obtain the theoretical maximum ampacity, and then compare it with the current ampacity.

5 Conclusion

By accurately monitoring the conductor temperature and the meteorological data in real time, the proposed system calculates the potential ampacity. Therefore, it enables the system operator to maximize the utilization of the transmission line, while ensuring safe operation. The benefits of dynamic capacity increasing consists of improving the reliability and the safety of the power system, reducing the capital expenditure, increasing the resources efficiency, etc. Based on the J2EE^{TM} multi-layer distributed architecture, the system is developed with strong information security, flexibility, cross-platform portability, scalability and maintainability. It has been successfully applied to a grid data supervision system, and has made great contribution for the development of the grid. The proposed system will help promoting the informatization, marketization and intelligentization of the power industry in the long run. However, the aging degree of the transmission line caused by maximizing its transmission capabilities is still under study.

References

1. Ye Hongsheng, Gong Dawei, Huang Weizhong, etc: Feasibility Study on Increasing Conductor Allowable Temperature and Engineering Practice. Electrical Equipment, 25(9), pp. 1-7. (2004)
2. Qian Zhiyin, Zhang Qiping: Improving Transmission Ability of 500kV Lines in East China Power Grid. Electrical Equipment, 10(6), pp. 8-12. (2003)
3. Yang Peng, Fang Xinyan.: Increasing transmission line capacity by DTCR model. East China Electric Power, 33(3), pp. 11-14. (2005)
4. DL/T 5092-1999P: Technical code for designing 110 500kV overhead transmission line
5. Wu Kehe, Xiao Li, Zhou Jing: The research and implementation of a monitoring system of transmission lines to dynamic increasing capacity. The informationization annual meeting of China's power industry (2009)
6. Fei Si Technology R & D Center: Developing Detail Explain JSP Application.Electronic Industry Press (2002)
7. Lin Huoming: EJB3.0 Entry Classical Arcobat.Tsinghua University Press (2008)