Information Fusion Based Fault Location Technology for Distribution Network

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***Abstract*—Along with the increasing the level of distribution network intelligence and the network complexity, the automatic fault location technology for distribution network is particularly important. But the traditional fault location methods based on one information source is impossible to locate the faults accurately because of there are losses or faults in the information from the distribution. So, the information fusion based fault location method for distribution network is proposed. When a fault occurs, one information matrix is created based on the action of all the protective relays, and the other information matrix is created based on the wave data of the current which is recorded at the foot node. The above information matrixes are combined using D-S evidence theory and the fault location is realized. The simulation results show that the fault location method for distribution network not only realizes accurate fault location, but also possesses stronger robustness.**

***Index Terms*—distributed network, fault location, information fusion, D-S evidence theory**

I. INTRODUCTION

With the increasing complexity of the distribution network, feeder automation has a rapid development. Feeder automation provides strong support for fault location in distribution network. At the same time, it also provides strong support for improving the quality and reliability of power supply[1-3]. The traditional fault location methods based on coordination between recloser and sectionalizer exist many shortcomings, such as, reclosing to fault point again, slow response rate and expanding fault regions easily. So the fault section location based on information of protection units and feeder terminal units(FTUs) are becoming research hotspots. Where the matrix algorithm[1, 2] and the over heated arcs searching algorithm[4, 5] have the simple principle and well definition. But these methods are based on complete and accurate information uploaded by FTUs. The intelligent fault location algorithm can realize fault section location at the case of exiting uncertain information, such as, genetic algorithm based fault location[6], rough set theory based fault location[7, 8], multi-agent based fault location[9], Bayes probability based fault location[10] and Petri-Nets based fault location[11]. But these methods can only provide a certain diagnosis result and the diagnosis result have the following disadvantages:

• It cannot reflect the fitness of the method. When the quality of communication is good, the information based on SCADA is reliable. But when the communication channel is disturbed, the information isn't reliable and the diagnosis result may be wrong. The difference cannot be reflected.

• It cannot provide the failure indication information.

• It makes against combination of different fault section location methods.

In one word, there are two problems for the control center to resolve the fault location with the information uploaded by the feeder automation system:

• For the vast amount and redundancy of the information, it is hard to process the data manually for the operators.

• Under the influence of the work environment of the equipment and the communication system, there are always some losses or faults in the information from the distribution network.

As a result, it is very important to syncretize the information from different information resources and find a new fault location method to locate the fault accurately even there are losses or faults in the information from the distribution.

Dempster-Shafer(D-S) evidence theory is one of the mathematical tools developed in the 70s. D-S evidence theory can robustly deal with incomplete data. The D-S evidence theory can be a tool for system modeling and information fusion. In fault diagnosis, because different evidences make different contributions to different faults, evidence importance should be considered for specific fault diagnosis through multi-resource information fusion[12, 13].

In this paper, in order to improve the fault location accuracy and robustness, through constructing the information matrixes based on the action of all protective relays switch and the wave data of the current respectively, the fault information are combined using the D-S evidence theory.

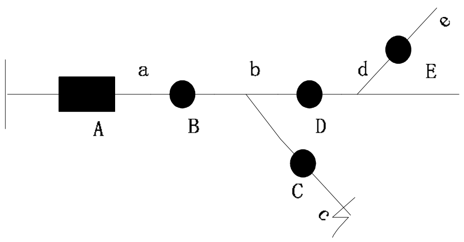
II. PROBLEM OF FAULT LOCATION BASED ON RECLOSERS AND SECTIONALIZERS

doi:10.4304/jsw.6.5.826-833

A. Principle of Fault Location Based on Reclosers and Sectionalizers

Now, there are three methods to implement the feeder automation, that is, mutual coordination of recloser with voltage-time type of sectionalizer, recloser with recloser and recloser with over-current pulse count type sectionalizer. Among them, the mutual coordination of recloser with voltage-time type of sectionalizer is the most popular one[14].

The Figure 1 shows the schematic diagram of fault isolation based on mutual coordination of recloser with voltage-time type of sectionalizer for typical radial distribution networks, where *A* is a recloser and *B*, *C*, *D* are sectionalizers. The first reclosing time of the recloser is 15s and the second reclosing time is 5s. The X-time limits of the sectionalizers *B* and *D* are 7s and the Y-time limits are 5s. The X-time limits of the sectionalizers *C* and *E* are 14s and the Y-time limits are 5s. The operation logics of the recloser and senctionalizers are showed as Figure 2.



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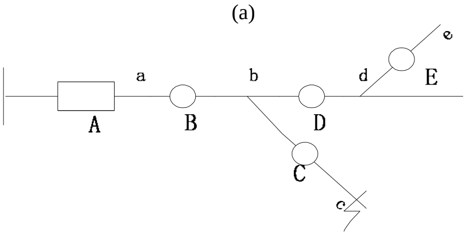

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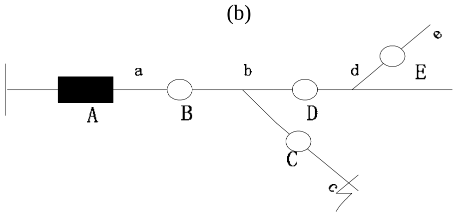

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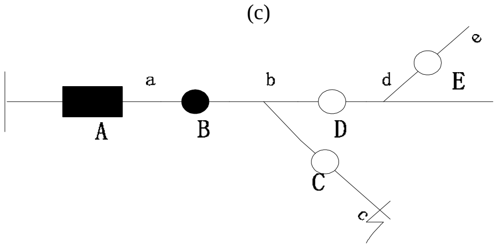

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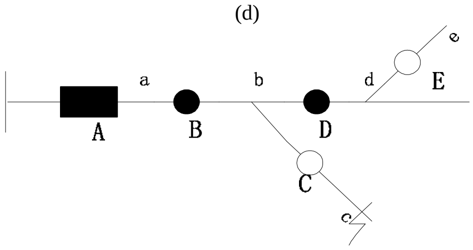

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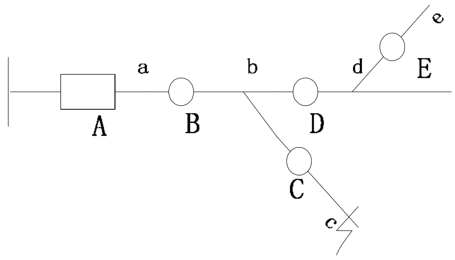

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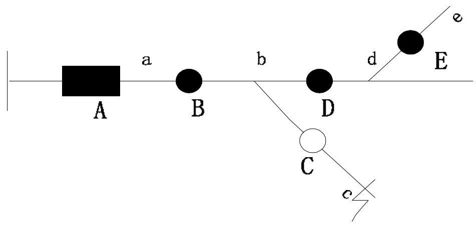


(g)

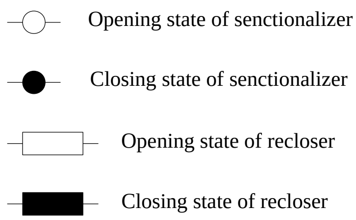
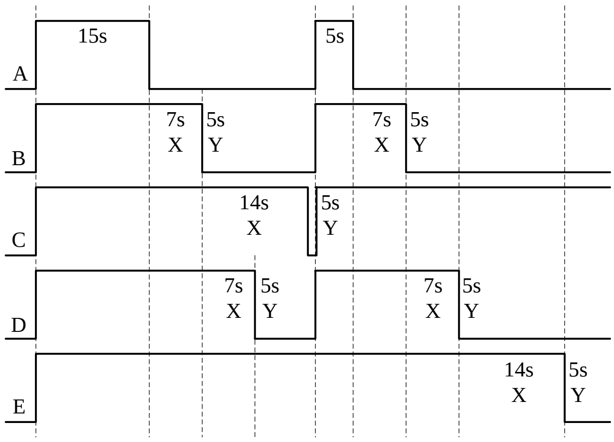


Figure 1. Schematic diagram of typical radial distribution networks



Note: High is opening, low is closing

Figure 2. Scheme of operation logic of all switches

The figure 1 (a)-(g) show the process of the fault section location. The figure 1 (a) is the normal operation state for the radial distribution networks. The figure 1 (b) shows that when a permanent fault happens in the *c* section, the recloser *A* trips off, and it leads to losing voltage of the line and the sectionalizers *B*, *C*, *D* and *E* tripping. The figure 1 (c) shows the recloser *A* performs the first reclosing operation after 15s of the fault tripping. The figure 1 (d) shows that after 7s time limits, the senctionalizer *B* recloses automatically and the power supply arrives at the *b* section. The figure 1 (e) shows that after another 7s time limits, the senctionalizer *D* recloses automatically and the power supply arrives at the *d* section. The figure 1 (f) shows that after 14s time limits after the senctionalizer *B* reclosing, the senctionalizer *C* recloses automatically. Because the fault of *c* section is the permanent fault, the recloser *A* trips off again and leads to the line losing voltage and the senctionalizer *B, C, D* and *E* tripping again. Because the senctionalizer *C* loses voltage before its Y-time limit (5s), the senctionalizer is locked. The figure 1 (g) shows that after 5s time limits after the recloser *A* trips off again, the recloser *A* recloses secondly and the senctionalizer *B*, *D* and *E* s recloses automatically. Because the senctionalizer *C* is locked in the switching-off state, the fault section is isolation and the power supply of the non-fault area is restored.

B. Problem of Fault Location Based on Reclosers and Sectionalizers

After fault isolation, the operation logics of switches are sent to the control center through the intelligent distributed terminal, the control center determines the fault location to remove the fault source. But the information received by the control center may be wrong because of existing strong electromagnetic interference in the communications network of the distribution network. The control center will make the wrong decision.

III. FAULT LOCATION METHOD BASED ON INFORMATION FUSION

A. Fault Location Method Based on D-S Evidence Theory

Let Θ be the frame of discernment i.e. the finite set of *N* mutually exclusive and exhaustive hypotheses. 2^{Θ} is the power set of Θ, such that if Θ={1, 2, …, *N*}, then 2^{Θ} ={Φ, {1}, {2}, …, {*N*}, {1,2}, {1,3}, …, {*N*-1, *N*}, {1,2,3}, Θ},where Φ denotes the empty set.

Definition 1 A basic probability assignment is a function m: $2^{\Theta} \rightarrow [0, 1]$, which satisfies the following conditions:

$$\begin{cases} \sum_{A \subset \Theta} m(A) = 1 \\ m(\phi) = 0 \end{cases} \tag{1}$$

m(*A*) is called basic probability number. It represents the proportion of all relevant and available evidence that supports the claim that a particular element of Θ belongs to the set *A* but to no particular subset of *A*.

Definition 2 The plausibility function is defined as:

$$Pl: 2^{\Theta} \rightarrow [0,1] \;\; and \;\; Pl(A) = \sum_{B \cap A \neq \phi} m(B) \tag{2}$$

The belief function *Bel*(*A*) measures the total amount of probability that must be distributed among the elements of *A*. It reflects inevitability and signifies the total degree of belief of *A* and constitutes a lower limit function on the probability of *A*. On the other hand, the plausibility function *Pl*(*A*) measures the maximal amount in *A*. It describes the total belief degree related to *A* and constitutes an upper limit function on the probability of *A*.

Suppose m_1 and m_2 are two basic probability assignment functions formed based on information obtained from two different information sources in the same frame of discernment Θ. According to Dempster's orthogonal rule of evidence combination, the combination of m_1 and m_2 is as follows:

$$m_1 \oplus m_2(C) = \frac{\sum_{A \cap B = C} m_1(A) m_2(B)}{1 - \sum_{A \cap B = \phi} m_1(A) m_2(B)} \tag{3}$$

The belief values of the action information of reclosers and sectionalizers and the current wave information at root node is regarded as m_1 and m_2 respectively. Then the m_1 and m_2 are combined according to equation (3) and the belief value of every protection zone is obtained. According to the belief value *m*, the fault location can be determined. The scheme of fault location method based on D-S evidence theory is showed as Figure 3.

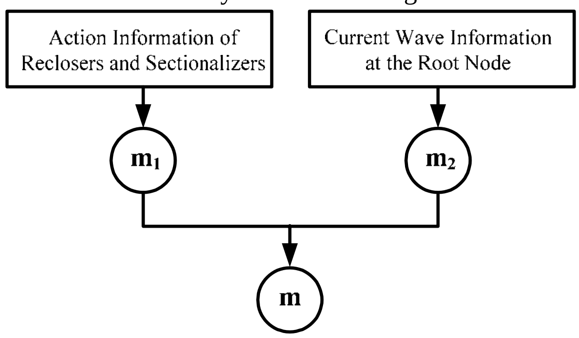


Figure 3. Scheme of fault location method based on D-S evidence theory

B. Model of Distribution Network

The simulation model is a 17-node 24.9kV distribution network with feeder automation, which is built in PSCAD/EMTDC, showed as Figure 4. *R*1-*R*4 indicate the reclosers and *D*1-*D*9 indicate the sectionalizers[16].

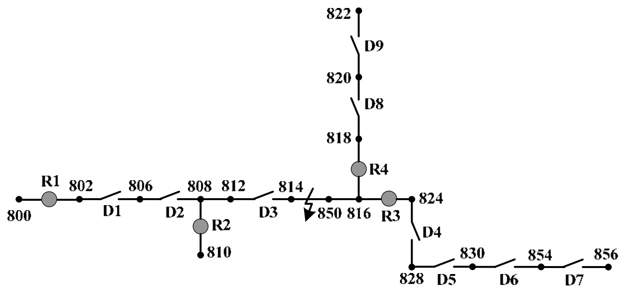


Figure 4. Simulation model of distribution network

C. Belief Assignment of FTU Information

According to the actions of reclosers and sectionalizers, the information matrix of the reclosers and sectionalizers is defined as *R* and D_k,(*k*=1,2, …, *u*):

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{u1} & r_{u2} & r_{u3} & r_{u4} & r_{u5} \end{bmatrix} \tag{4}$$

$$D_k = \begin{bmatrix} d_{k01} & d_{k02} & d_{k03} & d_{k04} & d_{k05} \\ d_{k21} & d_{k22} & d_{k23} & d_{k24} & d_{k25} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ d_{kv1} & d_{kv2} & d_{kv3} & d_{kv4} & d_{kv5} \end{bmatrix} \qquad (5)$$

where u is the number of the reclosers in the distributed network, v is the number of the sectionalizers in the corresponding recloser protection zone. In the information matrix, the first column indicates the first opening action, the second column indicates the first closing action, the third column indicates the second opening action, the forth column indicates the second closing action and the fifth column indicates the third opening action. Each row of the information matrix R corresponds to a recolser. The first row of the information matrix D_k indicates the switch actions of the corresponding recolser and the rows from 2 to u indicate the switch actions of the sectionalizers in corresponding recloser protection zone. r_{ij}=1 or d_{kij}=1 indicates that the corresponding action happens and r_{ij}=0 or d_{kij}=0 indicates that the corresponding action doesn't happen.

Suppose the actual information matrix of reclosers received by the control center from the distributed network is RA, the actual information matrix of sectionalizers in different protection zone received by the control center from the distributed network is DA_k respectively. The matrix RA is compared with an m×5 matrix which elements are all 1, and a statistics matrix RAS is obtained by counting the number of same elements in every row between the two matrixes. After the matrix RAS is normalized, the action probability matrix of reclosers PR is obtained. Similarly, the matrix DA_k is compared with every ideal information matrix when faults occur in corresponding sectionalizer protection zone, and a statistics matrix DAS_k is obtained by counting the number of same elements between the two matrixes. The first row of DAS_k is set to 0. After the matrix DAS_k is normalized, the action probability matrix of sectionalizers PD_k is obtained.

Suppose the permanent fault occurs in the node 856. The reclosers R_1, R_2, R_4 and the sectionalizers of their protection zone don't act. Only R_3, D_4, D_5, D_6 and D_7 perform automatic switch-off and switch-on action. After several automatic switch-off and switch-on actions, the fault section is isolated and the power supply of the sound area is restored. The action time sequence diagram is showed as Figure 5.

The Figure 5 shows the operation logic of the recloser and sectionalizers in R_3 protection zone. Suppose the fault happens at 0.3s, the recloser R_3 acts firstly, the four sectionalizers switch off because of losing voltage. After 1.5s, the recloser recloses automatically. Then, the sectinalizers D_4, D_5, D_6 and D_7 reclose automatically in turn after itself 0.7s time limits, where the sectinalizers D_4, D_5 and D_6 reclose successfully. When the sectionalizer D_7 recloses, the fault is connected to the system again because the fault section is located in D_7 section, the recloser R_3 switches off again and all the sectionalizers switches off because of losing voltage. Because the time interval between the two switching-on time of D_7 is less than the setting time limit 0.5s, the sectionalizer is locked. After 0.5s, the recloser recloses automatically, and the sectinalizers D_4, D_5 and D_6 recloses automatically in turn after itself 0.7s time limits, where the sectinalizers D_4, D_5 and D_6 recloses successfully. The locked sectionalizer D_7 don't reclose, the fault section is isolated and the power supply of the sound zone is restored.

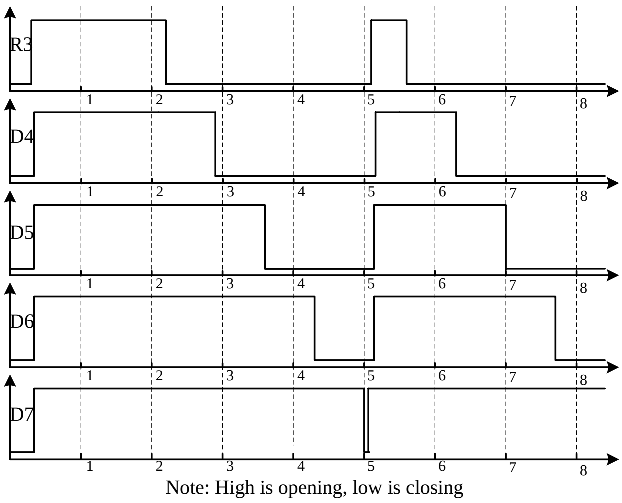


Figure 5. Scheme of protection action operation logic

The information matrix of the recloser R_3 is followed:

$$R = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

The information matrixes of the sectionalizers D_4, D_5, D_6 and D_7 are followed as:

$$D_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \ D_2 = \begin{bmatrix} 0 & 0 & 0 & 0 \end{bmatrix}$$

$$D_3 = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 \end{bmatrix}, \ D_4 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

The above-mentioned information matrixes can be obtained by the control center, if the relosers and sectionalizers can act correctly and there are no misoperations, moreover, there are no disturbances in the communication channel. The location result is true.

Under the influence of the work environment of the equipment and the communication system, there are always some losses or faults in the information from the distribution network. Suppose the actual information matrixes obtained by the control center are followed as:

$$RA = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix},\ DA_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

$$DA_2 = \begin{bmatrix} 0 & 0 & 0 & 0 \end{bmatrix}$$

$$DA_3 = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix},\ DA_4 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

According to these wrong information matrixes, the first belief value m_1 can be calculated as following. Comparing RA with a 4×5 matrix which elements are all 1, a statistics matrix RAS is obtained by counting the number of same elements in every row between the two matrixes. After the matrix RAS is normalized, the action probability matrix of reclosers P_R is obtained as following:

$$RWS = \begin{bmatrix} 0 \\ 0 \\ 5 \\ 0 \end{bmatrix},\ P_R = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix}$$

Every element in P_R from top to down is the probability value of the recloser R_1, R_2, R_3 and R_4 respectively.

Similarly, the matrix DA_1, DA_2, DA_3 and DA_4 is compared with the corresponding ideal information matrix when the fault occurs in corresponding sectionalizer protection zone respectively, and the statistics matrix DAS_1, DAS_2, DAS_3 and DAS_4 is obtained respectively by counting the number of same elements between the two matrixes. The first row of DAS_k is set to 0. After the matrix DAS_k is normalized, the action probability matrix of sectionalizers PD_k is obtained. These matrixes are as followed as:

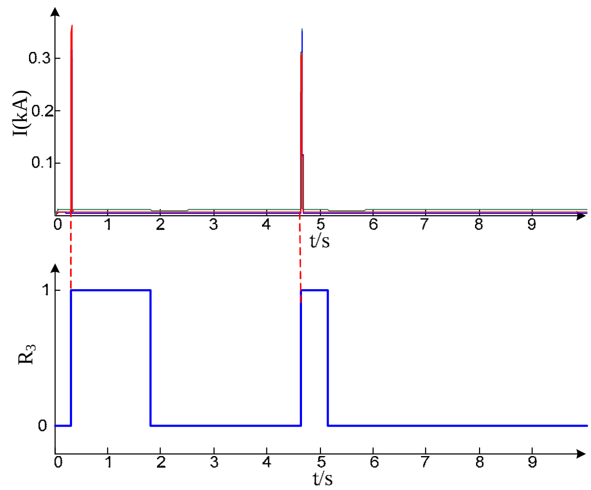
$$m_{11} = PD_1 = \begin{bmatrix} 0 \\ 0.4348 \\ 0.3043 \\ 0.2609 \end{bmatrix},\ m_{12} = PD_2 = \begin{bmatrix} 0 \end{bmatrix},$$

$$m_{13} = PD_3 = \begin{bmatrix} 0 \\ 0.1935 \\ 0.2419 \\ 0.2581 \\ 0.3056 \end{bmatrix},\ m_{14} = PD_2 = \begin{bmatrix} 0 \\ 0.6667 \\ 0.3333 \end{bmatrix}$$

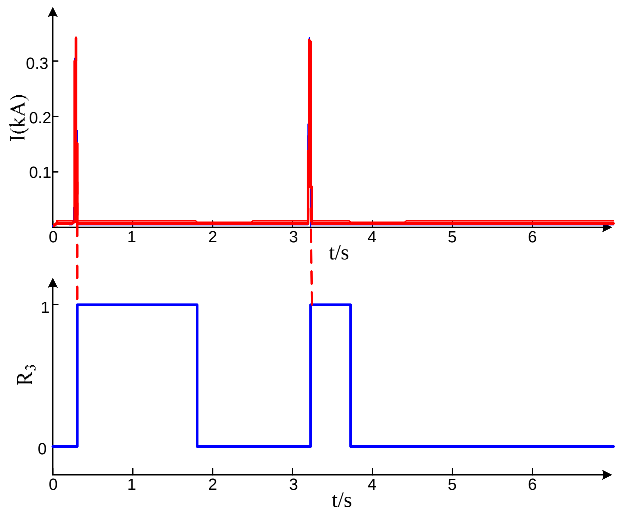
So, the probability that the fault locates in recloser R_1, R_2, R_3 and R_4 is 0, 0, 1 and 0 respectively. If the fault locates in the recloser R_1 protection zone, the locked probability of the recloser R_1, the sectionalizer D_1, D_2 and D_3 is 0, 0.4348, 0.3043 and 0.2609 respectively. There are no sectionalizers in the recloser R_2 protection zone, so only recloser R_2 is considered and its locked probability is 0. If the fault locates in the recloser R_3 protection zone, the locked probability of the recloser R_3, the sectionalizer D_4, D_5, D_6 and D_7 is 0, 0.1935, 0.2419, 0.2581 and 0.3056 respectively. If the fault locates in the recloser R_4 protection zone, the locked probability of the recloser R_4, the sectionalizer D_8 and D_9 is 0, 0.6667 and 0.3333 respectively.

D. Belief Assignment of Fault Recorder Information

When a permanent fault occurs and the corresponding protection acts, the actions of the reclosers will result in appearing a current pulse at the root node. So, two section fault current corresponding to two protection action at the root node can be detected. The diagram comparing operation logic of the recloser R_3 with the current waveform is showed as Figure 6. The diagram shows that the time interval between two current pulses is corresponds with the time interval between two reclosing, and the time interval between two reclosing corresponds with the locked sectionalizer. So, through calculating the time interval between the two current pulses at the root node, the control center can determine the locked sectionalizer, and the fault zone can be located.



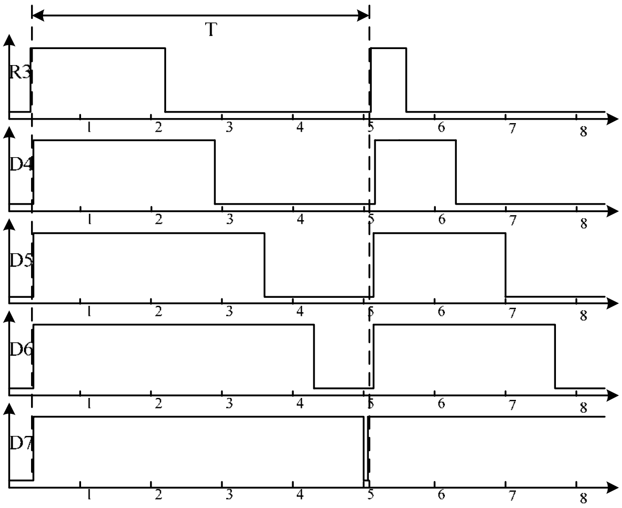
(a) Node 856 permanent fault



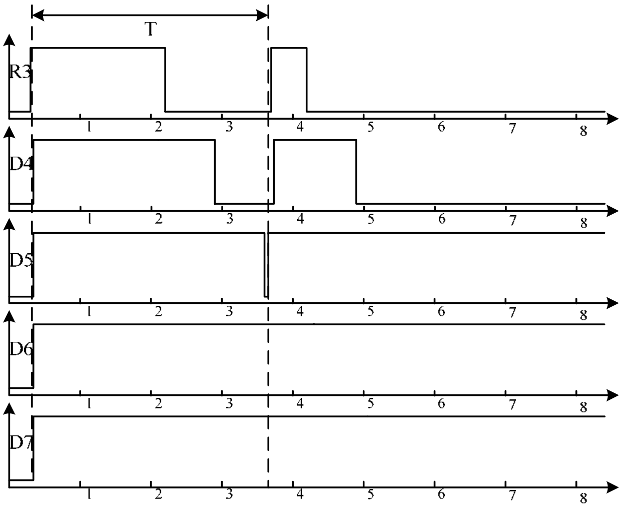
(b) Node 830 permanent fault

Figure 6. Diagram comparing operation logic with the current waveform

The time interval T has relationship with the location of the locked sectionalizer. It shows as Figure 7.



(a) Node 856 permanent fault



(b) Node 830 permanent fault

Figure 7. Relationship between time interval T and location of the locked sectionlizer

The diagram shows that the function between the time interval of two reclosing actions and the setting X-time limit of the locked sectionalizer is as follows:

$$T \approx t_{c1} + t_x \times d \tag{6}$$

where T is the setting time interval between two tripping actions, t_{c1} is the setting time of the first reclosing and t_{c1}=1.5s, t_x is the X-time limit of sectionalizer and t_x =0.7s, d indicates the position of the locked fault zone, for example, when the fault located at node 856, d is set at 4; when the fault located at node 830, d is set at 2.

So, the second belief assignment m_2 can be obtained through detecting the time interval between two section fault current at the root node, the process is followed as:

Firstly, the time interval between two fault current pulses, showed as Figure 8.

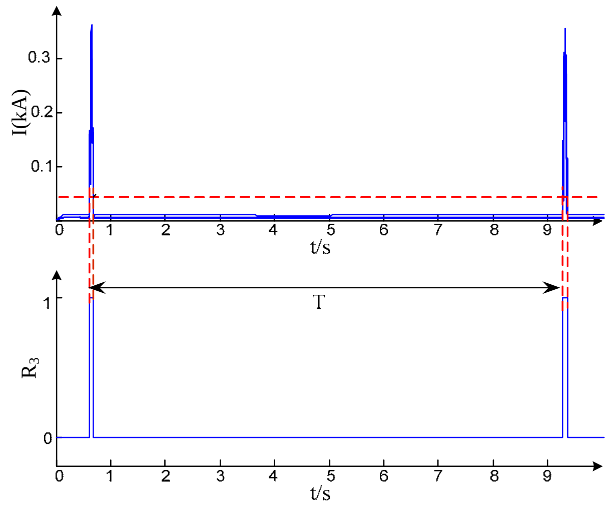


Figure 8. Diagram of detection between two fault current pulses

Secondly, a $1\times u$ probability matrix PC_k of the locked recloser or sectionalizer corresponding to the protection zone k is initialized to 0, where u is the maximal number of sectionalizers in the recloser protection zones. The locked probability of each recloser or sectionalizer is calculated according to the time interval T. The probability distributions are showed as Figure 9.

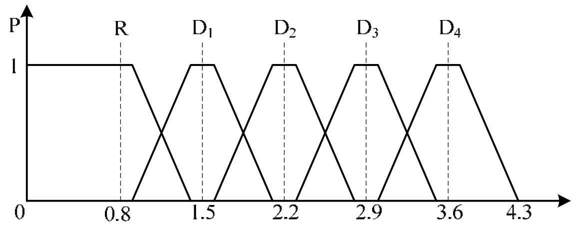


Figure 9. Diagram of probability distributions of the locked element

Finally, suppose u=5, according to T, the locked probability of recloser and sectionalizer is as follows.

If T<0.8s, the element of the first row of PC_k is set to 1. The elements of other rows of PC_k are determined as follows:

$$(T-0.8)\div 0.7 = d\cdots\cdots y \tag{7}$$

$$p = \begin{cases} 0 & (y \le 0.05) \\ \dfrac{y-0.05}{0.6} & (0.05 < y < 0.65) \\ 1 & (y \ge 0.65) \end{cases} \tag{8}$$

The element of d+1(d>0) row of PC_k is set to p and the element of the d row of PC_k is set to 1-p. The probability matrixes of other protection zone are composed of before m row of the PC_k, where m is the number of sectionalizers of corresponding to protection zone.

For example, the detected time interval between two fault current pulses is 4.2926s, the belief distribution matrix is followed as:

$$m_{23} = PC_3 = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

The belief matrix shows that the locked probability of the fourth sectionalizer is 1, and the locked probabilities of the other sectionalizers are 0.

E. Fault Location Method Based on D-S Evidence Theory

The probability matrix PD_k and PC_k is regarded as m_{1k} and m_{2k} respectively. Then the m_{1k} and m_{2k} are combined according to equation (3) and the probability assignment P_k of every protection zone is obtained. The element pr_i of the matrix PR multiplies the matrix P_k respectively and the final probability assignment matrix P is obtained. According to the matrix P, the fault location can be determined.

IV. Simulation Analyse

In the simulation model showed as Figure 4, suppose the permanent fault occurs in the D_3 protection zone. The information matrixes received by the control center receive from the distribution network are as follows:

$$RA = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix},\ DA_1 = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 \end{bmatrix}$$

$$DA_2 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \end{bmatrix},$$

$$DA_3 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 \end{bmatrix},\ DA_4 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

According to above principle, the action probability matrixes are as follows:

$$PR = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}, m_{11} = PD_1 = \begin{bmatrix} 0 \\ 0.2667 \\ 0.3333 \\ 0.4 \end{bmatrix}, m_{12} = PD_2 = \begin{bmatrix} 0 \end{bmatrix},$$

$$m_{13} = PD_1 = \begin{bmatrix} 0 \\ 0.3409 \\ 0.2727 \\ 0.2045 \\ 0.1818 \end{bmatrix}, m_{14} = PD_1 = \begin{bmatrix} 0 \\ 0.5882 \\ 0.4118 \end{bmatrix}$$

The current wave detected at root node 800 is showed as Figure 4. The calculated time T is 3.6514s. According to formula (7) and (8), the probability matrix PC_k is obtained as follows:

$$m_{21} = PC_1 = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0.9977 \end{bmatrix}, m_{22} = PC_2 = \begin{bmatrix} 0 \end{bmatrix}$$

$$m_{23} = PC_3 = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0.9977 \\ 0.0023 \end{bmatrix}, m_{24} = PC_4 = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

According to formula (3), the action probability matrix $m=m_1 \oplus m_2$ is combined. The element pr_1- pr_4 of the matrix PR multiplies the matrix m_1- m_4 respectively and the final probability assignment matrix P is obtained.

$$P = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

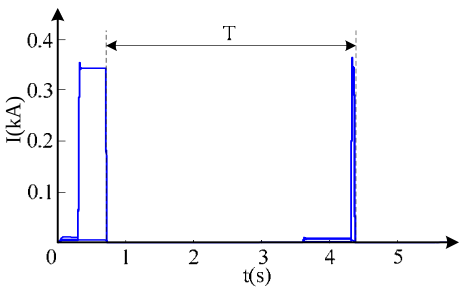


Figure 10. Current wave at root node 800

So, the fault position locates the sectionalizer D_3 of the recloser R_1 protection zone. The result of fault location is true.

V. Conclusion

The fault location method based on the information of reclosers and sectionalizers will be wrong when the electromagnetic interference exits in the communication system. Using D-S evidence theory, the information of reclosers and sectionalizers and the information of current wave at root node can be combined. The combined information can locate the fault position accurately.

Acknowledgment

This research has been supported by National Postdoctoral Science Foundation of P.R. China (20090461204), Natural Science Foundation of Shandong Province (ZR2010EL030), Postdoctoral Innovative Projects of Shandong Province (200903066) and Colleges and universities in Shandong Province Science and Technology Plan Project (J09LG09).

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