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REDUCTION OF FAULT TIME IN SMART GRID SYSTEM USING FUZZY LOGIC CONTROLLER

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ABSTRACT

Smart Energy Delivery System is a new trend in power delivery network system with a two way communication to improve the reliability and efficiency of the system. This will help in meeting the increase in demand. In this study, Reduction of Fault Analysis Time in Smart Energy Delivery System Using Fuzzy Logic has been investigated using a fuzzy logic model .

Keywords: Fuzzy logic controller, fault location, distance location, prioritization

I. INTRODUCTION

The digital revolution of the past few decades has increased the demand for electric power with high reliability and quality which is delivered. The power transmission system suffer from the fact that intelligence is only applied locally by protection system and by the central control system which is too slow and protection systems are limited to protection of specific components only[1].To add intelligence in the system each component requires individual processor which is robust in nature and communicate as well as cooperate with other distributed computing platform.

Electric power distribution systems are expected to function at all the time, even under the faulty conditions. However, when they operate under fault conditions, the system operator receives information which makes it very difficult to make decision on whether to restore a tripped feeder to normal operation. To cope with this uncertainty in decision making, a fault diagnostic method based on fuzzy logic is proposed.

In this system a method of fault detection is used in power system for reduction of fault time using fuzzy logic control. The history associated with fault occurred in power system can be effectively used as a strong database. The database will act as the trainer to the fuzzy expert system[2],[7].

II. CHARACTERIZATION OF FAULT DETECTION SYSTEM

The development of the diagnostic and fault location technologies are needed for the operation of smart grid technologies must integrate the following elements:

1. The registration and automatic characteristics analysis of fast electromagnetic processes, overvoltage, overcurrent and non-stationary disturbances.
2. One phase to ground fault detection after the insulation damage in distribution network with an insulated or compensated neutral.
3. One phase to ground fault spot location according to the initial current transient process in the distribution network with cable and overhead lines
4. The control of the resource of the equipment insulation.

Traditionally, network providers have relied on a combination of customer calls and alarms from circuit breakers at the zone substation to detect a fault on the high voltage network; visual inspection and re-energization of parts of the feeder to locate it; and manual switching by field crews to isolate faulty equipment and restore power[4] .

Long restoration times negatively affect network reliability, commonly measured in System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), Momentary Average Interruption Duration Index (MAIDI) and Momentary Average Interruption Frequency Index (MAIFI). SAIDI and SAIFI account for faults exceeding one minute, MAIDI and MAIFI for faults of less than one minute[8].

III. CALCULATION OF FAULT INDEX

The design of three phase transmission line fault detection system consists of three tower system which holds the three phase transmission wires. This system gets the supply from three different step-down transformers. Each pole is mounted with three current sensors for each phase which continuously monitors the current in the three phase transmission line. This sensed value is then sent to the microcontroller which performs the calculation of fault index at every instant and if this value is greater than the preset values then it sends the signal to LCD for the displaying of fault index value showing fault condition The microcontroller and LCD unit receives the input supply from the power supply unit which consist of step down transformer, diode bridge rectifier, capacitor and voltage regulator to provide 5V supply to the microcontroller

In the model design of obtaining fault current index the value of fault current ratio and fault index as displayed on the LCD display is as shown in the Table I given below

Table I. Fault Current Ratio and Fault Index for LG Fault

S.NO.	S1 = Ia/Ib	S2 = Ib/Ic	S3 = Ic/Ia	FAULT INDEX
1.	2.472	0.623	0.648	1.247
2.	0.317	0.447	0.705	0.489
3.	2.990	0.370	0.900	1.420
4.	9.960	0.143	0.696	3.599
5.	1.937	0.553	0.932	1.140

6.	0.175	1.220	4.65	2.017
7.	0.138	1.625	4.450	2.071
8.	1.895	1.123	0.460	1.159
9.	5.610	0.375	0.279	2.175
10.	2.612	0.6758	0.556	3.853

The table I shows the value of fault current ration and hence the fault index when a set of readings were obtained from the model by arbitrarily creating Line to Ground fault on phase A, Phase B and Phase C respectively.

The obtained value of fault current ratio and fault index for Line to Line fault as created in the model is shown in the table II:

Table II. Fault Current Ratio and Fault Index for LL Fault

S.NO.	S1 = Ia/Ib	S2 = Ib/Ic	S3 = Ic/Ia	FAULT INDEX
1.	2.144	0.864	0.539	1.182
2.	2.138	0.854	0.547	1.179
3.	3.330	0.433	0.695	1.489
4.	0.860	0.487	2.370	1.714
5.	3.390	0.409	0.718	1.505
6.	4.910	0.283	0.718	1.970
7.	6.519	0.191	0.801	2.503
8.	7.700	0.276	0.468	2.814
9.	2.340	0.759	0.563	1.220
10.	0.941	0.560	0.124	3.200

The table II shows the value of fault current ration and hence the fault index when a set of readings were obtained from the model by arbitrarily creating Line to Line fault on phase A-B, Phase B-C and Phase A-C respectively.

In the model design of obtaining fault current index the value of fault current ratio and fault index as displayed on the LCD display for LLL Fault is as shown in the Table III:

Table III. Fault Current Ratio and Fault Index for LLL Fault

S.NO.	S1 = Ia/Ib	S2 = Ib/Ic	S3 = Ic/Ia	FAULT INDEX
1.	2.244	1.799	1.557	1.500
2.	2.261	1.766	1.577	1.501
3.	3.530	0.393	0.718	1.540

4.	1.771	2.549	0.221	1.513
5.	3.509	1.394	1.723	2.211
6.	7.709	1.293	1.422	3.476
7.	4.899	1.306	1.666	2.623
8.	2.095	0.559	0.852	1.168
9.	2.248	0.786	0.565	1.190
10.	14.10	0.600	1.121	4.995

IV. DISTANCE LOCATION OF FAULT

The prototype design model of distance location of fault consists of three phase system which has toggle switch in each line at little distance and is used to arbitrarily create fault in each of the phases. When toggle switch is in ON position it indicates the faulty condition and send a high bit to the microcontroller. The microcontroller interprets the location of fault as the four switches are placed in each phase representing the fault at distance of 1Km each. The signal received from the switch will indicate the position of the fault. This calculated value of the distance of the fault is then displayed at the LCD. This value is also sent serially to Arduino USB-TTL and sent to Matlab through COMPORT. The value of distance of fault is thus indicated in the Simulink display. This is further used as an input of fuzzy logic for the prioritization of the fault

The distance of the fault located in three phase system is been calculated by the microcontroller as per the position of the arbitrary fault creation. This fault is thus displayed on the Simulink for further use as an input to the fuzzy controller to prioritize the fault. Some of the experimental positions are mentioned as below:

The given Fig.1 shows that the fault is been created in one phase that is it is a single line to ground fault and the distance as shown on LCD display is shown in Fig1.

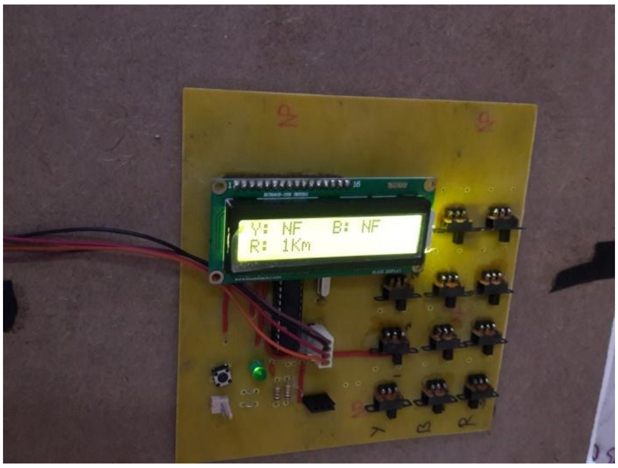

Fig.1 Single Line to Ground Fault Displayed on LCD

From the above Fig.1 it is clearly visible that an arbitrary fault is created in R phase by closing the toggle switch at position 1 indicating 1Km distance fault. So the line to Ground fault in Line R is displayed on LCD. This data is sent serially to COMPORT by Arduino and then read in Simulation.

The Result of LG fault in phase R is displayed in Simulink environment as shown in Fig.2

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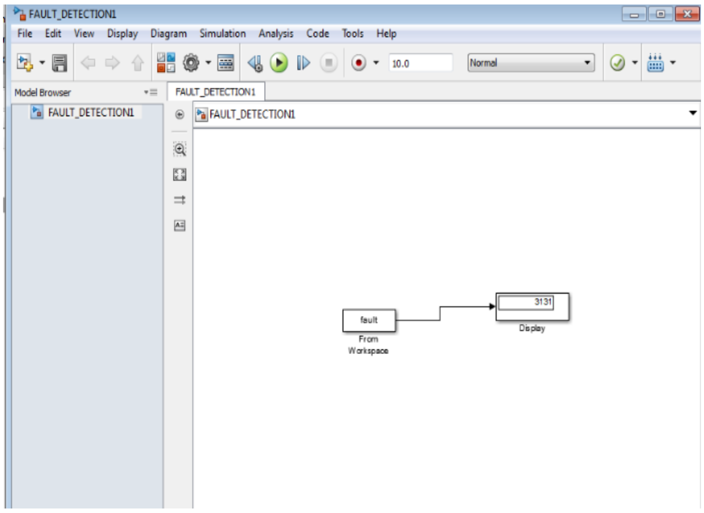

Fig.2. Single Line to Ground Fault Displayed in MATLAB Environment

The figure 2 displays 31 which is interpreted as third phase 1 Km. IN the coding the Y,B and R phase are indicated as Phase 1,2 and 3 Respectively and the distances as per the hardware is ranging from 1 to 4. SO the display 31 indicates that a fault has occurred in phase 3 i.e. in Phase Y and B at 3 Km and at 2Km distance respectively.

V. FUZZY LOGIC CONTROLLER FOR REDUCTION OF FAULT CLEARANCE TIME

In the proposed Smart Energy Delivery model, the power capacity of source, the price to generate unit power and distance between the source-sink are considered as inputs for the Fuzzy model. These three parameters are named as Fault Index, price and distance.The output is fault clerance time After that, the membership functions are constructed.

The membership function is of trapezoidal or triangular function and the main input parameters are:

i) Fault IndexThe fault current index is the first input parameter. This index of the fault current has been divided into three categories: Low, Medium and High. The low Fault Index value starts at 0 and goes all the way up to 1.5; beginning at 1.5, it starts to overlap with medium. Similarly, the medium starts at 1.5 and overlaps with high at 2.5. After 2.5, all the values are considered as high. All the input values of power are fuzzified using the membership function in the range of 0-5. It is used to maximize the amount of power utilization, so for rule generation, a higher power will get more priority.

ii) Price: The price of power generation is the second variable and is also divided into three categories: Low, Medium and High. The low value starts at 0 and goes all the way to 3 units; beginning at 3 units, it starts to overlap with medium. Similarly, the medium starts at 3 and overlaps with high at 6 units. After 8 units, all values are considered high. The unit is Rs/day. All the input values of power are fuzzified using this function in the range of 1-8. We want to give priority to the source which is offering power at a lower price, so a lower price will get more priority.

iii) Distance: The last Fuzzy variable is the distance between source and sink. It is also divided into three categories: low, medium and high. The low value starts at 0 and goes to 1 unit; beginning at 1 unit, it starts to overlap with medium. Similarly, the medium starts at 1 and overlaps with high at 2 units. After 2 units, all the values are considered high. The unit is miles. All the input values of power are fuzzified using this function in the range of 0-4

iv) Fault Clearance Time: The output parameter is defined in terms of fault clearance time which is defined as very small, small, moderate, average, large, and Very Large. The range of the output lies between 1 to 45 seconds. The very small value starts at 0 and goes to 15sec; beginning at 14sec, it starts to overlap with small and it ranges up to 25sec.From the 24sec it start to overlap with moderate time which ranges from 25sec to 30sec. At the beginning of 28sec it starts to overlap with average time. Similarly, the large time starts at 35sec and overlaps with Very high at 40sec. After 40sec, all the values are considered very large time

The simulations for the various types of faults were carried performed and the various values for both faulted and non-faulted current will be recorded. It will be able to detect single line to ground fault, phase to phase fault, double line to ground fault, and three phase fault.The rule base for fault clearance time is shown in table IV

Table 4.2 Fuzzy Logic Rule Base for Clearance time of Fault

S.NO.	FAULT INDEX	PRICE	DISTANCE	CLEARANCE TIME
1	LOW	LOW	LOW	VEY SMALL
2	LOW	LOW	MEDIUM	VERY SMALL
3	LOW	LOW	HIGH	VERY SMALL
4	LOW	MEDIUM	LOW	VERY SMALL
5	LOW	MEDIUM	MEDIUM	SMALL
6	LOW	MEDIUM	HIGH	SMALL
7	LOW	HIGH	LOW	SMALL
8	LOW	HIGH	MEDIUM	SMALL
9	LOW	HIGH	HIGH	SMALL
10	MEDIUM	LOW	LOW	MODERATE
11	MEDIUM	LOW	MEDIUM	MODERATE
12	MEDIUM	LOW	HIGH	AVERAGE
13	MEDIUM	MEDIUM	LOW	AVERAGE
14	MEDIUM	MEDIUM	MEDIUM	VERY SMALL
15	MEDIUM	MEDIUM	HIGH	VERY SMALL
16	MEDIUM	HIGH	LOW	SMALL
17	MEDIUM	HIGH	MEDIUM	SMALL
18	MEDIUM	HIGH	HIGH	SMALL
19	HIGH	LOW	LOW	LARGE
20	HIGH	LOW	MEDIUM	LARGE
21	HIGH	LOW	HIGH	LARGE
22	HIGH	MEDIUM	LOW	VERY LARGE
23	HIGH	MEDIUM	MEDIUM	VERY LARGE
24	HIGH	MEDIUM	HIGH	MODERATE
25	HIGH	HIGH	LOW	AVERAGE
26	HIGH	HIGH	MEDIUM	AVERAGE
27	HIGH	HIGH	HIGH	VERY LARGE

VI. RESULT AND CONCLUSION

The most common problem for the operator sitting in transmission or distribution station is to prioritize the clearance of the fault in case of multiple fault occurrences at a time which is quite common. This leads in further

more time for clearance of fault and majority of the times the fault with lower priority is cleared first and with the higher priority is cleared later. This can be minimized when handled by skillful and expericenced operator
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An efficient method to prioritize the fault is by using fuzzy logic controller which on the basis of pre- defined rule base can prioritize the fault resulting in clearance of fault in minimum time in a smart energy delivery system
When the case of Line to Ground fault is been considered and the ratio of fault current and fault index obtained from the Table 5.1 the fault index reads 2.14 and then distance considered for the same fault is 2 km and the arbitrary price of Rs. 4.5 then according to the membership function designed for the inputs the values are all medium as and from the rule base design as discussed in table IV the crisp value obtained is moderate clearance time which is shown in Fig.3

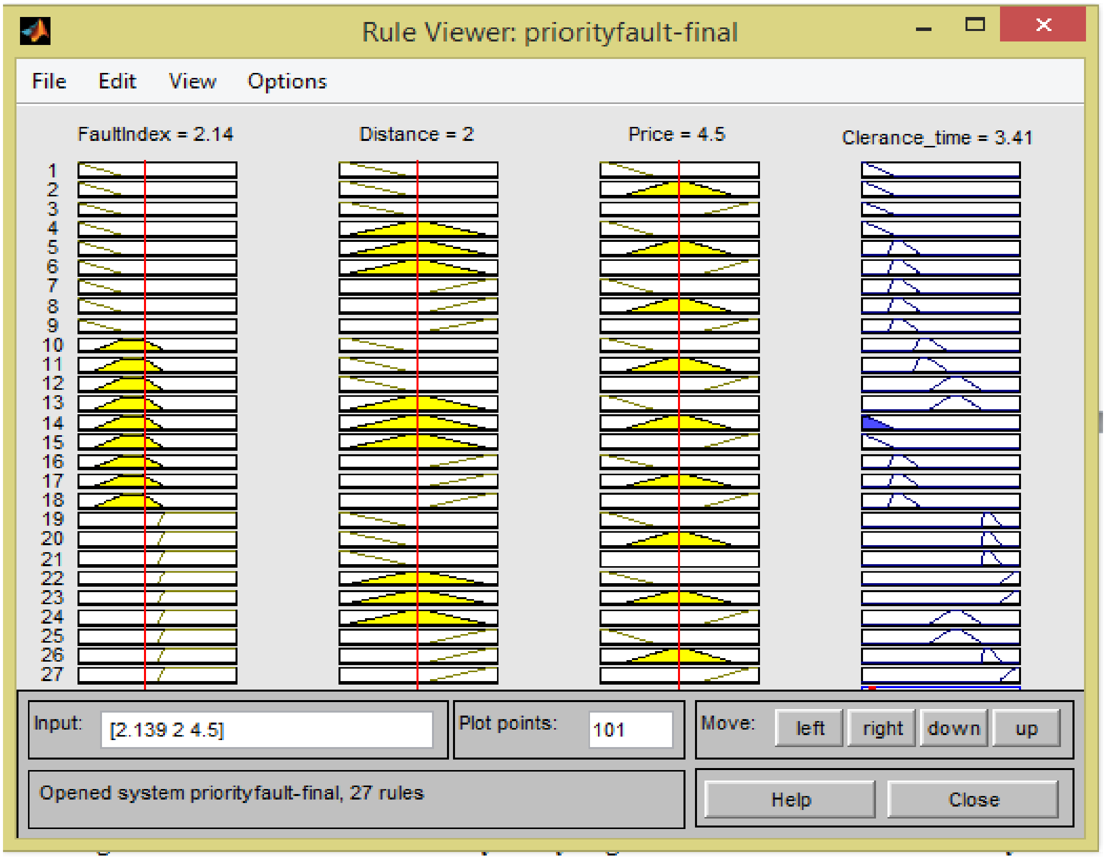

Fig. 3Rule Viewer for the Clearance Time Fuzzy Logic Controller for LG Fault

When a fault occurs, the fault is reported within a period of 5 to 10 minutes. After this the field crew report to the location of the fault which takes time to travel and the time to investigate by patrolling the line which utilizes a minimum time of 15 minutes. After this restoration process is done by manual switching which, take a minimum of 10 minutes in this process. This is the scenario when a single fault occurs at a time. When a multiple fault occurs at a time within same vicinity of transmission or distribution then the situation becomes more complex and a lot more time is also wasted in deciding the priority of clearance of the fault which may often result in wrong decision and the higher priority fault is attended last which is unhealthy and un-economical for the system

To reduce the complication in the above mentioned scenario the fuzzy logic controller for the prioritization of fault is been developed. The prototype model not only locates the distance of the occurrence of fault but also determine the fault Index and priority of clearance of fault is generated using fuzzy logic controller which defines the order of the clearance of the fault and thus reduces the fault restoration time significantly.

The Reduction of fault analysis time in Smart Energy Delivery System concludes that fuzzy set model can be applied in decision making of restoration of fault and is comparatively faster in computation. It can be used to filter out the best combination when a decision is crucial in terms of time.

This model not only limit to transmission system but can be applied in distribution section because the fuzzy set model are extremely scalable .In this way, it can incorporate self- healing characteristic in the grid function.

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