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THE NONLINEAR LOGIC THEORY APPLICATION FOR LIGHTNING SAFETY IN POWER ENGINEERING OBJECTS

A.M. Hashimov [1] H.B. Guliyev [2] F.L. Khidirov [2] R.B. Rustamov [1]

1. Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan
arif@physics.ab.az, r_rustamov@hotmail.com
2. Azerbaijan Research Institute of Energetics and Energy Design, Baku, Azerbaijan, huseyngulu@mail.ru

Abstract- As far as known the **l**ightning is a powerful natural electrostatic discharge produced during a thunderstorm, which is highly powerful source with a strong consequences for the nature and all features around. Lightning's abrupt electric discharge is accompanied by the emission of visible light and other forms of electromagnetic radiation. The electric current passing through the discharge channels rapidly heats and expands the air into plasma, producing acoustic shock waves (thunder) in the atmosphere.

It has been analyzed the lack of characteristics of tradition methods for assessment of lightning discharge parameters within the circumstance of the realistic information environment of raising of effectiveness for power supply objects. In the meantime, an application of nonlinear logic paradigm of the Soft Computing theory is substantiated. A possession function and their appropriate value of parameters within defined interval for term-majority of lightning parameters (the value of lightning current and front sharpness) are provided.

Keywords: Lightning Safety, Lightning Current, Lightning Front Sharpness, Nonlinear Majority, Possession Function.

I. INTRODUCTION

We are indicating natural impact of lightning. This impact required to be undertaken in power engineering. There is no doubt that it demands to develop appropriate approaches for safety options of lightning. Modern technology has used in wide areas of human life is a highly sensitive to such influences. For this reason it takes attention of researchers to implement a new subject for lightning processes to achieve a reliable safety systems for reduce of its impact.

One of the main factors influencing to the reliability of the power energy network system is the opening of the power energy transmission lines by lightning stroke. In the common condition of exploitation the quantity of openings by impact of Lightning stoke can reach of 30% even 50% than in case of automatic openings [1].

Up to date requirements in power energy reliability having priority in continues energy supply as well as development and improvement completely technology in this direction is going in rising way. An automatic repetitive connection (ARC) facilities operation does not meets today costumer's needs in the market when current breaks occur.

The methods used (power energy transmission line (PETL), transformer substation etc.) in lightning safety grade assessment do not provides consideration of all definite and indefinite factors (empirical and semi-empirical relation, electro geometrical developments, probability methods). There is opportunity to use the theory of probability and modern methods of mathematical statistic to develop model of assessment accountant problems of objects on lightning safety.

In many cases of theoretic and practical problems solution a parameters of lightning discharges (current amplitude, their sharpness etc.) are impossible to assess and consider for the reason of factors influencing to them as well as uncertainties. For instance, there is indication that the value of lightning current depends on the electrical charge collected in the clouds. The value of electrical charge mainly depends on condition of atmosphere, which creates problem accurately to consider dominating factors. For this reason, as supposed a best method of probability calculation cannot solve this problem [1]. Finally, the probability of consideration of unconsidered problems of lightning safety during design stage is being high.

Indication above issues demand to increase of accuracy assessment of lightning stroke safety of the engineering objects, safety equipment and the raising of efficiency their selection, the use a more modern mathematical technology.

In this case, nonlinear majority and nonlinear logic theory within the condition of uncertainties is being to be very actual. This paper approaches a general aspects of nonlinear theory application in lightning safety problems.

II. ANALYZING OF FACTORS AFFECTING TO NONLINEAR CHANGES OF LIGHTNING DISCHARGE PARAMETERS

Discharges between lightning clouds and Earth (objects) and characters and parameters of those discharges in point of view of safety aspect of engineering objects on the Earth are very important matter.

For the reason a small distance between local (mountainous and foothills areas) and frontal clods parameters of lightning discharges to Earth from those clods (current amplitude, sharpness of current impulse front, quantity of components, quantity of neutralized electrical charge of discharging, etc.) are different.

It is possible to fix the dependence of discharge current impulse of amplitude value and sharpness of front from the distance between cloud and Earth, clouds electrical charge and in case of discharging between cloud and object or Earth of the value of linking object with the Earth resistance (specific resistance of the soil).

In the lightning safety problem the link between lightning current amplitude with sharpness of impulse front is chartered by value of correlation coefficient. The direct measure based on the discharge current for the first component of lightning discharge of its amplitude and maximum sharpness front of correlation field is shown in Figure 1 [2].

As it seen from Figure 1 in the value of approximately 0-40 kA, within the maximum sharpness 0-20 kA/mks value of the filed we can consider correlation and estimate of probability characteristics. Out of this field, there is no any correlation between those quantities.

This can be explained with impact of nonlinear factors for the reason of influence numerical uncertainties to lightning quantities. In this uncertainty environment to create linear mathematical models is impossible.

An amount of lightning current is one of the factors affecting to the channel of wavelength resistance (Z_m). At the same time, an amount of wavelength resistance of lighting channel influencing to the value of current amplitude of object (I_{ob}) affecting by lightning struck. This dependence can be reflected as [2]:

$$I_{ob} = I_{R=0} \frac{Z_m}{Z_m + Z_{ekv}} \tag{1}$$

where, $I_{R=0}$ is the amplitude of bearer current of the object to the Earth through earthling and Z_{ekv} is equivalent resistance of the affected by lightning struck object.

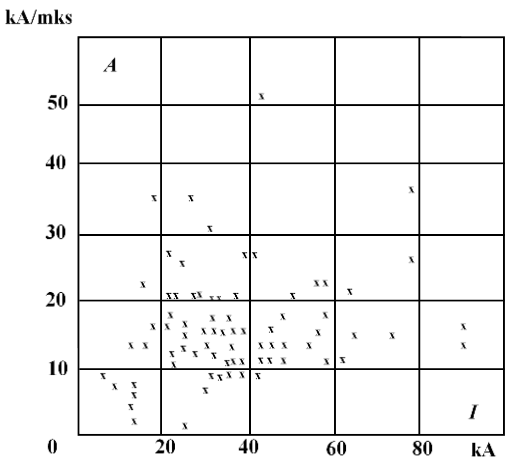

Figure 1. The amplitude of lightning current and maximum sharpness of correlation field

A quantities used in the Equation (1) cannot be defined due to the affects by nonlinear factors. As a result, amount of the current I_{ob} takes character of nonlinear. Therefore, there is a need to develop a new approach for enhancement of efficiency of safety of the engineering objects on the Earth from lightning. This comes to the stage of decision making in existing actual initial information environment.

III. APPLICATION OF NONLINEAR THEORY FOR ASSESSMENT OF LIGHTNING PARAMETERS

Taking into consideration above aspects it can be applied the theory of nonlinear majority and nonlinear logic of Soft Computing paradigm as modern mathematical technology for the assessment of lightning discharge characteristic parameters.

In the considered case, the lack of mathematical model or non-accuracy among lightning parameters of classic mathematic makes necessary of application of nonlinear theory. It can be demonstrated variety of dependences between lightning parameters as below:

$$\begin{aligned} I_{il} &= \tilde{f}\left(N_{dik,}q\right) \\ I_{ob} &= \tilde{f}\left(I_{R=0}, Z_m, Z_{ekv}\right) \\ P_0 &= \tilde{f}\left(N_{i,g}\right) \end{aligned} \tag{2}$$

where, q is value of electric demand, P_0 is density of lightning discharge on Earth surface of 1 km^2 per year, N_{ib} is lightning days and $\tilde{f}$ is nonlinear dependence.

The Equation (2) reflects nonlinear dependences and it is necessary to change into the linguistic variability in order to transfer to the nonlinear language. For instance, for the value of the lightning current amplitude a linguistic variability can be performed as below:

$$\forall I_i \; \langle I, \; T(I), \quad E, \; S, \; Q\rangle \tag{3}$$

where, I is the title of lightning current linguistic variability, $T(I)$ is the term-majority of the linguistic variability, $E, [0;1]$ is the interval given universal majority and $S, I, \; \forall I_i$ are the values of linguistic variability defined of syntaxes rule (contains condition and order parts) as well as sematic rule of transformation each new linguistic variability into nonlinear value. The I_i as nonlinear variability in meantime can be performed as:

$$\langle I_i, E, \; \tilde{U}_i\rangle, \; \forall i = \overline{1,n} \tag{4}$$

where, E is nonlinear variability quantity defining in the universal majority (lightning current), and $\tilde{U}_i$ is universal majority of I_i defining of limits of the non-linear sub-majority [3,4]:

$$\tilde{U}_i = \bigcup_{e \in E} \frac{\mu_{\tilde{U}(e)}}{e} \tag{5}$$

where $\mu_{\tilde{U}(e)}$ is possession function of nonlinear defined by sub-majority. For possession function, it is assumed $\mu_I(x): \; X \rightarrow [0;1]$. The possession function form is defined by depends of characteristics of its parameters.

The $T(I)$ is as a part of term-majority corresponding to the I_i as value for passion function with the picture of triangle all $\tilde{U}_i$ as nonlinear sub-majority can be analytically expressed as [4]:

$$\mu_I(x) = \begin{cases} 0, & x \le a \quad \text{and or} \quad x \ge c \\ \dfrac{x-a}{b-a}, & a < x \le b \\ \dfrac{c-x}{c-b} & b < x < c \end{cases} \tag{6}$$

where, (a,c) is bearer of nonlinear majority, x is pessimistic assessment of nonlinear variability and b is optimistic assessment of maximum coordinate-nonlinear variability.

It can be described as triangular of possession function in accordance with lightning current nonlinear variability of value $[4,9;28,6]$ kA [2] (Figure 2).

We can write the formula for term-majority defined in the lightning current of nonlinear variability $E_{1i},\ i=\overline{1,6}$ universe simoom:

$E_{11}=S$	(Small)	$\underline{\underline{\Delta}}(I,\mu_{11}(I))$
$E_{12}=M$	(Medium)	$\underline{\underline{\Delta}}(I,\mu_{12}(I))$
$E_{13}=SB$	(Slightly Big)	$\underline{\underline{\Delta}}(I,\mu_{13}(I))$
$E_{14}=B$	(Big)	$\underline{\underline{\Delta}}(I,\mu_{14}(I))$
$E_{15}=VB$	(Very Big)	$\underline{\underline{\Delta}}(I,\mu_{15}(I))$
$E_{16}=EB$	(Extremely Big)	$\underline{\underline{\Delta}}(I,\mu_{16}(I))$

We can perform for $T(I)$ term-majority using the Figure 2:
Small (S) is (0; 5) parameter with Z as picture of possession function;
Middle (M) is (0; 5; 10) parameter with triangle picture of possession function;
Slightly Big (SB) is (5; 10; 15) parameter with triangle picture of possession function;
Big (B) is (10; 15; 20) parameters with triangle picture of possession function;
Very Big (VB) is (15; 20; 25) parameter with triangle picture of possession function;
Extremely Big (EB) is (25; 27) parameter with S-picture of possession function.

The sharpness of lightning current for $A_{0,1}$ value within the interval $[1,7;14,1]$ for value [2] graphical picture of term-majority is presented in the form of trapeze:

$$\mu_{A_{0,1_1}}(x) = \begin{cases} 0, & x \le a \ ve\, ya \ x \ge d \\ \dfrac{x-a}{b-a}, & a < x \le b \\ \dfrac{d-x}{d-c} & b < x < d \end{cases} \tag{7}$$

where, (a, d) is bearer of nonlinear majority, and [b, c] is nucleus of nonlinear majority.
We can write the formula for term-majority defined within the $E_{2j},\ j=\overline{1,5}$ universe simoom of the lightning current nonlinear variability:

$E_{21}=VS$	(Very small)	$\underline{\underline{\Delta}}(A_{0,1},\mu_{21}(A_{0,1}))$
$E_{22}=S$	(Small)	$\underline{\underline{\Delta}}(A_{0,1},\mu_{22}(A_{0,1}))$
$E_{23}=M$	(Medium)	$\underline{\underline{\Delta}}(A_{0,1},\mu_{23}(A_{0,1}))$
$E_{24}=B$	(Big)	$\underline{\underline{\Delta}}(A_{0,1},\mu_{24}(A_{0,1}))$
$E_{25}=VB$	(Very big)	$\underline{\underline{\Delta}}(A_{0,1},\mu_{25}(A_{0,1}))$

It has been defined for term-majority of $A_{0,1}$ lightning current sharpness nonlinear variability $T(A_{0,1})$ based on Figure 3 as the following:

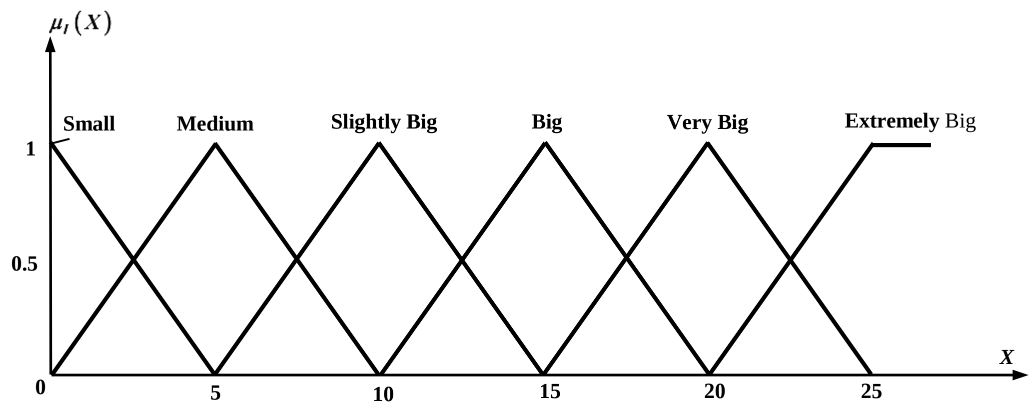

Figure 2. The term-majority of lightning current

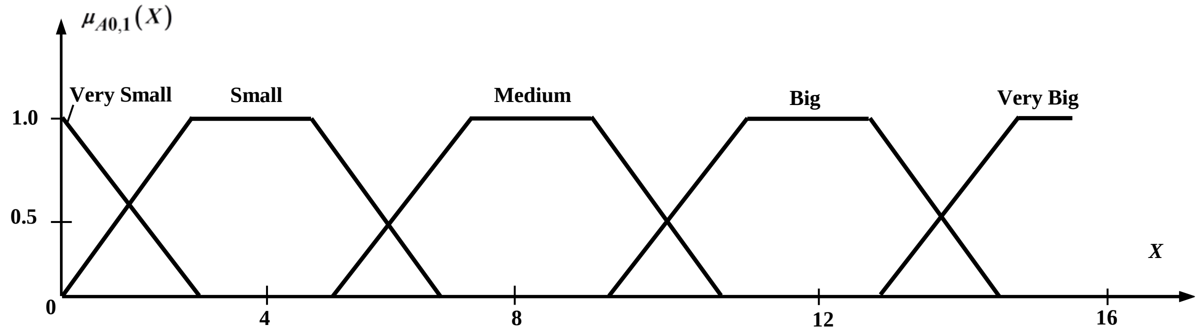

Figure 3. The term-majority of lightning current sharpness

Very Small (VS) is (0; 3) parameter with *Z* as picture of possession function;
Small (S) is (0; 3; 5; 7) parameter with trapeze picture of possession function;
Medium (M) is (5; 7; 9; 11) parameter with trapeze picture of possession function;
Big (B) is (9; 11; 13; 15) parameter with trapeze picture of possession function;
Very Big (VB) is (13; 15) parameter with *S*-picture of possession function.

The nonlinear majority and nonlinear logic theories can provide best results in case of numerous experimental information. This theory can interpreted, makes available easily to create models (linguistic model, model of relay, TSK model etc.); doesn't demand to develop accurate mathematical model and is tolerant to inaccuracy (robust).

IV. CONCLUSIONS

It has been analyzed a weaknesses of characters of the traditional methods for power engineering objects lightning safety efficiency and necessity of application of nonlinear logic paradigm is substantiated. It is provided possession functions for term-majority of lightning parameters (amplitude value of lightning and sharpness of front) and those examples by parameters.

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BIOGRAPHIES

Arif Mamed Hashimov was born in Shahbuz, Nakhchivan, Azerbaijan on September 28, 1949. He is a Professor of Power Engineering (1993); Chief Editor of Scientific Journal of "Power Engineering Problems" from 2000; Director of Institute of Physics of Azerbaijan National Academy of Sciences (Baku, Azerbaijan) from 2002 up to 2009; Academician from 2007; the First Vice-President of Azerbaijan National Academy of Sciences from 2007 up to 2013; and Director of Azerbaijan Research Institute of Energetics and Energy Design from 2014 till now. He is laureate of Azerbaijan State Prize (1978); Honored Scientist of Azerbaijan (2005); Cochairman of International Conferences on "Technical and Physical Problems of Power Engineering" (ICTPE) and Editor in Chief of International Journal on "Technical and Physical Problems of Engineering" (IJTPE). Now he is a High Consultant in "Azerenerji" JSC, Baku, Azerbaijan. His research areas are theory of non-linear electrical Networks with distributed parameters, neutral earthing and ferroresonant processes, alternative energy sources, high voltage physics and techniques, electrical physics. His publications are 290 articles and patents and 5 monographs.

Huseyngulu Bayram Guliyev received his M.Sc. and Ph.D. degrees and is a Lead Scientific Researcher, Manager of the Scientific Branch "Monitoring and Control of the Reactive Power" in Azerbaijan Research Institute of Energetics and Energy Design (Baku, Azerbaijan). Currently, he is an Associate Professor of Automation and Control Department in Azerbaijan Technical University (Baku, Azerbaijan). He has more than 110 published articles and 2 patents. His research interests are power systems operation and control, distributed generation systems, application of artificial intelligence to power systems control design and power quality.

Fakhraddin Latif Khidirov completed his high degree education in Electrical Networks and Systems at the Institute of Oil and Chemical, Baku, Azerbaijan in 1968. He is a Ph.D. of Technical Sciences has awarded by Moscow Institute of Energetic, Russia. Currently, he has been working as a senior researcher in the Research Laboratory of High Voltage in Power Engineering at Azerbaijan Research Institute of Energetics and Energy Design, Baku, Azerbaijan.

Rustam B. Rustamov was born in Ali Bayramli, Azerbaijan, on May 25, 1955. He is an independent expert on Space Science and Technology. In the past, he was in charging of the Azerbaijan National Aerospace Agency activities as an Acting Director General. He has mainly specialized in space instrumentation and remote sensing and GIS technology. He has graduated Ph.D. at the Russian Physical-Technical Institute, S. Petersburg, Russia. He was invited for the work at the European Space Agency within the Framework of the United Nations Program on Space Applications at the European Space Research and Technology Center, The Netherlands. He has appointed for the United Nations Office for Outer Space Affairs Action Teams (member, Vienna, Austria), United Nations Economical and Social Commission for Asia and the Pacific (national focal point, Thailand), International Astronautically Federation (Federation's contact, France), Resent Advances in Space Technologies International Conference Program Committee (member, Turkey). He is an author of 11 books published by the European and United States famous publishers and more than 100 scientific papers.