Development of Electrical Power System Reliability Based on System Parameters and Fuzzy Control

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

Abstract**—**Static reliability and dynamic reliability are based on electrical power system parameters. The dual network can work as deadbeat controller for the objective network the mechanical parameters are always coupled, with electrical parameters and they cannot be separated. One can use the Fuzzy logic theory to deal with electrical parameters coupled with mechanical parameters in calculation the reliability and costly depends on electrical built in reliability or material reliability and costly depends on electrical resistively P, Permittivity. (ε r) and magnetic permeability (μ_r). These specific (D) and represent R,C,L, parameters in macroscopic models, of electrical power system. System parameters are too many and one can take help of thermal conductivity, enthalpy, melting point specific heat capacity, adhesivity, compatibility, hardness, tensile strength, Fatigue Creep, Cracks, brittles and fracture.'). 1hese are all Fuzzy Parameters. The parameters represent MTBF and MTTF of the systems.

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

I. Introduction

Reliability can be controlled by proper control of parameters In Fuzzy space. The Fuzzy logic control can be used in a number of ways. The parameters can be fuzzfied and Fuzzy systems are obtained to work as controllers. Dual networks always work as Fuzzy logic 'deadbeat controllers. Such type of work is interesting for researchers and field engineers to thing about the reliability attributes. Such problems· are attempted by. Bondi, Dasgupta. Bit and Chhalotra but they have solved qualitative problems. Here one may find a qualitative as well as quantitative analysis and solid results on normal power systems working in the utility of the society and connected on the notional grid.

II. System Parameters and Fuzzy Logic

Electrical power systems are made with magnetic circuits, dielectric materials, conductor, insulators and other materials· of mechanical strength. The system parameters must obey Hook's law and Ohm's laws to keep the system lineae the linear system are easily controllable. System parameters can be classified as RLC. Resistance inductance and capacitance one more parameters is the Q-factor, quality of the coils or the condensers. This is mostly defined as the loss tangent in the coils condensers.

Where there is an electrical force, there must -be a mechanical force the analogues of R,L,e, are damper inertia ~nd -spring actions in the systems.One has to consider aft the parameters of electrical systems. The Fuzzy logic set theory can provide a solution of large and complicated problems which are yet pending to solve due to no methods available. Fuzzy set theory is simple to include any element in a system. The power system has an equivalent circuit using. RLC parameters but mechanical parameters have no place in these circuits.

One may' make a Fuzzy set using the Force - voltage analogy (F - V Analogy) for mechanical systems and electrical systems.

A Fuzzy Set F(x); nay be: Space - I

Fuzzy element		$\mu A(x)$	λ	λR	sec	T	A
Force	F	.779	.249	.1945	.805	4.016	.766
Velocity	V	.886	.121036	.1072	.892	8.26	.866
Displacement	X	.768	.264	.2027	.7972	3.78	.752
Mass	M	.912	.0921	.084	.915	10.85	.896
Damping Coefficient	D	0.812	.2082	.1691	.830	4.803	.796
Compliance	K	.926	.0768	.0712	.9288	13.02	.918
Voltage	V	0.896	.1098	.0984	9016	9.107	.886
Current	I	.936	.0661	.06206	.938	15.128	.923
Charge	V	0.918	.0855	.0785	.9214	11.696	.899
Inductance	L	.866	.14386	.1246	.8754	6.951	.833
Resistance	R	.859	.1528	.1305	.8694	6.541	.836
Capacitance	C	.936	.06613	.06206	.938	15.12	.926

The Fuzzy set of failure rates and life data are assumed highly uncertain. These are Fuzzified using Fuzzy membership function μ (A), wh.ere A is a subject of the Fuzzy set Z. One can use a number of methods of defuzzification. One of them is the Fuzzy cardinality and relative Fuzzy cardinality of the Fuzzy grades of truth.

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$$|\bar{A}| = fuzzy\_cardinality = \int_{1}^{\mu} \mu\bar{A}(\lambda), d\lambda = 10.494.........(i)$$

$$and |A| = Relative\_Fuzzy\_Coordinating = 0.8745$$

The MOM and COA may yield ……………..(ii)

$$\mu_{MOM} = 0.796, \mu_{COA} = 0.8569$$

Spacej – II (f-V) analogues

Fuzzy		$\mu_A(\lambda)$	λ	λR	Sec	T	A	M
f	V	.786	.2408	.1892	.8107	4.152	.766	.819
u	i	.889	.1176	.1046	.8954	8.503	.876	.88892
x	Q	.912	.0921	.084	.916	10.857	.896	.927
M	L	.938	.064	.06	.9399	15.625	.916	.941
D	R	.796	.2281	.1816	.8184	4.384	.786	.886
K	C	.899	.10647	.0957	.9042	9.392	.889	.916

Mechanical parameters of a power system are analogous of electrical parameters, in space - II. The cardinalities of the set would be 5.22 and relative cardinality O.87.at the failure rate $\lambda = .1392603$ and MTBF #7.18. The MoM (mean of moments) and CoA (centre of area) method may yield Fuzzy grades of truth .866 and 0.889. The analogue parameters also work with electrical parameters simultaneously.

Space -III (f - i) analogues (Inverse Analogy)

Fuzzy		$\mu_A(\lambda)$	λ	λR	Sec	T	A	M
f	i	.912	.0921	.084	.9169	10.85	.896	.926
u	V	.926	.0768	.07119	.928	13.02	.916	.936
x	q	.886	.121036	.10723	.89276	8.262	.866	.898
M	c	.792	.2332	.1847	.8153	4.288	.788	.809
D	G	.936	.06613	0.61906	.938	15.14	.916	.952
K	L	.898	.10758	.0966	.9033	9.2954	886	.912

The Space - III yields a cardinality 5.35 and reliability R = 0.8916 at Fuzzy failure rate λ = .1146614 and MTBF = 8.7213269 years. The average of cardinality, MOM and COA Fuzzy· grades of truth may yield a reliability.

$$R_{av} = \quad 886 at\ failure rat\ \lambda_{av} = 1021036$$

III. FORCE VOLTAGE ANALOGY AND FUZZY SET OF PARAMETERS

The twelve parameters in the Space - I are Fuzzy as they very randomly and uncertainly in the unbalanced conditions or over loading periods. The set is a mixture of electrical and mechanical parameters and they are connected by Electro - mechanism energy conversion. One may write down a Fuzzy equation in the time of non-linear working of the electrical power system.

$$La\frac{d_{ia}}{dt} + Ral'a + \frac{1}{Ca}\left[\int_0^t Cadt + g(a)\right] = va.................3$$

$$C_b\frac{dv_a}{dt} + C_bV_b + \frac{1}{L_b}\left[\int_0^t V_bdt + f_b(0)\right] = i_b$$

Fuzzy logic can permit work in the non-linear conditions provided adaptive controllers are connected with Fuzzy controllers Fig 1(a) and Fig (b) are the two Fuzzy networks that can be represented by Fuzzy grades of truth. The Fuzzy control is made by switching a series Fuzzy circuit to a parallel Fuzzy circuit and vice-versa.

The reliability is obtained through the Fuzzy set of failure rates λ_1.

$$f(\lambda) \quad = (\lambda_1, \lambda_2, \lambda_3......................\lambda_\lambda)................(4)$$

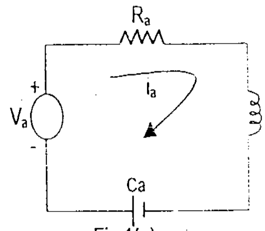


Fig 1(a)

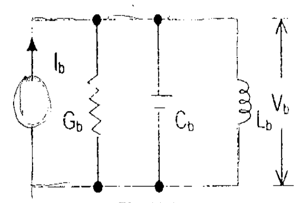


Fig 1(b)

Fig 1(a) and Fig 1 (b) are the Dual networks and work as Fuzzy logic controllers any power system can be reduced to a series circuit of fig 1 (a) or Fig 1 (b) to obtain a Voltage or current sources.

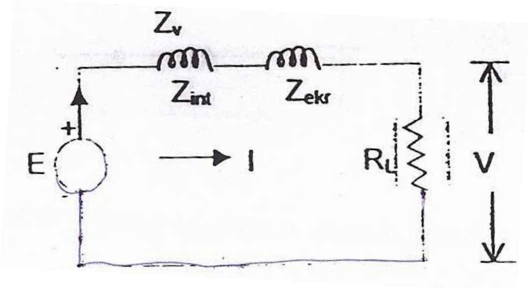
Fuzzy	$\mu_A(\lambda)$	λ	λR	Sec	T	M	A
Ia	.916	.0916	.0803	.9196	11.402	.927	.908
Va	.923	.0801	.074	.926	12.48	.936	.916
Ra	.889	.1176	.1046	.8954	8.503	.892	.876
La	.886	.121036	.1072	.8927	8.262	.788	.866
Ca	.796	.2281	0.1816	.8184	4.384	.916	.788
Fuzzy	$\mu_A(\lambda)$	λ	λR	Sec	T	M	A
I_b	.936	.066	.0619	.938	15.15	.926	.926
G_b	.892	.11428	.10194	.898	8.75	.912	.886
C_b	.796	.2281	.1816	.8184	4.384	.812	.788
L_b	.886	.121036	.10723	89276	8.262	.912	.867
V_b	.886	.1438	0.1246	.8184	6.954	.876	.858

The entire Fuzzy universe of discourse look alike but there is difference between failure rates. The two circuits are Fuzzy controller of each other. The joint circuit has a Fuzzy cardinality 8.786 and Reliability .8786. The MoM and CoA method may yield an average reliability Rav = .866 at failure rate .1438

The maintainability is availability may also be controlled by dual Fuzzy controllers.

IV. FUZZY LOGIC CONTROL: A DUAL SYSTEM

The Fuzzy logic controllers are smooth and accurate for reliability parameters. The reliability deviates from a given level of the standards. One can calculate the transfer function of a large power system and can be reduced to equivalent series or parallel network. It is found that the circuit may be reduced to a circuit given in Fig 1 (c)

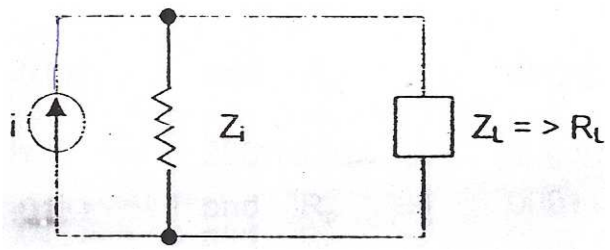


Equivalent Circuit of a power system Voltage Source If one wish to calculate the reliability of a particular element then, the venin's equivalent circuit will be preferred.

Space - IV (a)
The parameters may be assumed as follows

Fuzzy	$\mu_A(\lambda)$	λ	λR	Sec	T	A	M
Active	.912	.0921	.084	.916	10.857	.896	.923
Passive	.896	.1098	.0984	.9016	9.107	.886	.912
Unilateral	.779	.2497	.1945	.8054	4.0048	.866	.812
Bilateral	.886	.1438	.1246	.8754	6.954	.846	.866
Non-linear	.892	.1142	0.10194	.898	8.756	.882	.912
Lumped	.779	.2497	.1945	.8054	4.0048	.762	.812
distributed	.962	.387	.0372	.96273	25.84	.936	.932

The Fuzzy cardinality of a parameter may be 6972 and R = 8715.



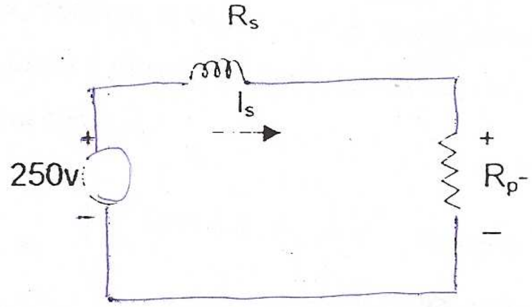
(Dual of Voltage Source A current Source)

The reliability of a circuit may be controlled by the dual networks If they are Fuzzy logic systems. The types of system parameters given In the space IV(a) and their Fuzzy logic membership functions are tabulated. No one parameter as Fuzzified in the table IV (a) for the networks of Fig 1 (a), Fig 1(b) and Fig 1(c}.

Let us represent internal resistance of a practical source by Rs and the resistance of the external power system by Rp. If the Rp is greater by several orders of magnitude than Rs under any set of the operating conditions, the source behaves much like an ideal voltage source. Similarly when the Internal distance -Rs of the practical source under any set operating conditions is much greater than the resistance of the power system by several orders of magnitudes, the source behaves much like an ideal current source.

The load resistance may vary from zero to infinity and the source will work its own dual for extreme conditions. The reliability will change accordingly.

The two types of sources need not be necessarily different types of machines but it is the behavior of the source which can enable; one to convert one dual to other dual circuit to take work of a deadbeat controller, for reliability control.



$$if \quad Rs \Rightarrow .01\Omega \quad and\ Rp \Rightarrow 10\Omega then:$$
$$is \quad \Rightarrow 250/10.01 \Rightarrow 24.975A ....(5)$$
$$if \quad Rs \Rightarrow .01\Omega \quad and\ Rp \Rightarrow .0001\Omega then:$$
$$is \quad \Rightarrow 250/(10.0001)$$
$$\Rightarrow 250/.0101 \quad \Rightarrow 250\,A$$

Thus the reliability of current source may be more than the voltage source. The voltage source may be switched to current source to obtain a dual the network. This process is used to convent an objective to Fuzzy logic deadbeat controller.

V. Mechanical Fuzzy System and Duals

A Fuzzy logic controller for a mechanical system representing shaft torque of motors or generators to control velocity and torque may be represented 1>Y fizzy equations as follows:

$$M\frac{du}{dt} = Du + \frac{1}{k}\left(\int_0^t u dt + f \times (0)\right) \quad = f\,(Transnational\ system)$$
$$f + f_M + f_0 + f_k \quad = \quad 0............................(6)$$

For any power system, the algebraic sum of externally applied forces and the forces resisting motion in any given direction is zero 0lle may call it the 0' Alembert's principle. One can obtain a Fuzzy equation for a rotational me mechanical system:

$$l_Q \frac{d\omega}{Dt} = DuW + \frac{1}{k_{14}}\left(\int_0^t \omega dt + f \times (0)\right) \quad = Torque = T$$
$$(Rotational\ system)$$
$$T + T_1 + T_D + T_k \quad = \quad 0............................(7)$$

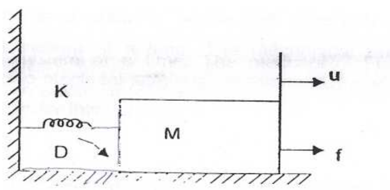
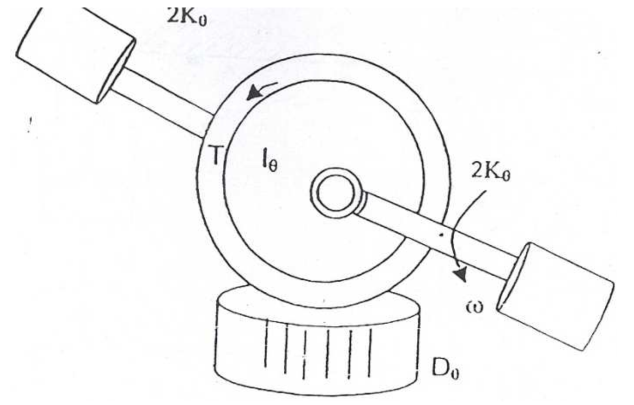


Fig2 (a): Fuzzy controller of Rotational system



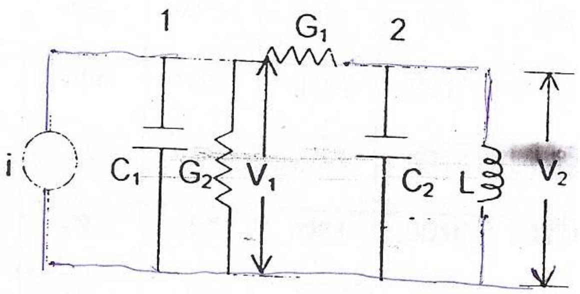


Fig 4 (b): f-I analogs (Dual network of f-v system - Fuzzy logic controller)

The translational system is a dual of the rotational system and works as Fuzzy logic control in the power system. The translational system is analogous to series R,LC network while rotational one is a parallel circuit working under electric current as a current source.

AU generators, motors, and mechanical drives have eiectro mechanical parameter coupling which is a Fuzzy space. One can calculate the reliability as a whole or in the part. One can use the electrical or mechanical system at a time. The mechanical Fuzzy 'system can be transformed to electrical side and vice-versa. One will need an appropriate transformation for this purpose.

VI. A Two Co-ordinate Mechanical System and Electrical Equivalent Circuits for Reliability

Most often used mechanical system in the electrical power system is a two co-ordinate mechanical system for Fuzzy logic systems. It is represented in Fig-3.

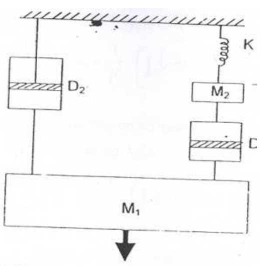


Fig3: A two co-ordinate mechanical system

One can simulate an electrical Fuzzy network using F-v analogy in Fig 4(a) fig 4 (b) for the F-I analogy.

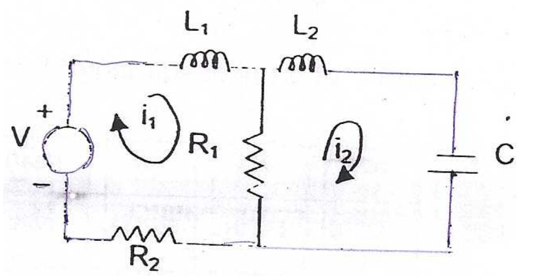


Fig-4(a): f-v analogs (Dual network of f-is system-Fuzzy logic controller)

Fig 3 may be represented by an equation to Fuzzy if in a set theory:

$$-Du_1M_2\frac{du_2}{dt}=Du_2+\frac{1}{k}\left(\int_0^t u_2dt+x_2(0)\right)\quad =0 \qquad (8)$$

The equation is transformed to two fuzzy logic networks shown in Fig 4(a) and Fig 4 (b) and the equations would be:

$$-R_1i_1L_2\frac{di_2}{dt}=R_1i_2+\frac{1}{C}\left(\int_0^t i_2dt+q_2(0)\right)\quad =0 \qquad (9)$$

$$-G_1v_1+C_2\frac{dv_2}{dt}=G_1v_2+\frac{1}{L}\left(\int_0^t v_2dt+\phi_2(0)\right)=0$$

These two dual networks can control each other and may be called the deadbeat Fuzzy logic controllers.

One can Fuzzy the networks of Fig 4 (a) and Fig 4 (b) in two modes And hyper space in table V space –V

Fuzzy	$\mu_A(\lambda)$	λ	λR	Sec	T	M	A
V	.886	.121036	.10723	.89276	8.262	.876	.892
Li	.916	.0877	.08036	.9196	11.402 5	.892	.927
C_1	.866	.1438	.1246	.8754	6.954	.833	.879
R_2	.912	.09211	.084	.916	10.856	.896	.923
R1	.896	.10981	.0984	.9016	9.1066	.866	.916
L_2	.918	.0855	.0785	.9214	11.696	.899	.927
C_2	.896	.1098	.0984	.9016	9.10746	876	918
C	.892	.11428	.10194	.898	8.75	886	918

Fuzzy	$\mu_A(\lambda)$	λ	λR	Sec	T	M	A
I	.926	.0768	.07119	.9288	13.0208	.913	.932
C_1	.928	.0747	.06934	.9306	13.386	.908	.947
G_2	.908	.0965	.08763	.91236	10.362	.898	.917
V_1	.896	.1098	.0984	.9016	9.1074	.886	.906
G_1	.886	.121036	.10723	.89276	8.262	.866	.897
C_2	.876	.1323	.116	.884	7.558	.872	.889
L	.866	.1438	.1246	.8754	6.954	.852	.873
V_2	.792	.2332	.1846	.8153	4.288	768	.803

The Sixteen elements make a Fuzzy cardinality |A| = 14.26 and R=e-xt = .89125, λ= .1151288 and MTBF = 8.686. The MoM and CoA methods may be used to find similar results. The average reliability would be Rav = .8692. The two systems are coupled and control one another as being the duals of one another.

VII. FUZZY CONTROL

A PID controller may be a series R, LC network or the parallel circuit of RLC working as the dual of the first. The dual parameter itself may be a controller. For example the capacitive reactance can neutralize the inductive rectangle when the two are connected ·in severs, One can ·call then the deadbeat controllers for each other element or parameter Thus a Dual circuit deadbeat Fuzzy logic controller can monitor the reliability well and accurately. The Fuzzy logic deadbeat controllers have following properties and characteristics.

Space -VI

Fuzzy	μA(λ)	λ	λR	Sec	T	A	M
Fuzzy logic deadbeat controller is a PID controller modified	.896	.10981	.0984	.9016	.91066	.886	.912
One can change the gain of the controller so that all the poles and zeros of the system are brought t to Zero	.886	.121036	.107238	.89276	.8262	.867	.892
The transfer function I of the controller is just inverse to the transfer. I function of the system I under control	.912	.092114	.084	.916	908	926	
The controllability index and obserability index are dual to each other and very small values. K=1 or K=2. K, number of strikes to bring poles to origin	916	.11428	.10194	898	892	887	
The RLC parameters of dedbeat controller are represented in Fuzzy grades of truth in place' of per unit values	.926	.07688	.07119	.9288	130072	912	937
The deadbeat errors of the system control. The errors in controller are negative direction as compared to the errors of system.	916	.08773	.08036	.9196	11.398	.908	
A power system entire work is simulated in Fuzzy systems	.866 .844	.14386	.1146	.8754	6.9512	.889	
The Fuzzy controller is the dual of the system under process:	932	.07042	.0656	.93436	14.2075	.913	.946
The process of control is simulated in Fuzzy set and its complementary function to make union and intersection of the two.	.928	.07472	.06934	.9306	13.383	.918	.932
The Fuzzy entropy is monitored· at every moment by the ratio of the intersection to the union	.911	.09321	.08491	.91508	10.728	.906	.921
Any dual network may work as a Fuzzy logic deadbeat controller.	.962 .	.03814	.03726	.96273	25:813	.932	.971
One can make an inverse analogy of the system to form a Fuzzy logic deadbeat controllers of the reliability:	.896.889	.1098	.0984	9016	9.10746	.889	.916
A control of the errors, deterioration and failure rate is a control attributes.	.887	.1199	.10636	.8936	8.34	877	896
The conductance can control a resistance I change, R by G, grade of Fuzzy truth.	.866	.1246	.1438	.8754	6.9541	836	889
The inductive reactance XL can control a capacitive Xc and reactance Vice-versa and are controllable.	.936	.06613	.061906	3809	15.12	.916	.942
The voltage may be controlled by a current and vice-versa. Every dual is used to control the objectives:	876	.13238	.11597	.884	7.554	866	.886
One can make a constraint to control an objective to a breakeven point	.962	.03874	.0371	.96273	25.813	942	.968
All duals con be made as constraint of the given objective one can plot them with the Fuzzy variable λ and its Fuzzy grades to truth μ□(λ)	.889	.1176	.1046	.8954	8.503	.876	.892

What is a fuzzy logic controller? It controls the errors and rate of change of errors. The errors have grades of truth. The rate of change of errors also has Fuzzy grades of truth. It controls Fuzzy grades of truth between 0 to 1	.936	.06613	.0619	.938	15.1217	.913	.948
Moreover mild, medium harsh and severe errors are mutually coupled. Positive small (PS) positive large (PL) zero. (ZE) and' NS (Negative, Small) negative large (NL) can be mutually coupled. It can work in large. Number modes.	.918	.0855	.0785	.9214	11.696	.908	.926
Do you understand Fuzzy logic deadbeat controller for reliability yes, The constraint is a controller. It may be inverse of the objective. It may be dual. It may be inverse I analogue. It IS I connected in series.	.892	.11428	.1024	.898	8.75	889	.906
the errors In the objective are positive while errors· In the constraint are negative, I and they are cancelled I instantaneously.	.918	.0855	.0785	.9214	11.69	.906	.923
I Fig 5(A) Fig 5(B} and i Fig 5(c} stand for control of reliability. in a Fuzzy' universe of discourse. A constrain is a controller. It is a dual, complementary inverse and deadbeat controller.	.926	0.387	.03726	.96273	25.83	.936	.972

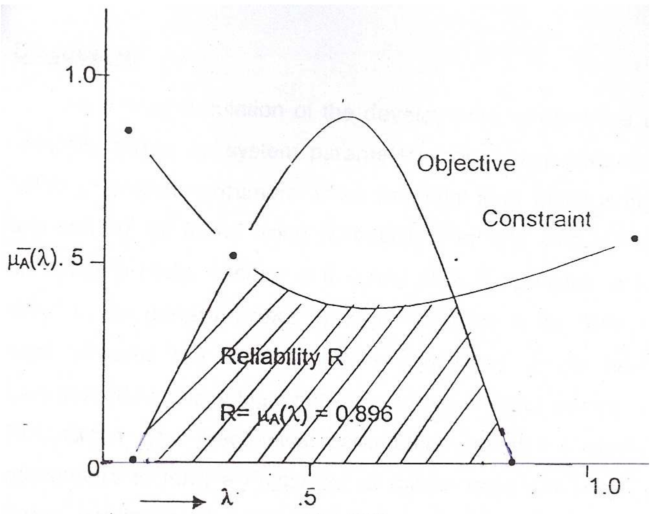


Fig 5(A)

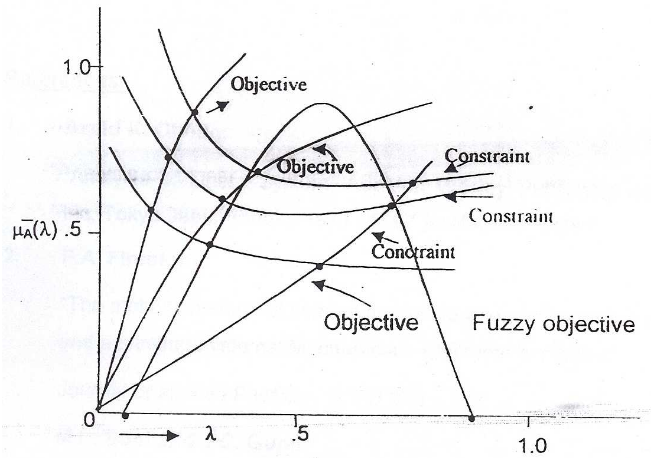


Fig 5 (b)

VIII. Discussion

A formal simulation of the development of electrical power system reliability based on system parameters and Fuzzy control is made. The failure rate of the parameter is an essential item which is highly uncertain anc:i cannot be found using probability methods. Fuzzy logic techniques are used to make attempt to find any clue pf reliability. It is a simulation work on the general power systems available in the MPEB Bhopal. The dual networks are used as Fuzzy controllers. Entire network may be transformed to Fuzzy logic networks to get a better control. PID control is RLC circuit. The mechanical parameters are also mixed with electrical pameters to form a Fuzzy set of failure rates. The reliability may be a Fuzzy cardinality. It may be solved using MoM and CoA methods of defuzzification. Reliability is Fuzzy grade of truth is a large random spaces.

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