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A View Mathematical Analysis of Reliability of Power System Considering RLS Parameters in Fuzzy Logic Space

R.N. Yadav, G.P. Chhalotra, R.K. Tiwari, Rajesh Khattri

***Abstract*—Beside all Engineering Systems Elect. Power System are merely subjected to uncertain failures. The electrical parameters of power system are also responsible for the losses, thermal breakdown and failure rates. The effect of 'R' 'L' and 'C' in failure rates of power system components can be simulated using fuzzy linguistic variables. 'RLC' power system may be lower low medium, higher and high, these. Fuzzy linguistic variables may be used to evaluate the failure rates of lower, low medium, higher and high values.**

The reciprocal of failure rates of different components will give the MTBF's of those components, along with its membership function or fuzzy grade of truths. The cardinality and relative cardinality of components may be evaluated. Assuming relative cardinality as an average reliability of the system its reliability may be investigate. Fuzzy relations may be used for analyzing the reliability attributes of power system. The optimized reliable condition may be evaluated.

***Index Terms*—Magnetic Perability, MTBF, MTTF**

I. INTRODUCTION

Electrical power system consists of generating substation (sending end), transmission line and primary and secondary receiving end substations. A compete diagram of a power system representing all the three phases becomes too complicated for a system of practical I size. It is much more practical to present a power system by means of simple symbols for each parameter (RLC). In power be represented by series impedances, to nominal- T and nominal - J respectively. Fig. 1 shows a short line and Fig.2 (a+b) presents the medium and long trans- mission lines.

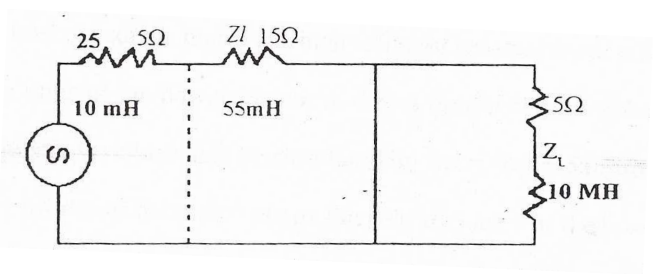
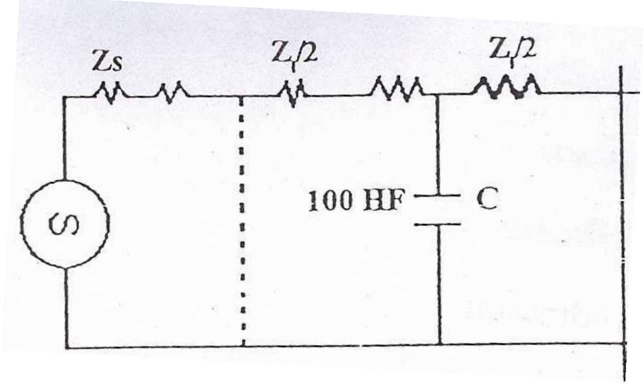


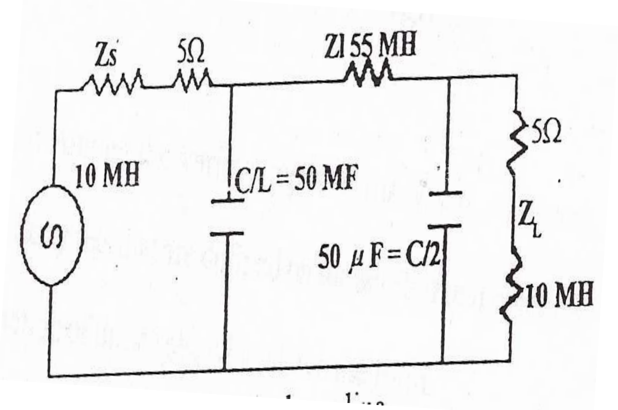
Fig-1: Short Transmission line (80 Km length)

The RCC parameter of transmission line is in lumped shaps and variation in RCC affects the regulation and effezievey oftJ1e supplied voltage to the consumer thus affects the reliability.



(a) Nominal- T line

Resistance of the power system is influenced by the ambient temperature, length of life nad area of cross section of the conductors. Higher the resistance higher will be the failure rates due to thermal losses.



(b) Nominal - π - line

Fig.2 Medium/Long line (160 Km and above) 0

Lower, medium, higher and high values of resistance will affect the failure rates of the power system in direct proportionally. These fuzzy linguistic variables may be simulated by fuzzy-logic. Similarly inductance influences the supply voltage thus the adequacy of the power system Adequacy is a parameter of reliability and varies in direct proportion Higher the inductance lower will be adequacy and

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Dr. R.N. Yadav, Director, Grade Scientist & Head, Research Development Centre, Regional Research Laboratory, Advanced Materials and Process Research Institute, Govt. of India, Bhopal(M.P.), India

Dr. G.P. Chhalotra, Professor, Department of Electrical Engineering (Retired), Govt. Engineering College, Jabalpur (M.P.), India

Dr. R.K. Tiwari, Director, TIT-MBA College, Bhopal(M.P.), India

Rajesh Khattri, Research Scholar, RGPV Technical University, Bhopal (M.P.), India, (e-mail: khattri.bpl@gmail.com).

thus reliability of power system. The inductance affects the reliability of power system in inverse proportion. Similarly capacitance increases the adequacy there by reliability of power system proportionally. The low, lower, medium, higher and high values of resistances, inductances and capacitances of power system which includes the source impedance lord impedance the line impedances influxes the disability of power system as these parameters are varying in nature and depends in many factors as temperature, humidity, mechanical strength, length/cross section of conductors, line voltage currents, conductor materials etc.

II. SIMULATION OF RLC PARAMETER IN FUZZY LOGIC

Fuzzy Numbers: Among the various types of fuzzy sets, of special significance are fuzzy sets that are defined on the set R of real numbers.

Membership functions of these sets, which have the form:

$$A: R\ [0, 1] \qquad \ldots\ldots\ldots\ldots..(i)$$

Clearly have a quantitative meaning and may, under certain conditions, be viewed as fuzzy numbers or fuzzy variables. To view them in this way, they should capture intuitive conceptions of approximate number or interval of real number Such .concepts are essential for characterizing states of fuzzy variables and consequently, play an important role in many applications including fuzzy decision making, optimization, and statistics with imprecise probabilities.

Although the triangular and trapezoidal shapes of member-ship functions are used most often for representing fuzzy numbers, other shapes may be preferable in some applications. The following theorem shows that membership function MA(x) of fuzzy numbers may be, in general, piecewise - defined functions.

Let A ^ E (R), Then A ^ is fuzzy number if and only if there exists a closed interval $[a,b] \neq \phi$ such that:

$$\mu A(x) = \begin{Bmatrix} 1 & for\ XE\ (a,b) \\ l(x)\ for\ XE(-\infty,a) \\ \gamma(x)\ for\ XE(b,\infty) \end{Bmatrix} \qquad \ldots\ldots\ldots.2$$

Linguistic Variables: The concept of a fuzzy number plays central role in formulating quantitative fuzzy variables. These are variables, hose states are fuzzy numbers. When, in addition, the fuzzy numbers represent linguistic concepts, such as low, lower, medium, higher and high, an so on, as interpreted in a particular context, the resulting constructs are usually called linguistic variables.

Each linguistic variable the states of which are expressed by linguistic terms interpreted as specific fuzzy numbers is defined in terms of base variables, th~ values of which are real numbers within a specific range. A base variable is a variable in the classical sense, exemplified by a physical variable i.e. here RLC parameters of power system in a linguistic variable, and linguistic terms representing approximate values fuzzy numbers.

As example of a linguistic variable -is shown in Fig. 03. Its name is power system parameters RLC, it is characterized by five basic linguistic terms low, lower, medium, higher high. Each of the basic linguistic terms is assigned one of give fuzzy numbers. The fuzzy numbers whose membership functions have the usual trapecoidal shapes are defined on the interval (0125-2) for resistance, (0,75MH) for inductance and (0,100MF) for capacitance. The characters for RLC are as below:

Low	=	RL,	LL	CI,
Lower	=	R LW,	LLW	CLW
Medium	=	RM	LM	CM
Higher	=	Rhr	Lhr	Chr
High	=	RH	LH	CH

Where RLC parameters consists of source impedance, line impedance and the load impedances.

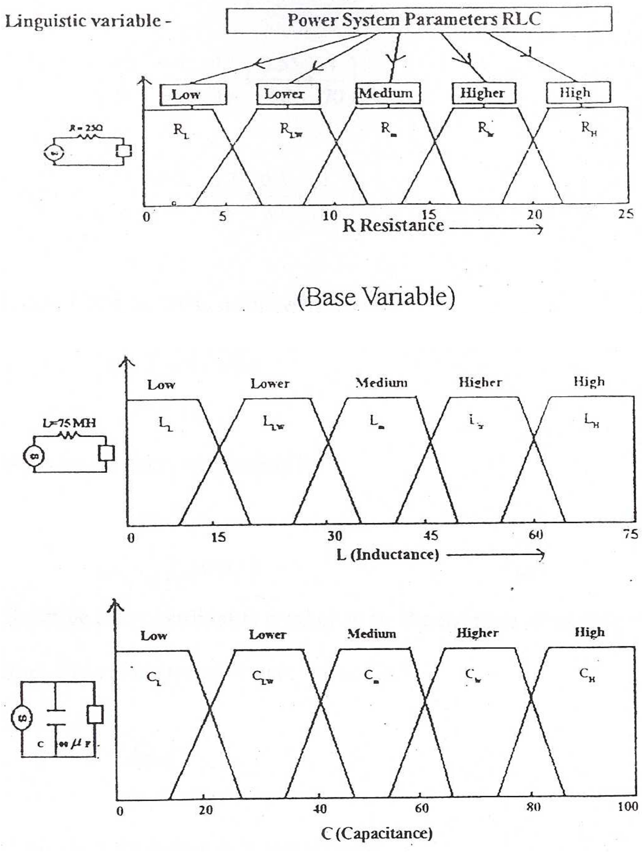


Fig. 3 Linguistic Variable of RLC Parameters

From fig. 3 the fuzzy sets for RLC parameters may be written as below:

$$Set\ R = \left(\frac{0.65}{4} + \frac{0.5}{10} + \frac{0.4}{16} + \frac{0.5}{20} + \frac{1}{24} \right)$$

$$Set\ L = \left(\frac{0.2}{20} + \frac{0.4}{32} + \frac{0.5}{45} + \frac{0.55}{58} + \frac{1}{70} \right)$$

$$Set\ C = \left(\frac{0.1}{25} + \frac{0.7}{45} + \frac{0.3}{65} + \frac{0.5}{80} + \frac{1}{100} \right) \qquad \ldots\ldots..(4)$$

Fuzzy cardinality is defined:

$$|A| = \sum_{i=1}^{n} \mu A(x)\, d(x) \qquad ....5$$

And Relative fuzzy cardinality by:

$$|A| = \frac{1}{n} \sum_{i=1}^{n} \mu A(x)\, dx \qquad ....6$$

If Relative fuzzy cardinality is taken to be the average reliability then failure rate of fuzzy parameter is defined by:

$$\lambda = -n \,||\, A \,|| \qquad ....7$$

And MTBF's for failure rate λ is give by:

$$MTBF = \frac{1}{\lambda} \qquad ....8$$

Using egn (5), (6), (7) and (8) the fuzzy cardinality relative cardinality, failure rate and MTBF due to power system RLC parameter may be calculated as below. Fuzzy cardinality of resistance is

$$|R| = \sum_{i-1}^{As} \mu_R(x)\, dx$$

$$= 0.65 + 05 + 0.4 + 0.5 + 1$$

$$= 3.05$$

Failure rate of power system due to resistance parameter

$$\lambda = -In\,|R|$$

$$= -In\, 0.61$$

$$= 40.4743$$

MTBF of power system considering resistance parameter failure:

$$MTBF = \frac{1}{\lambda} = \frac{1}{0.4943}$$

$$= 2.023 \; years$$

Similarly cardinality of inductance is 2.65 relative cardinality is 0.53 failure rate to inductance is 0.6348 and MTBF is 1.575 years.

The cardinality of capacitance is 2.6 relative cardinality (average reliability) is 0.52 failure rate due to capacitance is 0.64 and MTBF is 1.529 years.

III. FUZZY RELATIONS AND SIMULATION OF RLC PARAMETERS FOR OPTIMUM RELIABILITY OF POWER SYSTEM

In power system the RLC parameters are presented by vectors. The Rand L in power system is related in series and same current flows through it 'C' parameter is related in parallel and same voltage is appeared across it. The fuzzy sets of RLC shown in equation (4) are used for finding fuzzy relations between them.

Fuzzy relations map elements of one universe, say X, to those of another universe, Say Y, through the cartesian product of the two universes. However the strength of the relation between ordered pairs of the two universes is measured with a membership function (fuzzy grade of truth) expressing various degrees of strength of the relation on the unit interval (0, 1). Hence a fuzzy relation R is a mapping from the Cartesian space X XY to the interval (0, 1) where the strength of the mapping is -expressed by the membership function of the relation for ordered pairs from the two universes or $\mu_R(x,y)$.

The cardinality of capacitance is 2.6 relative cardinality (average reliability) is 0.52 failure rate due to capacitance is 0.654 and MTBF is 1.529 years.

The Cartesian product defined by A x B = R is implemented in the same fashion as is the cross product of two vectors. Each of the fuzzy sets could be thought of as a vector of membership values, each value is associated with a particular element in each set.

IV. FUZZY COMPOSITION

Fuzzy composition can be defined as below. Let R is a fuzzy relation on the Cartesian space X x Y, S is a fuzzy relation on YXZ, then fuzzy max-min composition is defined in terms of the set- theoretic notation and membership function theoretic notation in the following manner.

$$T = R \; o \; S$$

$$\mu_\tau(x,y) = \vee_{yes} \left(\mu_R(x,y) \wedge \mu_s(y,z)\right) \qquad 13$$

Considering equation (4) the fuzzy relations of RLC parameters of power system can be evaluated. Firstly fuzzy relation of RL parameters is evaluated using equation (12) such that

RL=RxL

$$RL = \begin{array}{c|ccccc} & 20 & 32 & 45 & 58 & 70 \\ \hline 4 & 0.2 & 0.4 & 0.5 & 0.55 & 0.65 \\ 10 & 0.2 & 0.4 & 0.5 & 0.5 & 0.5 \\ 16 & 0.2 & 0.4 & 0.5 & 0.4 & 0.4 \\ 20 & 0.2 & 0.4 & 0.5 & 0.5 & 0.5 \\ 24 & 0.2 & 0.4 & 0.5 & 0.55 & 1 \end{array}$$

Using equation (12) relation between LC parameter may evaluate such that:

RC = RL o LC

$$LC=\begin{array}{c|ccccc} & 25 & 45 & 65 & 80 & 100 \\ \hline 20 & 0.1 & 0.2 & 0.2 & 0.2 & 0.2 \\ 32 & 0.1 & 0.4 & 0.3 & 0.4 & 0.4 \\ 45 & 0.1 & 0.5 & 0.3 & 0.5 & 0.5 \\ 58 & 0.1 & 0.55 & 0.3 & 0.5 & 0.55 \\ 70 & 0.1 & 0.7 & 0.3 & 0.5 & 1 \end{array}$$

………………………..(15)

Using equation (13) the composition of RL & LC can be evaluated which will give us the fuzzy relation between RC parameters.

RC = RL o LC

$$RC=\begin{array}{c|ccccc} & 25 & 45 & 65 & 80 & 100 \\ \hline 4 & 0.1 & 0.55 & 0.2 & 0.5 & 0.65 \\ 10 & 0.1 & 0.5 & 0.3 & 0.5 & 0.5 \\ 16 & 0.1 & 0.4 & 0.3 & 0.4 & 0.4 \\ 20 & 0.1 & 0.5 & 0.3 & 0.5 & 0.5 \\ 24 & 0.1 & 0.55 & 0.3 & 0.5 & 1 \end{array}$$

……………..16

For example μ_{RC} (RL, LC)= μ_{RC}(24, 45)= max [min (0.2,0,2), min (0.4,0,4), min (0.5,0,5), min (0.55,0.55), min (1,0.1)]

The μRC (24, 45) is obtained by applying max-Olin operation similar as the matrix operation in matrix equation 14 & equation 15. The first row of RL matrix (see. dash line in matrix equation 14) is operated with first column of LC matrix (see dash line in matrix equation 15) to obtain the element common to first row and first column RC matrix applying showing this operation is given for membership function of RC matrix common to fifth row 100 second column i.e μ_{RC} (24, 45) obtained by operating fifth row of Re matrix with second column of LC matrix.

From equation 14 the element μ_{RC} (10.32) = 0.4 can explained as the fuzzy grade of truth of fuzzy' relation between set R and Set L such that for resistance of Ion and inductance of 3 2 mH, the membership function of their fuzzy relations would be 0.4 for this relation being reliable operation of power system.

Similarly for μ_{RC} (24.45) = 0.55 can be explained as the fuzzy membership function of fuzzy relation of resistance of 24D and capacitance of 45 μF is 0.55.

Lf the fuzzy relations of given fuzzy sets is

$$\begin{bmatrix} \mu 11 & \mu 21 & \mu 31 & \mu 41 & \mu 51 \\ \mu 12 & \mu 23 & \mu 32 & \mu 42 & \mu 52 \\ \mu 13 & \mu 23 & \mu 33 & \mu 43 & \mu 53 \\ \mu 14 & \mu 24 & \mu 34 & \mu 44 & \mu 54 \\ \mu 15 & \mu 25 & \mu 35 & \mu 45 & \mu 55 \end{bmatrix} \quad ....17$$

The fuzzy cardinality of 25 elements can be written as –

$$=\sum \mu_{ij}$$

$$=\sum(\mu 11+\mu 12-\mu 21+\mu 22-\mu 31+\mu 32- \quad ......18$$
$$\mu 41+\mu 42-\mu 51+\mu 55$$

Fuzzy cardinality of 25 elements of fuzzy relation of RL parameter is:

$$=0.2\ x\ 5+0.4x8+0.5x8+0.55x2+0.65+1$$
$$=1+3.2+4+1.1+0.65+1$$
$$=10.95$$

Relative Cardinality = 1/25 x 10.95 = 0.438
(Average reliability)
Failure rate ‘λ’ = -In 0.438 = 0.8255
And MTBF = 1/λ = 1-211 years
Cardinality of 254 elements of LC parameters.
= 0.1x 5+0.2x4+0.3x4+0.4x3+ 0.5 x 5+0.55 x 2 + 0.7 +1
= 0.5+1.5+1.2+4.0+1.1+0.65+1
= 9.95
Relative Cardinality= 1/25 x 9.95 = 0.398
Failure rate λ = - In 0.398 = 0.921
MTBFs = 1.08 years

In the above calculation we can see that the RL and RC parameter relations have MTBF’s more than 1 year but the LC parameter relation is more serene and have MTBF’s les than1 year.

The result of the above reliability calculations for individual R.L and C parameters and for fuzzy relations of RL, LC and RC parameter are shown in table 1.

S. No	Parameters of power system	Failure rate	MTBF’s
1.	Resistance ‘R’	0.4943	2.023 years
2.	Inductance ‘L’	0.6348	1.575 years
3.	Capacitance ‘C’	0.654	1.529 years
4.	Resistance – Inductance ‘RL’	0.8255	1.211 years
5.	Inductance-Capacitance ‘LC’	1.08	0.9788 years
6.	Resistance-Capacitance ‘RL’	0.921	1.08 years

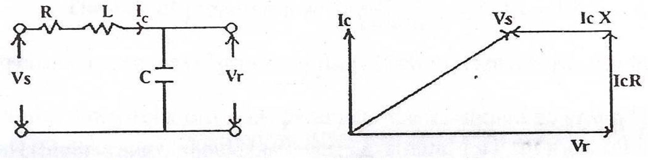
The three basic elements of electrical engineering are resistor, inductor and capacitor. The resistance consumes ohmic or dissipative energy whereas the inductor and capacitor store in the positive half· cycle and give away in the negative half cycle of supply the magnetic field and electric field energies respectively.

In an electric power system it is difficult to predict the load variation accurately. The load devices may vary from a few watt night lamps to multi-megawatt induction motors. Active power 'p' and reactive power Q both increases as the square of voltage magnitude. Also with increasing frequency the active power 'P' decreases whereas Q increases.

The need for ensuring a high degree of service reliability in the operation of modem power system is most urgent. The supply should not only be reliable but should be of good quality. Transposition of conductors keeps the system balanced, voltage drops of different magnitude in conductor is-due to unequal inductances in three phases.

The physical· significance of surge impedance in long transmission line i.e. for lossless line the surge impedance $\sum = \sqrt{LIC}$ very important because surge impedance loading (SIL) of a line is the power transmitted when the line is terminated through a resistance equal to surge impedance. The approximate value of surge impedance for overhead line is 400 Ω . The phase angle of Zc for transmission lines is usually between 00and 150. Higher the value of capacitance lower will be the value of surge impedance. In present power system the value of capacitance is taken to be very high hence the proposed line for LC combination (see table]) is most unreliable and full of risk. Zc affects the incident and reflected voltage of transmission line.

When a long line is operating under no load or light load condition the receiving end voltage is greater than the sending end voltage. This is known as farranti-effect. The simple explanation of farranti-effect can be given by approximating the distributed parameters of the line by lumped impedance as shown in fig.4 since usually the capacitive reactance of line is quite large as compared to the inductive reactance under no load or lightly loaded condition, the current is of leading p. f.



(a) Line under on load condition (b) Phase or Diagram of lime

The charging current products drop in the reactance of the line which is in phase opposition to the receiving end voltage and hence the sending end voltage becomes smaller than the receiving end voltage the present line has higher Rand L which courses higher drop due to charging current and reduces the sending and voltage. The farranti- effect can also be explained on the basis of net reactive power on line. It is known that if the reactive power generated at a point is more than the reactive absorbed, the voltage at that point becomes higher than the normal value and vice versa The inductive reactance of the line is a sink for the reactive power whereas the shunt capacitances generate reactive power. It fact if the line loading corresponds to the surge impedance loading (SIL), the voltage is same everywhere as the reactive power absorbed then equals the generated by the line. The SIL therefore gives definite meaning to the terms lightly loaded or lightly loaded lines. If the loading is less than SIL, the reactive power generated is more than absorbed; therefore the receiving end voltage is greater than the sending end voltage.

The SIL of proposed line is $\sqrt{\frac{75*10^{-3}}{100*10^{-3}}}$ which is very small and hence the LC parameter fuzzy relation is not reliable, for more reliable fuzzy relation of LC parameter the 'C should be around mH (higher) and C should be lowest i.e. around 1μF for most reliable condition. For the given high value of capacitance (around 100μF) the higher reactive power is generated but the reactive power absorbing element ‘L’ has of very low value (75 mH) which causes additional reactive power to generate resulting in farranti-effect which reduces the reliability of power system fig. 3 shows that for each of L = 160mH and C = 1 μF the fuzzy grade of truth is ‘I’ hence system is highly reliable.

V. DISCUSSION

Reference 1 and 2 have explained the representation of power system by a single line diagram assuming R,. Land C as a lumped parameters. Reference 3 and 4 has provided us the guidelines to simulate the behavior of power system with varying nature of parameters. The resistance value of power system has been represented by the fuzzy linguistic variables and a set for the 'R' parameter in fuzzy space is generated similarly set L and set C for inductance and capacitor have been developed.

The cardinality and relative cardinality of individual R, Land C parameters are evaluated and assuming relative cardinality to be equal to average reliability the failure rates and thereby MTBF's have been found (Reference 5 to 10).

The fuzzy relations between RL, LC, and RC parameter are worked out using fuzzy relations of fuzzy sets. The relation has been observed to be unreliable for its present power plant parameters and same conclusions are carried out to find the 'L' and" 'C' value of transmission for its surge impedance loading (Reference 11 to 14).

The effect of R, L, C, R L, L C and RC parameters are worked out and discussed. The failure rates arid MTBF's of the above parameters are evaluated and optimized for the reliable SIL loading of transmission line.

REFERENCES

[1] Wadhwa C. L “Electrical Power Systems" Book New age in ternational (P) Ltd. publisher 1996.

[2] Nagrath 1.J. & D.P. Kothan : Modern Power System Analysis" Book Tata McGraw Hill publishing Company Ltd. New Delhi 1991.

[3] Timothy J. Ross “Fuzzy Logic with Engineering Applications"' University of New Maxico McGraw Hill Inc.1995.

[4] George. Klir and Bo Yuan "Fuzzy sets and Fuzzy Logic Theory and Applications" PHI Pv1. Ltd. New Delhi 2001 .

[5] Mishra M.K. , G.P. Chhalotra, R.S. Mahajan, MF Qureshi “A study of Reliability attributes of underground Electrical power planning and Distribution" proceeding of all India seminar on power systems recent advances and prospects in 21 century.

[6] Mishra M.K., G.P. Chhalotra, R.S. Mahajan, M.F. Qureshi "A certaining Safety and Reliability Attributes of Electricity uses in underground coal mines - A fuzzy logic approach" International. Sysposium on mine planning and Equipment Selection" New Delhi India 2001.

[7] Endenyl. J. "Reliability Modelling in Electrical Power System" John Wiley & Sons, New York, 1973

[8] Bondi A.A. “Rdiability as a material property "Joumel of Engineering materials and Technology AMSE, Vol-l 0 I PP 24-32,

[9] Bit A.K., MP Biswal and S.S. Alam “Fuzzy programming approach to multicriteria decision making transposition problem" Fuzzy Sets and Systems, North Holland, PP 135-141. 1992.
[10] Chhalotra G P., M. Balakrishnan & A.C. Rao "Simulation of reliability indices of power systems by transient model using transformation method" Modelling Simulation & control, AMSE France, Vol-26, NO.1, 1990.
[11] Zadeh L A. --Fuzzy Sets "Information control Vol-18, 1965.
[12] Qureshi M. F . 'Reliability Evaluation of Generating System" ME. Thesis. Ram Durgavati University Jabalpur (India), 1998.
[13] Mlshra R. B. and A.K. Azad “Generating System reliability evolution - Joint PDF approach IE (I) Journal of IE Nov; ·1996.