Adaptive Topological Analysis Model of Low Voltage Power Supply System in Coal Mine Based on Incidence Matrix

Xinliang Wang [a], Zhigang Guo [b], Jianing Zou [c]

School of Physics and Electronic Information Engineering, Henan Polytechnic University, Jiaozuo 454000, China.

[a]junci158@163.com, [b]756073673@qq.com, [c]690293351@qq.com

Abstract

In the low voltage power supply system of coal mine, manual setting calculation method is mainly adopt, This method is inefficient and error-prone. This paper presents an adaptive topology analysis model of low voltage power supply system in coal mine based on incidence matrix, which can automatically complete the adaptive topology analysis of low voltage power supply system in coal mine. The simulation results show that the final incidence matrix G between the power supply line and the power supply line calculated by the model can accurately obtain the actual power supply relationship between the electrical equipment,and provides an effective network topology analysis model for the automatic setting calculation of the low - voltage power supply system of the coal mine.

Keywords

Topology analysis, self-adaptive, incidence matrix, low voltage power supply system.

1. Introduction

In the process of setting calculating the low voltage power supply system in actual coal mine, most of them adopt manual calculation method, This method is inefficient and error-prone. In order to realize the automatic setting calculation of low voltage power supply system in coal mine , it is necessary to construct the network topology analysis model of low voltage power supply system and realize the self - learning of network topology , which is one of the main problems to be solved in this paper.

The literatures [1,2]calculates according to the state of some switches, The topology analysis of the power system is completed by analyzing the node voltage equation in Switch closing state and opening state, This method only needs to search a few switching states to get the result. The literatures [3]Wang Xiangzhong et al. used the node-branch incidence matrix to represent the topology of the power network, which can also realize the analysis and identification of the power network topology faster. The literatures [4,5] incidence matrix marking method and loop matrix method are used to realize the network topology analysis, and the half-path search method is used to update the topological structure of the local network. The literatures [6],a new method of generating incidence matrix for on-line analysis of network topology is presented. The literatures [7] put forward the network topology analysis method based on incidence matrix can effectively realize the network topology identification of coal mine high voltage power network, but it only solves the problem of network topology learning under the single busbar separation operation mode of coal mine high voltage power network.

The above methods are mainly based on the power system or coal mine high-voltage power supply system power network structure characteristics, and build the corresponding network topology analysis model. The adaptive topology analysis model of low voltage power supply system in coal mine based on incidence matrix is presented in this paper, which can automatically complete the adaptive topology analysis of low voltage power supply system in coal mine. It provides an effective network topology analysis model for realizing automatic setting calculation of low voltage power supply system in coal mine.

2. Adaptive Topological Analysis Model

Set up system reactance of mine low voltage power supply system under maximum operation mode and system reactance under minimum operation mode. Set up low voltage switch of power supply for low voltage power supply system in mine, The low - voltage switch of the power supply refers to the low - voltage switch which is directly powered by the superior power supply department; The power supply line refers to the low-voltage cable in the low-voltage power supply system; Low-voltage switches include feed switches and electromagnetic starters.

According to the power supply relationship of mine low voltage power supply system, the incidence matrix A between power supply line and low voltage switch, the incidence matrix B between low voltage switch and power supply line, and the incidence matrix D between low voltage switch and low voltage switch are generated; The incidence matrix A of the power supply line and low voltage switch indicates the direct power supply relationship of the low voltage power supply line and the low voltage switch in the mine, low voltage switch and power supply line incidence matrix B represent the direct power supply relationship of low voltage switch and power supply line in mine low voltage power grid, low voltage switch and low voltage switch incidence matrix D denotes the direct power supply relationship between low voltage switch and low voltage switch in mine low voltage power network; If there are n power supply lines and m low voltage switches, Then the incidence matrix A is n row m column, the incidence matrix B m row n column, and the incidence matrix D m row m column; The incidence matrix A takes the power supply line sequence number as the line number and the low voltage switch sequence number as the column number; The incidence matrix B takes the low voltage switch sequence number as the line number and the power supply line sequence number as the column number; The incidence matrix D takes the low-voltage switch sequence number as the line number and the low-voltage switch sequence number as the column number; The main steps are as follows:

Step 1). In the process of generating the incidence matrix A, The element in row i and column j in A is denoted by A_{ij}, if the power supply line corresponding to the line number i of line i is supplied directly by the low-voltage switch corresponding to the column number j of column j of the j column, and the low voltage switch corresponding to the j th column is in a closed state , then $A_{ij} = 1$, otherwise $A_{ij} = 0$;

Step 2). In the process of generating the incidence matrix B, the elements in the j column of line i in B is denoted by B_{ij}, if the low-voltage switch corresponding to the line number i of line i is directly supplied by the power supply line corresponding to the column number j of column j, And the low voltage switch corresponding to the line number i of the line i of line i is in the closing state, then $B_{ij} = 1$, otherwise $B_{ij} = 0$;

Step 3). In the process of generating the incidence matrix D, The element in row i and column j in D is denoted by D_{ij}; When m is not equal to n, if the low-voltage switch corresponding to the line number i of line i is directly supplied by the low-voltage switch corresponding to the column number j of column j,and the corresponding low-voltage switches are all in the closing state, then $D_{ij} = 1$, otherwise $D_{ij} = 0$; When i equals j, If the line number i of line i corresponds to the low voltage switch in the state of closing, then $D_{ij} = 1$, otherwise $D_{ij} = 0$.

According to the connectivity of unidirectional graph, the final relation matrix G (n row n column)of Power supply relationship and power supply line is calculated by the correlation matrix A. B and D; By default, The multiplication of matrix elements and matrix elements is binary logic "and" operator,The addition of matrix elements and matrix elements is binary logic "or" operator; The main steps are as follows:

Step 1). The incidence matrix C is calculated according to the incidence matrix A and the incidence matrix D,C=A*D.

Step 2). Compare whether matrix A and matrix C are the same, if different, the matrix C value is given to the matrix A,(Repeat step 1); On the other hand, if C and A are the same, the calculated matrix C is the final incidence matrix E between the power supply line and the low-voltage switch, and matrix E represents the final power supply relationship between the power supply line and the low-voltage switch in the mine low-voltage power network,(execution step 3);

Step 3). The matrix of low voltage switch of power supply is represented by L(m row 1column),$L^T = [L_1 \ \ L_2 \ \cdots \ L_i \ \cdots L_m \ ]$,

$$L_i = \begin{cases} 1, If\ the\ low\ voltage\ switch\ i\ is\ a\ power\ switch \\ 0, If\ the\ low\ voltage\ switch\ i\ is\ not\ a\ power\ switch \end{cases}, 1 \le i \le m; \quad (1)$$

Matrix P represents the power supply line matrix, $P^T = [P_1 \ \ P_2 \ \cdots \ P_i \ \cdots P_n \ ]$, $1 \le i \le n$; $P_i = 1$ indicates that the corresponding line i is a power supply line, $P_i = 0$ indicates that the corresponding line i is not a power supply line, i represents the sequence number of the power supply line; P=E*L; The power supply line corresponding to the line number of all elements in matrix P with a value of 1 is a power supply line;

Step 4). The first stage incidence matrix F of power supply lines and power supply lines is obtained according to the calculation of the incidence matrix E and B,F=E*B; Because the unidirectional diagram structure is used, the power supply relationship between the power supply line I and the power supply line j has not been correctly reflected; Therefore, the power supply correlation matrix F needs to be modified to get the modified matrix NF; The elements in column j in row i in F are denoted by F_{ij} , the elements in column j in row i in NF are denoted by NF_{ij};if i≠ j,then NF_{ij}=F_{ij}; if i=j, then $NF_{ij} = 1$;

Step 5). Matrix NF and self matrix multiplication are carried out to obtain a new matrix H ;

Step 6). Compare whether matrix H and matrix NF are the same, if different, the matrix H value is given to the matrix NF,(Repeat step 5); On the other hand, if H and NF are the same, then the matrix H obtained by calculation is the final power supply incidence matrix G between power supply line and Power supply relationship.

3. Simulation Analysis

Figure 1 is a diagram of low voltage power supply system in mine, In figure 1, the low-voltage switch filled with black is the opening state, and the unfilled low-voltage switch is the closing state; The network topology analysis of mine low voltage power supply system shown in figure 1 is carried out according to the constructed adaptive topology analysis model; The simulation process is as follows:

According to the power supply relation of mine low voltage power supply system, the incidence matrix A of power supply line and low voltage switch, the incidence matrix B of low voltage switch and power supply line, and the incidence matrix D of low voltage switch and low voltage switch are generated; The main steps are as follows:

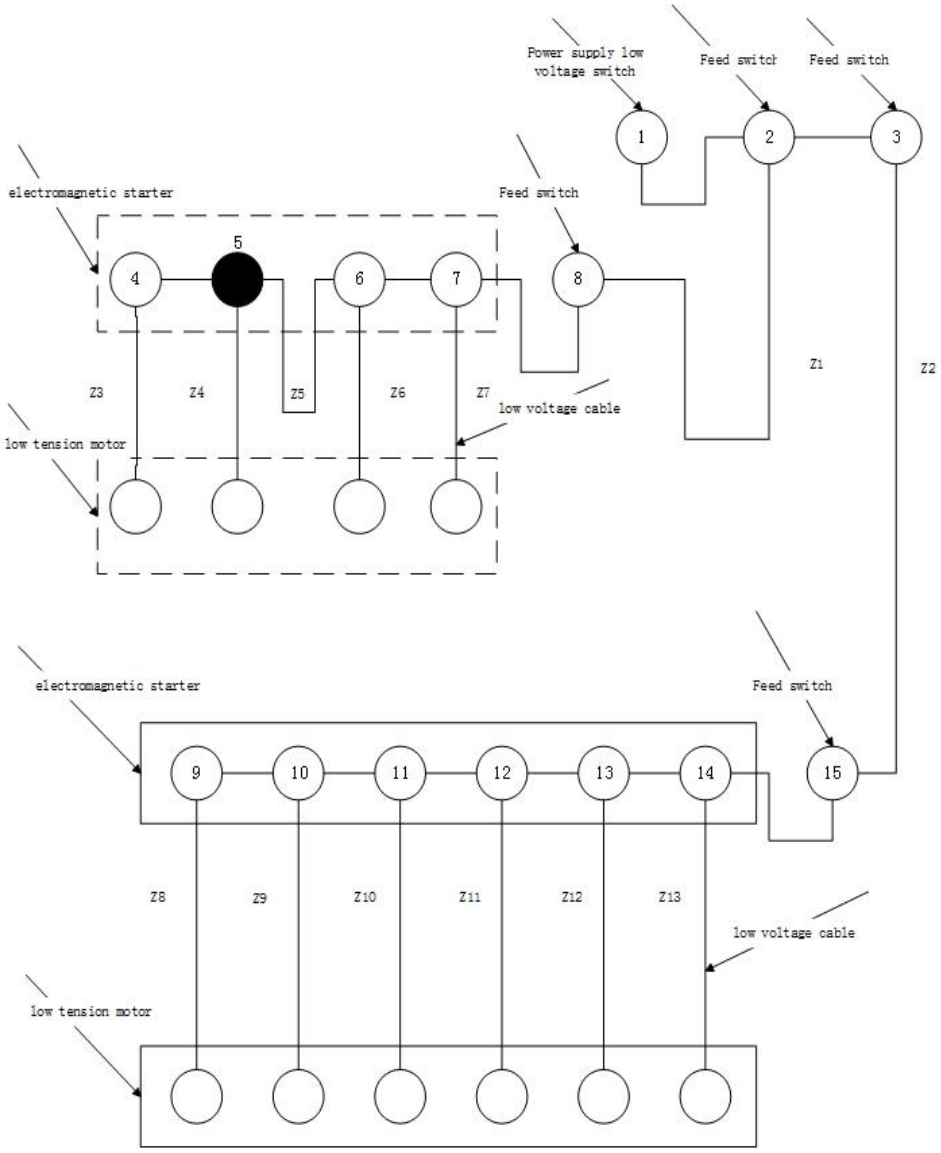

Figure 1. Low voltage power supply system diagram

Step 1). According to the mine low voltage power supply system shown in figure 1, the incidence matrix A is generated;

$$A=\begin{bmatrix}0&1&0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&1&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&1&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\end{bmatrix};$$

Step 2). According to the mine low voltage power supply system shown in figure 1, the incidence matrix B is generated;

$$B=\begin{bmatrix}0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&1&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\1&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0\\0&1&0&0&0&0&0&0&0&0&0&0&0\end{bmatrix};$$

Step 3). According to the mine low voltage power supply system shown in figure 1, the incidence matrix D is generated;

$$D=\begin{bmatrix}1&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\1&1&0&0&0&0&0&0&0&0&0&0&0&0&0\\1&0&1&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&1&0&1&0&0&0&0&0&0&0\\0&0&0&0&0&0&1&1&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&1&0&0&0&0&0&1\\0&0&0&0&0&0&0&0&0&1&0&0&0&0&1\\0&0&0&0&0&0&0&0&0&0&1&0&0&0&1\\0&0&0&0&0&0&0&0&0&0&0&1&0&0&1\\0&0&0&0&0&0&0&0&0&0&0&0&1&0&1\\0&0&0&0&0&0&0&0&0&0&0&0&0&1&1\\0&0&0&0&0&0&0&0&0&0&0&0&0&0&1\end{bmatrix}.$$

$$E=\begin{bmatrix}1&1&0&0&0&0&0&0&0&0&0&0&0&0&0\\1&0&1&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\0&0&0&0&0&1&0&1&0&0&0&0&0&0&0\\0&0&0&0&0&0&1&1&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&1&0&0&0&0&0&1\\0&0&0&0&0&0&0&0&0&1&0&0&0&0&1\\0&0&0&0&0&0&0&0&0&0&1&0&0&0&1\\0&0&0&0&0&0&0&0&0&0&0&1&0&0&1\\0&0&0&0&0&0&0&0&0&0&0&0&1&0&1\\0&0&0&0&0&0&0&0&0&0&0&0&0&1&1\\0&0&0&0&0&0&0&0&0&0&0&0&0&0&1\end{bmatrix};$$

According to the connectivity of unidirectional graph, the final relation matrix G (n row n column)of Power supply relationship and power supply line is calculated by the correlation matrix A. B and D; The main steps are as follows:

Step 1). The final incidence matrix E for calculating the power supply line and the low voltage switch, matrix E represents the final power supply relationship between the power supply line and the low-voltage switch in the mine low-voltage power network,

Step 2). According to the mine low voltage power supply system shown in figure 1, the low voltage switch 1 is the low voltage switch of the power supply, power supply low voltage switch matrix.

$$L^T = [1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0], \mathrm{P} = \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

Then the supply lines Z1 and Z2 are power supply lines;

Step 3). Calculation incidence matrix NF,

$$\mathrm{NF}=\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix};$$

Step 4). Final power supply incidence matrix G for calculating the relationship between power supply line and power supply line,

$$\mathrm{G}=\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

According to the actual power supply relation of the high voltage power supply system diagram shown in figure 1, it can be seen that the ultimate power supply incidence matrix G between power supply lines and power supply lines is consistent with the actual power supply relationship between low voltage equipment. The validity of the proposed adaptive topology analysis model is verified effectively.

4. Conclusion

In this paper, an adaptive topology analysis model of low voltage power supply system in coal mine based on incidence matrix is proposed, which can automatically complete the adaptive topology analysis of low voltage power supply system in coal mine. The simulation results show that the final incidence matrix G of the power supply relationship between the power supply line and the power supply line can accurately obtain the actual power supply relationship between the electrical equipment. It provides an effective network topology analysis model for realizing automatic setting calculation of low voltage power supply system in coal mine.

Acknowledgements

This paper is supported by the Doctor Fund of Henan Polytechnic University (Grant No B2012-073), the Key Lab of Mine Informatization, Henan Polytechnic University (KY2015-08), Key Science and Technology Program of Henan Province (172102210274).

References

[1] Zhang jinfang, Qian cheng, Wang zengping: New algorithm for topology analysis of grid system based on generalized kirchhoff current law, Electric Power Automation Equipment, Vol. 33(2013) No. 5, p. 43-49.

[2] Chen Jingcheng, Zhang Xuesong, Wang Feng: Distribution network modeling and connectivity analysis, Power System Technology, Vol. 23(1999) No. 5, p. 52-54.

[3] Wang xiang zhong, Li xiao lan: Topology identification of power network based on incidence matrix, Power System Technology, Vol. 25(2001) No. 2, p.10-12.

[4] Ma jing, Zhang Yuyu, Ma Wei, et al: Power network topological analysis based on incidence matrix notation method and loop matrix, Automation of Electric Power Systems, Vol. 38 (2014) No. 12, p.74-80.

[5] Cui Y:Matrix coloring method and its application in network topology analysis of powersystem ,Power System Protection & Control, Vol.36(2008)No.16, p.5312-5315.

[6] Yang xiuxia,Zhang xiaofeng,Zhang yi: Isolated power network topology analisis and its application in service restoration, Electric Power Automation Equipment, Vol. 38(2014)No.12, p.74-80.

[7] Yang qianihui: Relay protection setting and calibration system for underground high voltage power grid in coal mine(MS., Henan Polytechnic University, China 2016).