Fuzzy Logic used in the Management of Interventions during Power Outages

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***Abstract*— The main objective of this work is to explain how to apply fuzzy logic in order to make the best decision that allow operators to optimize their emergency rules face the unplanned outages. It will use as major variables the dysfunction and the interruption rates of electrical distribution network. The linguistic rules are obtained from experts in electrical distribution network.**

Keywords*— *Fuzzy logic, Iterruption, Sensitive sites, Dysfunction rate, Distribution network.

I. INTRODUCTION

Since the invention of electricity, several historical breakdowns have occurred in the world. Thy have had a strong impact on the economy. The biggest failure in the history of the number of individuals involved is the one that struck India in 2012 [7].

Power failures are particularly critical at sites where the environment and public safety are at risk. Institutions such as hospitals, sewage treatment plants, mines, and the like will usually have backup power sources such as standby generators, which will automatically start up when electrical power is lost [8].

The legitimacy of the distributor of such a network as a dealer depends heavily on its ability to minimize recovery time in case of failure on the network and to control problems of service quality perceived by users. Despite such a system is considered as stable and reliable, it is not immune to the daily disturbances (cuts, power surges, harmonics, voltage drops ...).

The frequency of these failures and their direct impact on consumer satisfaction show the need for better post-incident management. And in particular, the implementation of an interim solution for powering sensitive sites pending final restored. Interrupt management on the electricity distribution network is made by a dispatching room attached to the company responsible for the distribution. The goal is to identify in real time the system disturbances and execute the maneuvers needed to restore service promptly; including the precise fault location and isolation for repair. For an efficient distributor these operations take less than 15 minutes for 75% of customers cut off [1]. In some cases, the recovery time can be up to 4 hours; or even more. During this period the operator may decide to temporarily power sensitive customers by generators. This decision was taken after consulting experts in different farms.

In this paper, fuzzy logic is introduced to take account of the weaknesses displayed by the existing decision tools in terms of their responsiveness in an imprecise environment and the variables are not homogeneous. Specifically, with fuzzy logic we are able to obtain a single value (output) from the imprecise data (input).

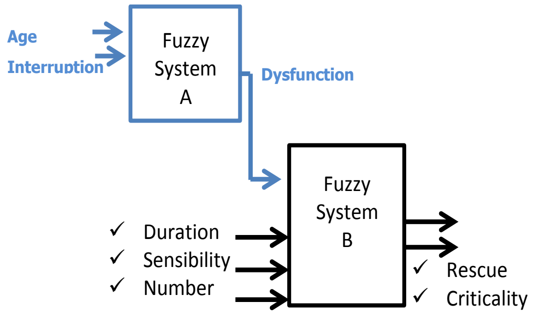

Fig.1. General diagram of the system.

This paper proposes the application of fuzzy logic to evaluate the level of emergency to be given to sensitive customers after a service interruption. This emergency level is combined with the dysfunction rate of the electrical network, to evaluate its criticality.

This paper is organized as follows: section II, gives a description of a proposed system based on fuzzy logic. Section III presents the simulation on Matlab of the system. And the conclusions are given in section IV.

II. SYSTEM DESCRIPTION

The proposed model is divided on three parties that based on Mamdani fuzzy inference [2] [3] [4]. The first bloc uses as input variables: the duration of the interruption, the customers' sensitivity and the number of clients to restore. The output is the net value of the emergency level.

The second bloc uses as input variables: the age and the interruption rate of the network. The output is the dysfunction rate of the electrical network.

These two output variable are re-injected in the third bloc as input variables in order to get a level of criticality [6]. It allows us to determine the severity level of interruption, if it is acceptable or not, in order to better control risks and manage priorities. Once complete analysis, we will have all the information necessary to decide the type of rescue to be made.

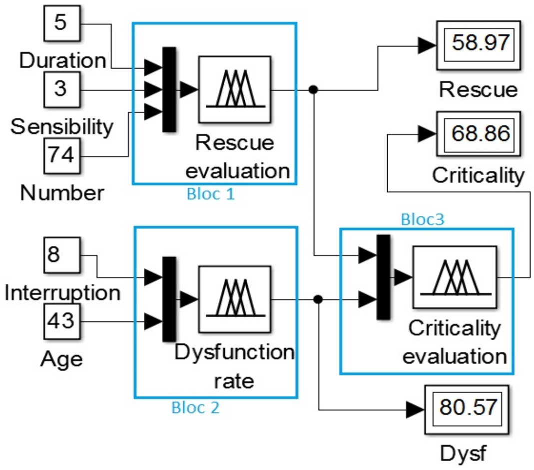

Fig.2. Detailed diagram of the system.

III. SIMULATION ON MATLAB

A. Input and output variables

1) Rescue evaluation:

We use as input variables: The sensitive customers, the number of clients to restore and duration of the interruption. The output is the net value of the emergency level.

a) Input variable interrupt duration:

In the proposed model, the variable duration is divided into 3 levels:

- Short when it's <4 h,
- Long when it's between 2 and 8 hours,
- Very long when it's > 6 h.

These levels are given here as an indication. But it is quite possible to imagine a different process that aims to estimate these periods in function of other variables; such as SAIFI and SAIDI indicators, the cause of the failure, the nature of the failure, duration of response and repairs, etc.

b) Customer input variable sensitivity

In the proposed model the input variable sensitivity is divided into 5 levels [5]:

- Normal,
- Sensitive (hospital, school),
- Large (office building),
- Critical (water tank)
- Strategic (Royal Palace).

NB: These levels are given here as an indication. But it is quite possible to imagine a different process which aims to estimate these levels depending on other variables; such as customer segments, contract requirements, etc.

c) Input variable number of customers cut off

In the proposed model, the input variable Number of customers cut is divided into 3 levels:

- Low (<100 customers),
- Small (50 to 200),
- High (> 150).

d) Output variable rescue level

In the proposed model, the output variable Rescue is divided into 5 levels on a scale of 10:

- Rescue unnecessary (NON <3),
- Local rescue by means of the Direction (1 <Local <5),
- Strengthening by the neighboring Direction (3 < neighbor <7),
- Strengthening by other Directions (5 < other <9),
- Crisis level (7 <crisis) when the means of all departments are no longer sufficient; and must be called possibly outsourcing to strengthen.

2) Dysfunction evaluation

We use as input variables: The age and the interruption rate. The output is the net value of the dysfunction rate.

We use the age of the power grid in order to take account of the technological obsolescence and the physical wear and tear.

The interruption rate is used in order to take account of the incidents by subsidiary or geographical area (per 100 km of the network).

It is obtained by dividing the number of unplanned power cuts on the network (multiplied by 100 Km) by the linear of electricity network (in km).

a) Input variable age of the network:

In the proposed model, the variable Age is divided into 3 levels:

- Low (Low < 30 years),
- Medium 10 < medium < 50 years,
- High when it's > 30 years.

b) Input variable interruption rate

In the proposed model the input variable interruption rate is divided into 5 levels [5]:

- Rare when value is under 2.5,
- Occasional when it's between 0 and 5,
- Medium when it's between 2.5 and 7.5,
- High when it's between 5 and 10,
- Continuous when it's more than 7.5.

c) Output variable dysfunction

In the proposed model the output variable dysfunction is divided into 5 levels [5]:

- Very low when value is under 25%,
- Low when it's between 0% and 50%,
- Medium when it's between 25% and 75%,
- High when it's between 50% and 100%,
- Very high when it's > 75%.

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3) Criticality evaluation

We use as input variables: The dysfunction and the rescue level. The output is the net value of the criticality.

a) *Input variable dysfunction*: It's equal to the output variable that comes from the second bloc.

b) Output variable criticality:

In the proposed model the input variable criticality is divided into 4 levels [5]:

- Acceptable when value is under 33%,
- Possible when it's between 0% and 67%,
- Moderate when it's between 33% and 67%,
- Unacceptable when > 67%.

B. The fuzzy inference

The fuzzy inference is a system that uses fuzzy logic to map input to output variables. The fuzzy rules are gained by doing interviews with experts and operators in different plantations.

As it can be seen in Table 1; three input variables gives a maximum of (5 * 3 * 3) = 45 rules for the inference system.

Duration of intrruption	Nomber of customers cut off	Sensibility of customers is				
		Normal	Sensitive	Large	Critical	Strategic
Short	Low	Non	Non	Non	Non	Non
	Small	Non	Non	Non	Non	Non
	High	Non	Non	Non	Non	Non
Long	Low	Non	Local	Local	Local	Local
	Small	Non	Local	Neighbor	Neighbor	Neighbor
	High	Non	Local	Other	Other	Other
Very Long	Low	Local	Neighbor	Other	Crisis	Crisis
	Small	Other	Other	Crisis	Crisis	Crisis
	High	Crisis	Crisis	Crisis	Crisis	Crisis

Tableau 1: Fuzzy rules for rescue evaluation

In table 2, we can see that two input variables give (5*5) = 25 rules for the inference system.

Dysfunction Rate	Level of rescue				
	None	Local	Neighbor	Other	Crisis
VeryHigh	Acceptable	Possible	Moderate	Unacceptable	Unacceptable
High	Acceptable	Possible	Moderate	Unacceptable	Unacceptable
Medium	Acceptable	Possible	Moderate	Moderate	Moderate
Low	Acceptable	Acceptable	Possible	Possible	Possible
VeryLow	Acceptable	Acceptable	Acceptable	Acceptable	Possible

Tableau 2: Fuzzy rules for criticality evaluation

In table 3, we can see that two input variables give (5*3) = 15 rules for the inference system.

Interruption rate	Age		
	Low	Medium	High
Continuous	H	VH	VH
High	M	H	VH
Medium	L	M	H
Occasionel	VL	L	M
Rare	VL	VL	L

Tableau 3: Fuzzy rules for dysfunction rate evaluation

C. Simulation

The type of the proposed model is based on Mamdani fuzzy inference [2] [3] [4]. The method used to transform the fuzzy outputs from the systems to crisp values (defuzzification) is the center of gravity (COG).

As example, it is shown in Figure 3, for input values (duration outage = 5h; customer sensitivity level of cut = 3; number of customers cut = 74); a single value of 59, is obtained for the output variable "level of rescue".

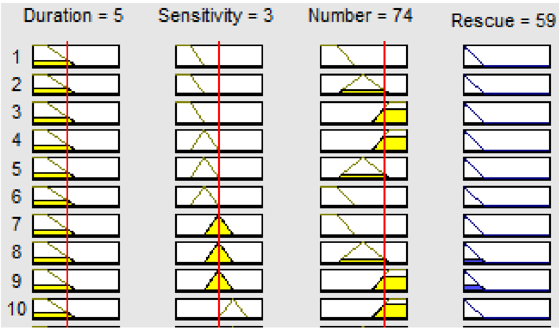

Figure 3: output variable Rescue

And, as shown in figure 4, with input value Age equal 43 years and input value Interruption equal 8, we obtained 80.6 for the output variable Dysfunction.

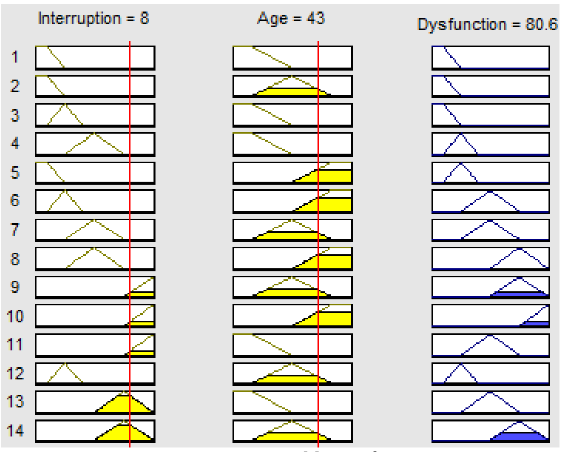

Figure 4: output variable Dysfunction

And, as shown in figure 5, with input value Rescue equal 59 and input value Dysfunction equal 80.6, we obtained 68.9 for the output variable Criticality.

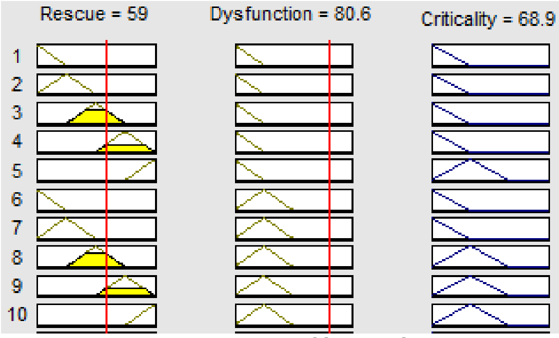

Figure 5: output variable Criticality

NB: Reducing criticality can be improved by reducing the number of faults (SAIFI measurement) and reducing the repair time (SAIDI measurement) by means of various design and maintenance strategies [7].

IV. CONCLUSION

Using fuzzy logic allows us to formally model the aggregates needed for decision making in a possibilistic field and allows us to integrate the non-palpable character of the desire to provide better service to customers. It is then to find compromises guaranteeing a possibility of more accurate decision. However, the use of this method for improving the quality of service and in particular to reflect the customer's relief level is original.

The application of fuzzy logic allows us to obtain a single value of the level of emergency to be given to sensitive customer after a service interruption. This emergency level is combined with the dysfunction rate of the electrical network, to evaluate its criticality.

The rate of dysfunction by post or by geographical area, more or less large, helps decision-making in relation to: prioritizing the assistance to be provided to the cut-off area and planning investments or maintenance.

Reducing criticality can be improved by reducing the number of faults and reducing the repair time by means of various design and maintenance strategies.

On perspective, we can try to experiment the presented approach. The implementation of this method to real cases of power outages will compare the different assumptions expressed.

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