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Fuzzy Relation Through Sagittal Diagram To Identify Fault Section Of Power System

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Abstract

This paper presents fuzzy relation through sagittal diagram to identify fault section of power system. Sagittal diagram has been constructed using parametric operators to obtain the membership degree of alarm pattern. In power system protection, there are many malfunctions and wrong alarms in protective device operations involve in relays and circuit breakers. The fuzzy relation is used to determine the membership degree and later obtained hamacher's operator. The possibility of faulted sections are presents a higher membership degree than un-faulted sections. The results show that fuzzy relation can be successfully achieved in fault identification.

Keywords: alarm pattern, sagittal diagram, fuzzy relation, power system fault

1. Introduction

Power system protection purposes to identify a fault section using information on operation of the relays and circuit breakers. Relays and circuit breakers are protection devices which are worked for power system if there are disturbance. The protection devices are responsible for detecting fault in line system and bus system based on alarm and message by relays and circuit breakers. The fuzzy relation can learn the correlation between faults and related alarm pattern. Many applications of intelligent techniques for alarm processing have been proposed such as fuzzy relation, artificial neural network and neuro-fuzzy. One of them use expert systems (Min et.al, 2001; Lin, 2004; Edwin et.al, 2001) in which alarm pattern is used for the construction of a knowledge base.

Alternatively, the application of fuzzy allows one to take into account the qualitative information provided by human expert (Edwin, 2001). Fuzzy relations are established with knowledge base on protection devices operation for faults. There are two techniques available to construct alarm pattern, which are;

(i) Rough set which utilizes the redundancy in alarm information. This method is capable of identifying minimal set of alarms that characterize the faults occurred. Rough set has been successfully used for pattern classification of patients based on medical data attributes and then has been applied in power system to classify the operation point (Oi et.al, 1997).
(ii) Sagittal diagram. This technique is more logical and efficient approach than estimation of possibility of fault in power system protection (Min et.al, 2001).

Table 1 is decision table for the system shown Fig. 2, protective devices (relays & circuit breakers) operate, 1 indicates protective devices operate, 0 indicates protective devices not operate. It proposes the method to reflect the change of the power system fault using information of actuated relays and circuit breakers tripped.

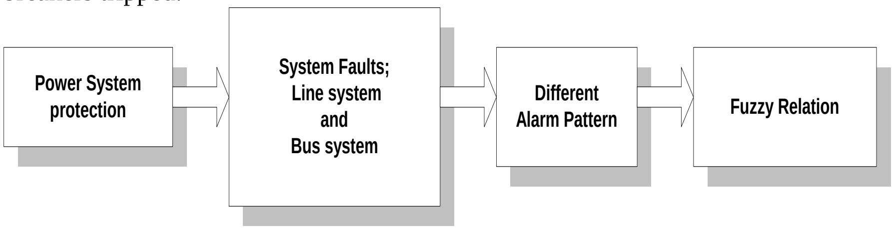

Fig.1 Concept of Alarm Processing

In this work, focus has been given to sagittal diagram. Once sagittal diagram is built, then fault sections are diagnosed using the operation in fuzzy relation. The block diagram in Fig.1 illustrates the flow. Fault formations are created in the power system protection {line system} and {bus system} for alarm pattern using fuzzy relation. This technique provided good performance for fault section to reduce the fault candidate's possibility.

2. Methodology

Protection System in Power System

The protection devices are responsible for tripping the circuit breakers on transmission line as soon as possible. The protection system is consisted of main protection relays (MP), and two back up protection relays that are; primary back up protection relays (SP_1) and secondary back up protection relays (SP_2).

Fig. 2 shows a simple power system model. For illustration, suppose that a fault occurs on line 4-5, which causes the action of the main protective relays L_{4-5}MP4 and L_{4-5}MP5 to trip CB4 and CB5. If there are some problems with circuit breakers and fail to trip and isolate the fault section is not isolated, then back up protection relays will operate. If CB4 is not tripped, primary back up protection relay L_{4-5} $SP_1$4 trips CB4. If CB5 is not tripped, primary back up protection L4-5 SP15 trips CB5. Table 1 is the decision table for sample system in Fig. 2.

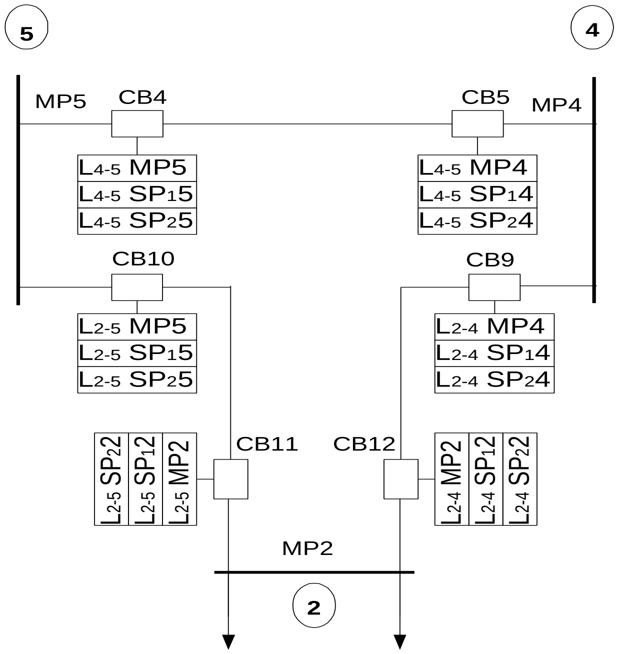

Fig.2 Test System

Where:
MP_k : Main protection relay of bus
SP_1 : Primary back up protection relay
SP_2 : Secondary back up protection relay
L_{k-n} MPk: Main protection relay of line
$L_{k-n}SP_1k$: Primary back up protection relay of line
$L_{k-n}SP_2k$: Secondary back up protection relay of line

The Fuzzy Relation and Sagittal Diagram Approach to Power System

The associations among relays and circuit breakers can be determined in the sagittal diagram on Fig. 1. The sagittal diagram is built base on operations of protection relays and circuit breakers in occurrence of power system fault. Fig. 3 illustrated the sagittal diagram for transmission line 4-5. Fuzzy relations are fuzzy sets defined on universal sets which are Cartesian products. All operations on fuzzy sets, that are; complement, intersection, union, subset, etc are applicable to fuzzy relations as well.

As an example, a binary fuzzy relation R defined on a set A of documents and a set B of key terms, which is important in information retrieval systems. A fuzzy set uses a common function such as triangular, trapezoidal, Gaussian, etc called membership functions to support the membership value of its element.

Table 1 *The Condition of Alarm Pattern*
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Circuit Breakers And Relays	Fault occurrences
	Line 4-5
CB4	1
CB5	1
CB9	0
CB10	0
CB11	0
CB12	0
$L_{4\text{-}5}$MP5	1
$L_{2\text{-}5}$MP5	0
$L_{2\text{-}4}$MP4	0
$L_{4\text{-}5}SP_1$4	1
$L_{4\text{-}5}SP_1$5	1
$L_{4\text{-}5}SP_2$4	0
$L_{4\text{-}5}SP_2$5	0
$L_{2\text{-}5}SP_1$5	0
$L_{2\text{-}5}SP_2$5	0
$L_{2\text{-}4}SP_1$4	0
$L_{2\text{-}4}SP_2$4	0
$L_{2\text{-}4}SP_1$2	0
$L_{2\text{-}4}SP_2$2	0
$L_{2\text{-}5}SP_1$2	0
$L_{2\text{-}5}SP_2$2	0

Its membership function is defined on the Cartesian product A x B. For each document *a* in set A and each key term *b* in set B, the membership degree R(*a*,*b*) may be interpreted in this case as the degree of relevance of the document *a* to the key term *b*. This characterization of the relationship between documents and key terms is highly expressive. For power systems fault proposed sagittal diagrams that have three sets of nodes; set 1-sections, set 2- relays, set-3 circuit breakers (Cho and Park, 1997).

Fig. 3 constructs by the principle of operations of relays and circuit breakers in the occurrence of the fault, therefore it is denoted by arrows. The label on the line is determined statistically considering the uncertainties of operation and the priorities of relays and circuit breakers when fault occurs (Oi et.al, 1997). As the MP is most closely related to a fault, the label of this line is 0.8, and the label of the line SP1 to section is 0.7. Then the label of the line connected a SP2 to section 0.55.

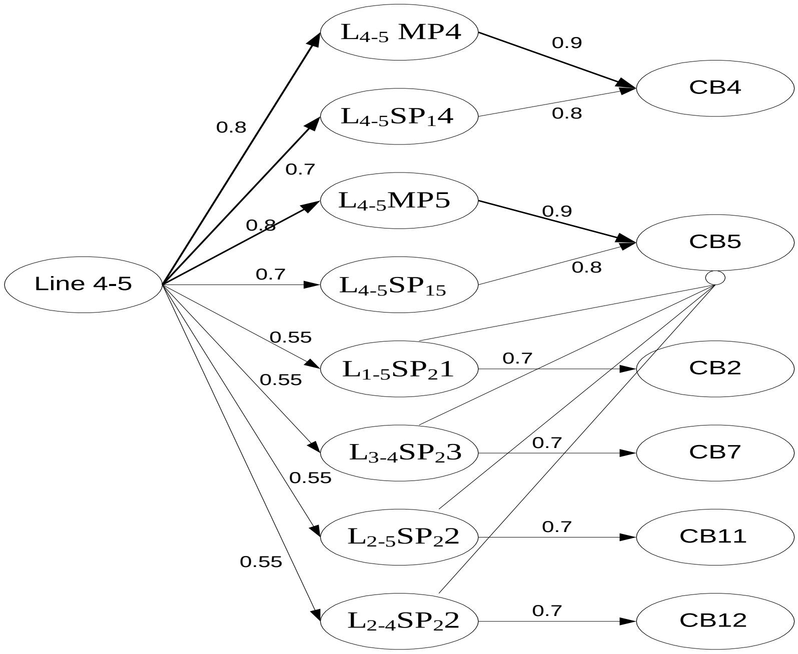

Fig. 3 *Sagittal Diagram of Model Power System*

There are many fuzzy set operations to get membership degree, which are; Hamacher's operator, Yager's operator, Dubois & Prade's operator, Dombi's operator (Edwin et.al, 2001). This paper presents Hamacher's operator for calculating membership degree base on equation (1) & (2). The intersection and union of two fuzzy sets A and B is a fuzzy set whose membership function is given by equations below.

1. Fuzzy intersection (i)

   Fuzzy intersection is defined as [5]:

$$\mu_{A\cap B}(x) = \frac{ab}{\gamma + (1-\gamma)(a+b-ab)} \quad (1)$$

2. Fuzzy union (u)

   Fuzzy union is defined as [5]:

$$\mu_{A\cup B}(x) = \frac{a+b+(\gamma' - 1)ab}{1+\gamma' ab} \quad (2)$$

$\gamma = 5$

$\gamma' = \gamma - 1$

Where:

γ : Parameters value for Hamacher's operator

$\mu_A(x) = a$: Expressing membership in set A for the element x in the universe.

$\mu_B(x) = b$: Expressing membership in set B for the element x in the universe.

3. Result and Discussion

Sagittal Diagram for Fault Section Identification of Power System

The sagittal diagram is considered to determine fault section in power system fault. The fuzzy sets between alarm pattern and protection system can be determined with sagittal diagram by performing (Cho and Park, 1997):

(i) The intersection of the labels of the lines that make a path to be through set 1, set 2, and set 3, provided that both the nodes of set 2 and set 3 operate.
(ii) The union of the step 1's results for the paths connected to one section (or a node of set 1).
(iii) Step 2's result is determined as the degree of membership of section's being in the fault.

From Figure 3, if $L_{4\text{-}5}MP4$, $L_{4\text{-}5}SP_15$, $L_{2\text{-}4}SP_25$, CB4, CB5 and CB10 operate, then membership degree of $L_{4\text{-}5}$ is $u(0.7347,0.5957)=0.8661$ from eq. (2). While $L_{4\text{-}5}SP_15$ and CB5 operate and make path, the path made by $L_{2\text{-}4}SP_25$ and CB10 is ignored. If the $L_{4\text{-}5}SP_15$ and CB5 did not operate, the membership degree of $L_{4\text{-}5}$ become u(0.7347,0.4451)=0.8360.

Then it can determine membership degree in fault set. If a fault occurs in transmission line, protective devices are operated and then fault section candidate can be selected among many section based on message of the protection system. If fault in any section is isolated by protection system then relays operated and circuit breakers tripped make a path in the sagittal diagram. This faulted path is called the colored path, and the colored path can be considered as fault section candidate according to Fig. 4.

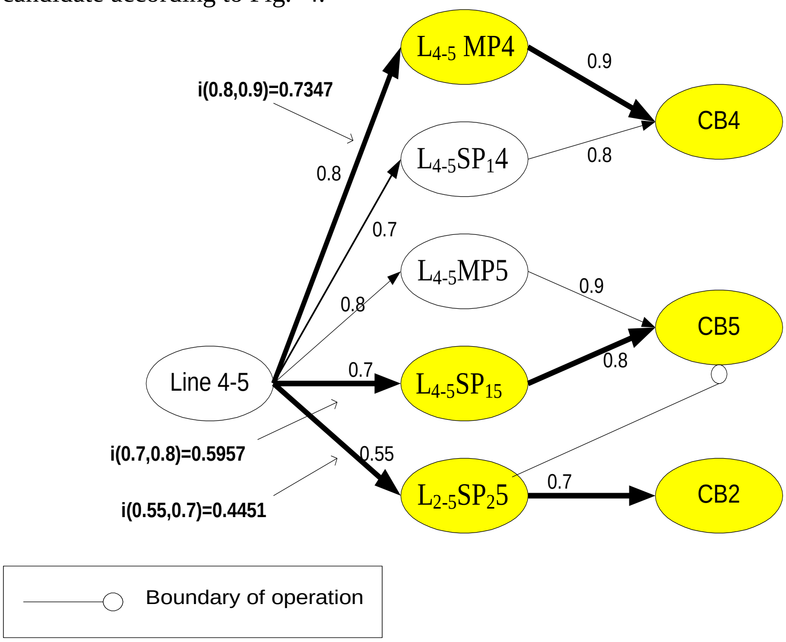

***Fig. 4** Possibility Protective Devices Operations with Sagittal Diagram*

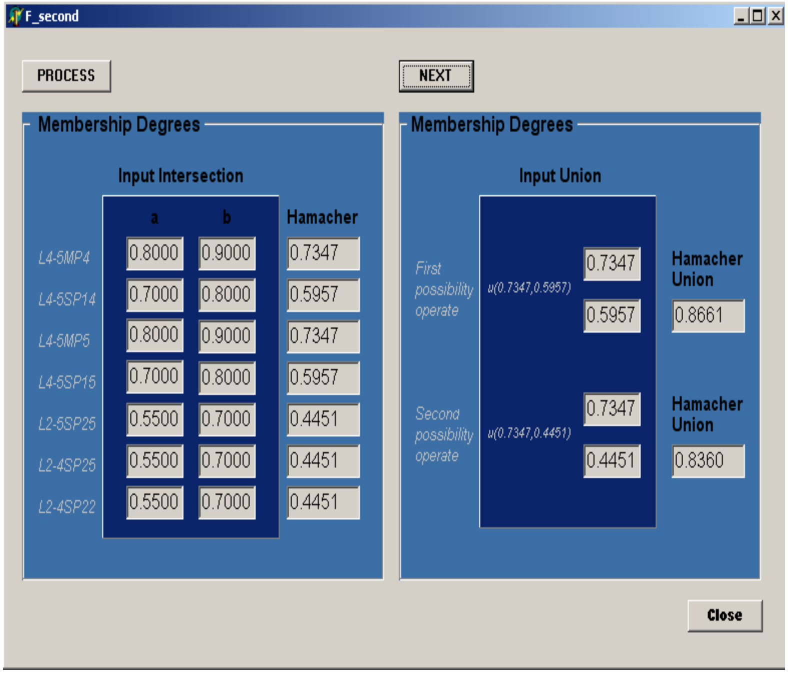

***Fig.5** Possibility Protective Devices Operations with Result ofMembership Degree*

Table 2 illustrates the result with hamacher's operator, possibility relays and circuit breakers operated by using equation (1). The steps obtain membership degree in section (4). The input value (0.8,0.9), (0.7,0.8), (0.55,0.7) calculate for fuzzy intersection base on eq (1). Results of fuzzy intersection as an input which are (0.7347,0.5957), (0.7347,0.4451) to calculate with fuzzy union base on eq. (2). From the membership degree of intersection selects the highest value to determine the possibility of fault as input for fuzzy union.

***Table 2** Membership Degree (Intersection Operation)*

	Membership Degree	Alarm Message
Line 4-5	i(0.8,0.9)=0.7347	$L_{4\text{-}5}$MP4,CB4
Line 4-5	i(0.7,0.8)=0.5957	$L_{4\text{-}5}SP_1$4,CB5
Line 2-5	i(0.55,0.7)=0.4451	$L_{2\text{-}5}SP_2$5,CB10
Line 2-4	i(0.55,0.7)=0.4451	$L_{2\text{-}4}SP_2$4,CB9 $L_{2\text{-}4}SP_2$2,CB12

Table 3 illustrates the result of hamacher's operator, possibility of fault in the line section using equation (2). Choosing are between two membership degrees values from a fault section particularly the highest value.

Table 3 *Membership Degree (Union Operation)*

	Membership Degree	**Justification**
Line 4-5	u(0.7347,0.5957) =0.8661	First Possibility Operation
	u(0.7347,0.4451) =0.8360	Second Possibility Operation

4. Conclusion

Fuzzy relation through sagittal diagram to identify fault section of power system has been presented in this paper. Based on alarm message one can estimate fault section using operation of fuzzy relation. It is shown that the membership degrees for the test system tested can represent the possible fault sections.

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