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퍼지 로직을 이용한 배전계통 복구

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Fuzzy-Logic Based Service Restoration of Primary Distribution Systems

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Abstract

Service restoration has become more important function in the distribution systems. Conventional scheme considers only the single criterion such as margin, switching number and thus lacks the practical power. This paper proposes a new scheme adopting the fuzzy decision making technique, generating a more effective restoration plan.

1. Introduction

One of the most important functions in DAS (Distribution Automatión System) is the service restoration in case of the fault on the primary feeder. There have been many research efforts in this area [1,2] and recent study includes the expert system approach [3,4]. Most of the researches have focused on the search for the optimal solution based on the single criterion such as the margin, loss reduction, number of switchings, etc. The search process follows the sequential order of specific restoration schemes in an attempt to find the feasible solution with satisfied conditions. However in practice it is hard to define the optimality and the decision making performed by the human operators involves the evaluation of the multi-criteria looking for the solution of a good quality. Evaluation includes various factors such as a number of switching, feeder loading, live load transfer, preparedness for a contingency, protection coordination, etc.
In this paper, a new restoration strategy adopting the fuzzy-decision making technique in order to find a best solution considering various practical factors is proposed.

2. Fuzzy Service Restoration Strategy

The restoration strategy proposed in this study first attempts to find the multi solutions which satisfy the consideration factors with the higher priority and then applying the fuzzy decision making technique to evaluate the overall quality of the plan based on the next priority factors, determining the best one.

2.1 Assumptions

The following assumptions have been made for this study: (1) both automatic and manual switches are installed in the system (2) the location and the number of the automatic switch is determined in such a way that easy load separation is achieved considering the load management and load magnitude, load characteristic (3) the restoration is carried out by using the backup feeders controlled by the same control center to which the faulted feeder belongs (4) in any outage, its full restoration is possible and thus no load priority is considered (5) there is no preference difference between different types of switches in switching (6) there is no possibility of the consecutive fault on the faulted feeder (7) only single communication failure could happen during execution of the single restoration plan.

2.2 Multi Practical Factors in Restoration

The primary goal in case of the emergency like a feeder fault is to restore the outage area as soon as possible. Therefore considering the communication reliability, the number of switching which is directly related to the execution of the restoration plan is one of the most important factors while those related to the post-restoration situation such as the contingency preparedness, loss reduction, load balancing, etc. have less importance and the protection coordination factor is considered to have the least priority since the original protection function of the backup feeders will be preserved regardless of the transferred load. Table 1 shows the consideration factors categorized according to their priority.

Table 1. Consideration factors and priority

Priority	Consideration Factors
1	Speed, Outage Load, Number of Switchings
2	Contingency Preparedness, Load Balance Voltage Drop, Live Load Transfer, Loss
3	Protective Device Coordination

How the each factor is taken care of in the proposed method is described in the following.

(1) Speed: two-phase restoration - full automatic restoration and semi automatic restoration - is adopted. The former refers to restoration by only the remote-controlled automatic switches and the latter refers to restoration by both automatic and manual switches accomplishing restoration of the area not covered by the full automatic restoration.

(2) Number of switching: the number of switching is minimized by adopting the margin-based search in finding the appropriate backup feeder, which would result in the minimal number of separation of the outage area.

(3) Contingency preparedness: the post-restoration system should be well prepared for the another possible fault on the system, which means there should exist a corresponding restoration plan for any contingency. The proposed method in establishing the plan searches for the backup feeder which has more ties and bigger margin.

(4) Loss minimization, voltage drop reduction, load balancing: these factors implicitly related to each other are considered in maximum loading setting on the backup feeders and selection of backup feeder with the lower loading.

(5) Protection coordination: protection factor is taken into consideration only when the probability of the another fault on the faulted feeder is rather high like the stormy weather.

2.3 Restoration Schemes

The proposed restoration method consists of five basic schemes - self backup restoration, single backup restoration, double backup restoration, triple backup restoration, single backup and level-2 load transfer, double backup and level-2 transfer and details of each scheme is described in the following.

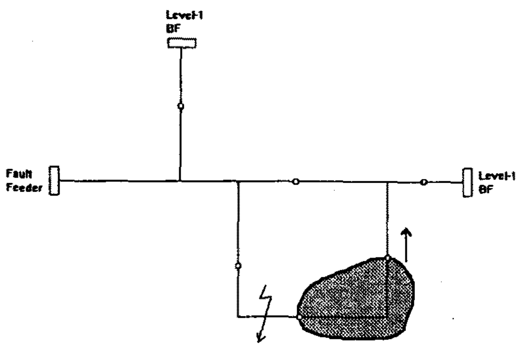


Fig 1. Self Restoration

(1) Self Restoration (SELF): This scheme handles the case when a faulted feeder has a self loop and the fault has occurred on the loop so that the outage can be easily restored by the self feeder as shown in Fig. 1.

(2) Single Grouping Restoration (SGR): This scheme attempts to find all possible backup feeders each of which has enough margin to pick up the outage load.

(3) Double Grouping Restoration (DGR): This scheme searches for all possible combination of two backup feeders which can share the outage load. The load division is to occur on the point along the straight line connecting two backup feeders, which gives the best loading balance between them.

(4) Triple Grouping Restoration (TGR): This scheme tries to find all possible combination of three backup feeders which can share the outage load. Two load division points are determined in such a way that could give the best loading balance and are located on Y connecting three backup feeders.

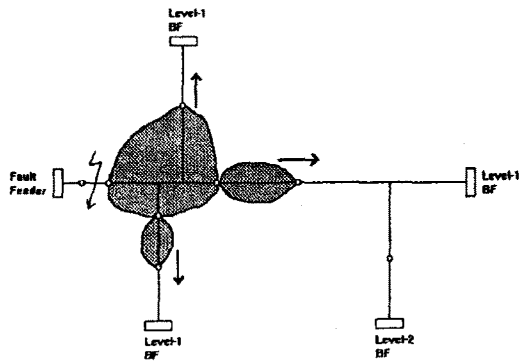


Fig 2. Triple Grouping Restoration

(5) Single Grouping and Level-2 Load Transfer (SGR&LT): This scheme looks for a backup feeder whose overloading can be released by its corresponding level-2 feeder. For this sum of two feeders should be bigger than the outage load.

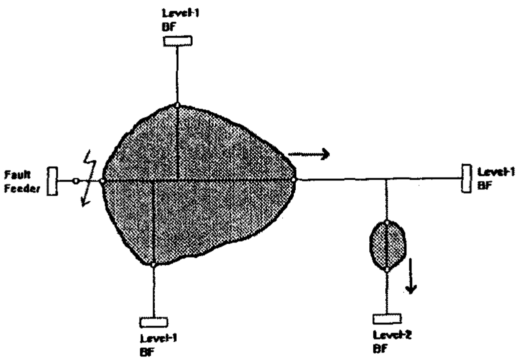


Fig 3. Single Grouping and Level-2 Load Transfer

(6) Double Grouping and Level-2 Load Transfer (DGR&LT): This scheme searches for two backup feeders, one of which would experience overloading due to outage load pickup but its overloading can be released by its corresponding level-2 feeder.

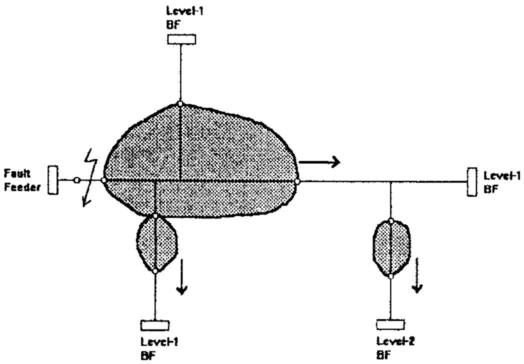


Fig 4. Double Grouping and Level-2 Load Transfer

The core process of the proposed restoration method can be well understood through the flow diagram shown in Fig.5. It basically applies the each scheme in a sequential order and in any step if any solution is found then a set of solutions for fuzzy evaluation is constructed from the solutions of more than two schemes applied in sequence. The fuzzy evaluation on the components of the set determines the best restoration plan.

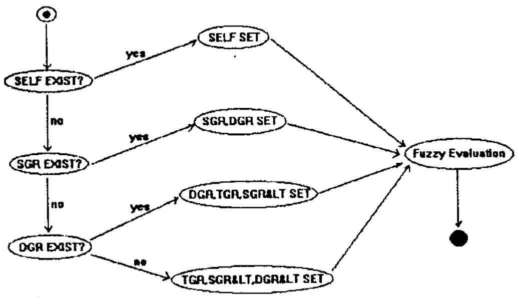
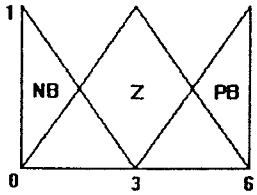


Fig 5. Flow Diagram

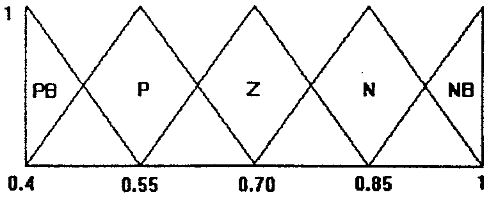
2.4 Fuzzy Decision Making

The evaluation of the practical factors described in 2.2 except the speed is fuzzy and selection of the best plan is carried out by using the fuzzy decision making technique. There are two levels of the decision making involved during the planning process: local decision and global decision. The former deals with the determination of the switches to be opened and closed in each scheme and it is based on the margin, while the latter determines the best plan from the set of candidate plans using the fuzzy decision technique. The candidate set is constructed with those plans which have switchings within two more switchings than the feasible plan firstly found. The fuzzy decision criteria and their corresponding fuzzy rules and membership functions used in this study are as follows:



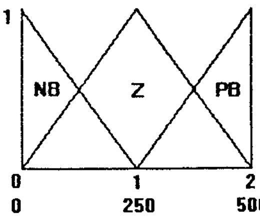
if #_of_Switching is Positive_Big then Plan is Poor
if #_of_Switching is Zero then Plan is SoSo
if #_of_Switching is Negative_Big then Plan is Very_Good

(a) Number of Switchings



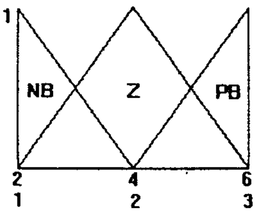
if Max_Load_Factor is Negative_Big then Plan is Very_Good
if Max_Load_Factor is Negative then Plan is Very_Good
if Max_Load_Factor is Zero then Plan is Very_Good
if Max_Load_Factor is Positive then Plan is Poor
if Max_Load_Factor is Positive_Big then Plan is Very_Poor

(b) Maximum Load Factor



#_of_LT	LT_Amount	Plan
Negative_Big	Negative Big	Very_Good
Zero	Negative Big	SoSo
Zero	Positive_Big	SoSo
Zero	Zero	Poor
Positive_Big	Negative Big	Poor
Positive_Big	Positive_Big	Poor
Positive_Big	Zero	Very_Poor

(c) Live Load Transfer



#_of_BFs	Load/Margin	Plan
Positive_Big	Positive_Big	Very_Good
Positive_Big	Zero	Good
Positive_Big	Negative_Big	Poor
Zero	Positive_Big	Very_Good
Zero	Zero	Good
Zero	Negative_Big	Poor
Negative_Big	Positive_Big	SoSo
Negative_Big	Zero	Poor
Negative_Big	Negative_Big	Very_Poor

(d) Contingency Preparedness

Fig 6. Membership Function and Fuzzy Rule

Membership function for the plan evaluation is defined in Fig. 7.

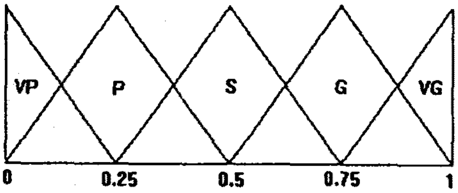


Fig. 7. Plan Membership Function

Evaluation of the fuzzy rules in each category is performed separately and the weighted sum of each evaluation is performed for each plan in order to select the best plan. In evaluating the fuzzy rules, the max-min composition is used and for defuzzification, the center of gravity is applied.

3. Conclusions

This study proposes a service restoration strategy adopting the weighted fuzzy-decision making technique. It has a capability of yielding a best compromising solution among various practical factors. The system applying this strategy has been implemented using OOP (Object Oriented Programming) methodology. Tests on the example systems and discussions with operators have proved its effectiveness.

4. References

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