Using Fuzzy Techniques For The Calculation Of Permanent Power Flow Of Electric Distribution Networks

Cristian . Bogoi
National Power Grid- Company" TRANSELECTRICA S.A. " Bucharest, ROMANIA
email: cbogoi@transelectrica.ro www : http://www.transelectrica.ro

Abstract-- The introducing of fuzzy techniques and models in the calculation of permanent power flow of radial electric distribution networks deals with the use of representation models of uncertain or inaccurate data and the turning to account of knowledge and experience of experts in the management of uncertain data. The theories relating to the fuzzy numbers are simplified into a form suitable for practical application. The utilization of the fuzzy approach is demonstrated by a radial load flow method where the voltage in the substation and the power demands are represented by fuzzy numbers.

***Keywords*--Distribution networks, Fuzzy numbers, Fuzzy sets, Uncertainty**

I. INTRODUCTION

When the scheming of electric distribution networks is going to be planned, some of the used data is more or less uncertain. Loads depend on time and there is no possibility to predict a clear value for the peak load of a certain year, but data errors may occur in an existent electric network**.** So far scheming of electric distribution networks has used deterministic calculation techniques. The fuzzy technique presented by Prof. Zadeh was an alternative way of working with uncertain or inaccurate data.

In the management of uncertain and inaccurate data the application of fuzzy techniques assumes the transition from the concept of "probability" to the concept of "possibility."

This paper describes the possibility of representing uncertain data, the operations between fuzzy numbers and the calculation algorithm of the permanent power flow of radial electric distribution networks by using fuzzy techniques.

Due to a better modeling of available data, the application of the "possibility" - fuzzy theory opens a wide outlook for the permanent power flow of a radial electric distribution network.

II. FUZZY METHOD FOR THE CALCULATION OF PERMANENT POWER FLOW

When scheduling electric distribution networks, some of the data used for calculations is more or less uncertain.

Uncertainties:

- The load with customers varies over time, having a dynamic feature;
- The forecasting of exact values for the peak load of a certain year is impossible;
- Errors existing in input data for an electric network, such as wrong line length, wrong types of conductors;
- The values of electric network components (R, X, etc.) are uncertain, being influenced by various external factors;
- Potential measuring errors of some input data;
- Unsteady voltage due to the permanent change of customers' load;
- The moment of value measuring does not coincide with the moment of calculating the same value.

In the management of uncertain and inaccurate data, the application of fuzzy techniques assumes the shifting from the concept of "probability" to the concept of "possibility".

The possibility is defined by a number between 1 (completely possible) and 0 (completely impossible).

According to the theory of "possibility", the calculation of permanent flow of electric distribution networks is based on the use of fuzzy numbers, to show the possibility that an uncertain input value may be considered a semantic concept ("very small", "small", "medium", "large", "very large").

A fuzzy number is a real fuzzy subset, which is "normal" and "convex".

Let us consider a set E of real numbers. We know that for ordinary sets the characteristic function attached to the elements of the set is defined as[1]:

$$\forall x \in E \; : \; \mu(x) \in \{0,1\}$$

There are some possibilities to represent uncertain input data as fuzzy numbers [2]:

- By using a linguistic syntax:

We know that fuzzy number A:

- is never below a_1
- is usually between a_2 and a_3
- is never over a_4

$$A = [a_1, a_2, a_3, a_4]$$

- When the uncertainty occurs out of rounding up values or measuring errors.

If we assume that the value of fuzzy number A is approximately a_0 with a minimum error e_r, then the parameters of the fuzzy number can be defined as:

$$\begin{cases} a_1 = a_0 - e_r \\ a_2 = a_0 - \dfrac{e_r}{2} \\ a_3 = a_0 + \dfrac{e_r}{2} \\ a_4 = a_0 + e_r \end{cases} \quad (1)$$

- Over a sample of empirical data

If there is a sample x_i, i = 1...n (n>30), than:

$$a_1 = \min(x_i)$$

$$a_2 = E(x) - \frac{E(x) - \min(x_i)}{2} \quad (2)$$

$$a_3 = E(x) + \frac{\max(x_i) - E(x)}{2}$$

$$a_4 = \max(x_i)$$

where E(x) is the value calculated out of a sample.

A trapezoidal fuzzy number can be expressed by: $A = [a_1, a_2, a_3, a_4]$ and its trapezoidal membership function [2]:

$$\mu_A(x) = \begin{cases} 0, x \le a_1 \\ \dfrac{x - a_1}{a_2 - a_1}, a_1 \le x \le a_2 \\ 1, a_2 \le x \le a_3 \\ \dfrac{a_4 - x}{a_4 - a_3}, a_3 \le x \le a_4 \\ 0, x \ge a_4 \end{cases} \quad (3)$$

A set is called fuzzy, if its specific function is $\forall x \in E \ : \ \mu_A(x) \in \{0,1\}$.

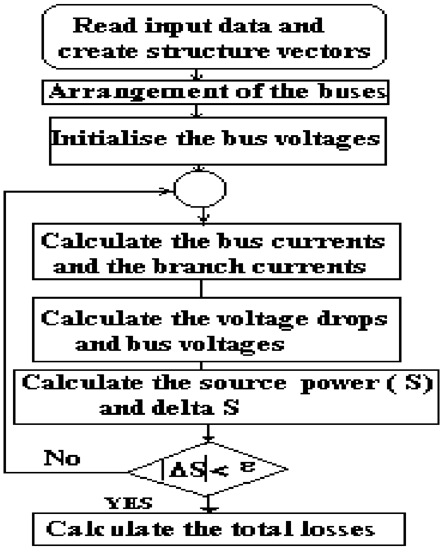

Fig. 1 . Logic scheme of the calculation program of the permanent power flow

The calculation algorithm for the permanent power flow of electric distribution networks is similar to the algorithm Increasing - Decreasing [3] for the calculation of permanent power flow (Fig .1) , where variables are defined through fuzzy numbers and the operations among them are defined through operations between fuzzy numbers.

One developed a calculation program, based on the algorithm and the techniques with fuzzy sets, for the analysis of the permanent power flow of an electric distribution network of medium voltage.

III. OPERATIONS WITH FUZZY NUMBERS

Let be A and B two fuzzy numbers with trapezoidal membership functions [2]:

$$A = [a_1, a_2, a_3, a_4], \qquad B = [b_1, b_2, b_3, b_4]$$

Let be fuzzy number C defined as a function of two fuzzy numbers A and B, C = f (A,B), than its membership function is [2]:

$$\mu_c(z) = \max[\ \min \{ \mu_A(z), \mu_B(z) \mid f(x,y)=z \} \ ] \quad (4)$$

- addition of two fuzzy numbers A and B

$$A + B = [a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4] \quad (5)$$

-subtraction of two fuzzy numbers A and B

$$A - B = [a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4] \quad (6)$$

-multiplication of two fuzzy numbers A and B

$$A \bullet B = [\begin{matrix} \min(a_1b_1, a_1b_4, a_4b_1, a_4b_4), \\ \min(a_2b_2, a_2b_3, a_3b_2, a_3b_3), \\ \max(a_3b_3, a_3b_2, a_2b_3, a_2b_2), \\ \max(a_4b_4, a_4b_1, a_1b_4, a_1b_1) \end{matrix}] \quad (7)$$

-division of two fuzzy numbers A and B

$$\frac{A}{B} = \left[\begin{matrix} \min\left(\frac{a_1}{b_1}, \frac{a_1}{b_4}, \frac{a_4}{b_1}, \frac{a_4}{b_4}\right), \min\left(\frac{a_2}{b_2}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_3}{b_3}\right), \\ \min\left(\frac{a_3}{b_3}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_2}{b_2}\right), \min\left(\frac{a_4}{b_4}, \frac{a_4}{b_1}, \frac{a_1}{b_4}, \frac{a_1}{b_1}\right) \end{matrix} \right] \quad (8)$$

IV. PROGRAM TESTING

The program was tested in a town electric network including 34 nodes and 33 radial sides [2] with 20 kV nominal voltage, developed by aid of C++.

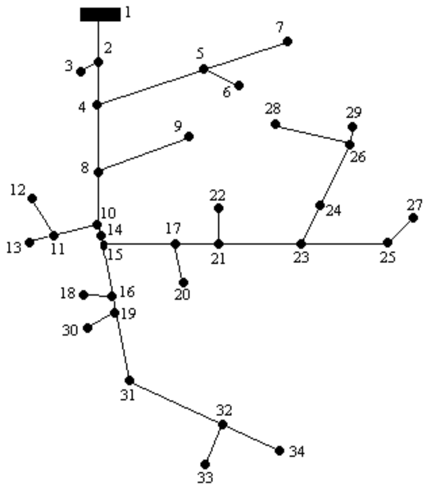

Fig.2. TEST network scheme

Let us consider following uncertain input data: line resistance, line reactance, voltage at source node, customers' active and reactive power and length of electric line.

Let us consider voltage at source Ufuzzy - satisfactory = 21 kV and assume a maximum allowable deviation of er = +/- 5%.

Ufuzzy - satisfactory = [19.95, 20.475, 21.525,22.05] kV expressed as a fuzzy number.

We have assumed a maximum error for each uncertain input data:

- For the voltage Us , e r(U) = 0.35 kV, of the source representing +1.67% U s, the plot of the transformer,

- For the length of the line , e r(L) = 6.52 m at 1 km.

- For the power demands at the customers, values from the node data.

The partial results obtained after running the calculation program are presented below:

LINE	NOD I	NOD J	STATUS	I 1Lat	I 2Lat	I 3Lat	I 4Lat	I 1Lat /Imax	I 2Lat /Imax	I 3Lat /Imax	I 4Lat /Imax
-	-	-	-	[A]	[A]	[A]	[A]	[u.r.]	[u.r.]	[u.r.]	[u.r.]
1	1	2	1	13.1	14.9	18.8	21.7	0.05	0.06	0.08	0.09
2	2	3	1	0.4	0.4	0.5	0.5	0	0	0	0
3	2	4	1	12.8	14.5	18.3	21.2	0.05	0.06	0.07	0.08
4	4	5	1	0.7	0.7	0.9	1.1	0	0	0	0

where the electric current ILat = [I1Lat, I2Lat, I3Lat, I4Lat] is represented as a fuzzy number.

NODE	Pc1	Qc1	Pc2	Qc2	Pc3	Qc3	Pc4	Qc4	U1	U2	U3	U4
-	[kW]	[kVAr]	[kW]	[kVAr]	[kW]	[kVAr]	[kW]	[kVAr]	[kV]	[kV]	[kV]	[kV]
1	0	0	0	0	0	0	0	0	20.649	20.825	21.175	21.351
2	0	0	0	0	0	0	0	0	20.423	20.634	21.034	21.237
3	12.1	4	13.4	4.4	15.4	5.1	16.6	5.4	20.423	20.633	21.034	21.237
4	0	0	0	0	0	0	0	0	20.285	20.517	20.948	21.168
5	0	0	0	0	0	0	0	0	20.263	20.498	20.934	21.157
6	0	0	0	0	0	0	0	0	20.263	20.498	20.934	21.157
7	21.4	7	25.4	8.3	31.3	10.3	35.7	11.7	20.253	20.49	20.928	21.152

where voltages U =[U1,U2,U3,U4], P2 = [Pc1,Pc2,Pc3,Pc4] and Qc [Qc1, Qc2, Qc3, Qc4] are represented as fuzzy numbers.

The results can offer the precise limits between which measurable values have to lie. A basic feature of the fuzzy set theory is the trust in the results. This trust was developed by aid of the trust interval quantified through the membership function of the fuzzy theory.

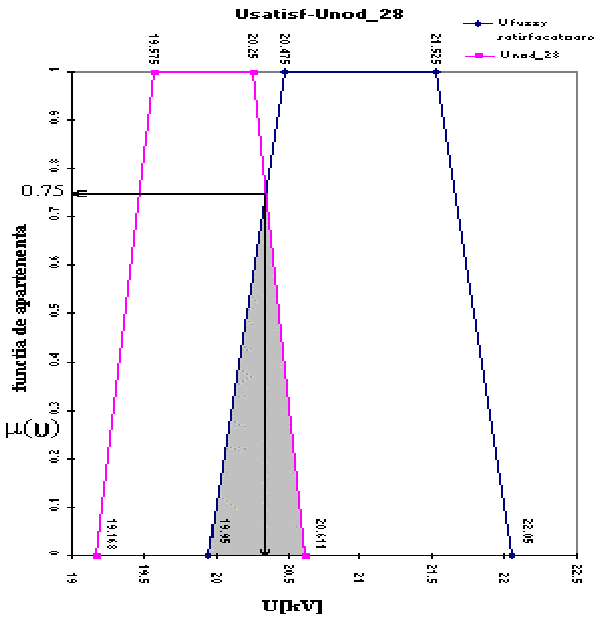

Fig.3 Membership function for U_{Satisf} - U_{nod28}

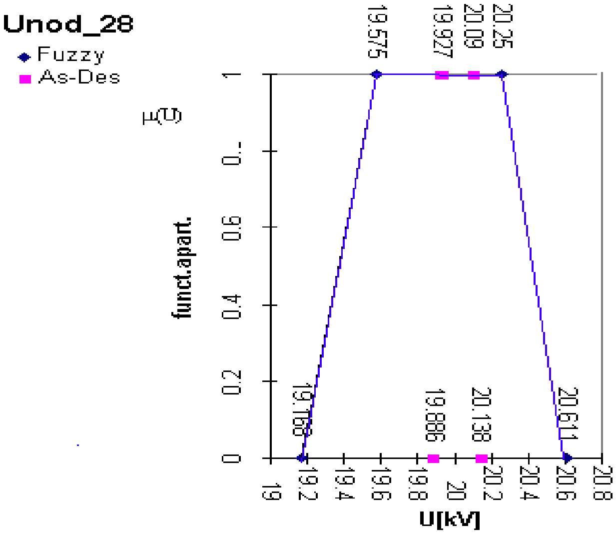

Fig. 4 Membership function for U_{28} and comparison between Fuzzy , Asc-Desc power flow methods.

Figure 3 shows the voltage in node 28, Unod 28. If it is 20.35 kV it has a maximum satisfaction degree of 0.75 and it decreases down to 0 if it lies between (19.95; 20.611) kV. If the voltage lies between (19.163; 19.95) kV, then it reaches its maximum non-satisfaction degree for the voltage at the imposed source Usatisfactory source.

The trust in the result is assessed by means of the trust interval [19.63; 20.611].

Figure 4 shows that Unode 28 obtained through the Increasing-Decreasing Method for four distinct permanent power flows Us1=20.649 kV , Us2=20.825 kV, Us3=21.175 kV, Us4=21.351 kV is within the interval Ufuzzy-node 28, with error er = =/-3.5% as compared to Ufuzzy-node28.

It is obvious that using fuzzy techniques for the calculation of permanent power flow makes it possible to transit from punctual values of a node voltage to an interval that allows the progressive transition from a value to another. Although starting from uncertain input data, the fuzzy techniques ascertain the limits between which the voltage in the related node should lie.

V. CONCLUSIONS

The reason for using fuzzy techniques for the calculation of permanent power flow is a better modeling of the available information. In practice, the powers demanded by customers are dynamic, being quite difficult to give its exact values. The result is that these values have a big degree of uncertainty. This uncertainty can be quantified by aid of the membership functions of the fuzzy techniques. In the fuzzy theory this values will be expressed by transforming them into fuzzy numbers.

The results expressed as fuzzy numbers can most exactly give us the ranges in which the measurable values should lie (the interval of trust in the result).

More than that, although the results clearly show the degree of uncertainty, the fuzzy techniques applied in the permanent power flow gives the interval in which the voltage in a determined node of the electric network will certainly lie.

The fuzzy techniques introduced in the calculations of the permanent power flow of the electric network help in making qualitative assessments regarding the satisfaction degree of the operating conditions of electric networks.

Fuzzy techniques allow dealing with uncertain operation data, by modeling uncertainty in the absence of any statistics and making an intuitive connection between algorithmic and numerical models.

By obtaining an interval for which we know the way results may vary, fuzzy techniques applied in the scheming of distribution electric network gives us the possibility to work with uncertain data. Fuzzy techniques can be used there where only linguistic descriptions are available.

The fuzzy theory opens a new outlook on the management of the electric networks, with following advantages:

- Methods of statement representation in a natural language;
- Modeling of uncertainties in absence of any statistic;
- Models of solving a lot of aims

VI. REFERENCES

[1] D Petricica, M.Eremia, C.Bulac - "Artificial inteligence for control and operation of electric distribution networks.Fuzzy Sets." , University of Bucharest, Faculty of Power Engineering,1998.

[2] K. Kauhaniemi - "Fuzzy models and techniques for the calculation of radial distribution networks" , Athena Power Tech Conference, 1993,APT IS-362,pp423-428.

[3] G.R.- Cespedes New method for the analysis of distribution networks , IEEE Transactions on Power Delivery, vol.5,No.1, January 1990,pp391-396.

[4] L.A. Zadeh -Fuzzy sets , Information and Control,8, pp 338-353, 1965

[5] A. Kaufmann, M.M. Gupta - Introduction to fuzzy arithmetic; Theory and Aplications, New York

[6] V.Miranda, M.A.C.C. Matos"Distribution system planning with techniques" CIRED 10th -,IEE Conference on

Electricity Distribution ,IEE Conference Publication No.305,paper 6.472 ,Brighton,UK,1989

VII. BIOGRAPHIES

Cristian Bogoi was born in Bucharest, Romania, on May 22,1972.He received his M.Sc. degree in electrical engineering from Politehnica University of Bucharest,Bucharest, Romnaia,1996.

At present he holds the Head of EMS/SCADA Department in National Power Grid Company .His research interests include electricity distribution and transmission networks, EMS/SCADA systems.