CLASSIFICATION of FAULTS and THEIR CAUSES in ELECTRIC MOTORS BY USING FUZZY CLASSIFICATION METHODS

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Abstract : In this study, D.C. Motor Fuzzy Fault Cause Classifier (DCMFFCC) process which is one of the effective and important decision-making in recent years by making use of fuzzy logic trechnics. This study aims at diasgnosing possiblre fault and their causes by applying the developed system to the D.C. Motors. Developed original fuzzy classification system by using Fuzzy Logic Control (FLC) and fuzzy classification principles, classfies three faults and one normal working status in the motors when they are active. With this approach, motor in question can work more effective and safetier.

Keywords : fuzzy logic, fuzzy classification, fuzzy logic control, membership functions.

1.Introduction

Fuzzy Logic is based on multi-valued logic that was introduced by A.L. Zadeh in 1960^s for fiest time(1). First applications were apply to the process control by Mamdani (2). Fuzzy logic is an important technic to get rid of weakness of classic logic and it is a science which has been developed rapidly. Since classic logic uses binary logic, it is not accepted by human thought (3).Our present technology mostly covers classical approach, that's why human-based thought systems were not able to realise as much as fuzzy logic.Basicly, fuzzy theory is a mathematic science. Mainly it covers human thinking style.ç With fuzzy sets based on linguistic variables, it is possible to get rid of weakness of conventional logic(4). Espically studying on PID systems mainly get classical logic. That's why required optimisations can not be done as it should be (5). In this phase, fuzzy apprtoach is very important. System.which has human charecters like " little, .nore or less or like " acquires an effective decision making period (6). Fuzzy logic has been used effectively and has been developed for over 20 years. Most of the problems are solved by means of classification and recognation by fuzzy logic. We gain optimal approaches for solving problems(7). Our studying covers fuzzy logic and the principles of fuzzy classifications. For this reason , developed and classified fuzzy process bases on electric motors. That's why, study was based on a d.c. motor as a model. The most popular four positions will be recognised with their causes. Classification process is designed by makig use of fuzzy methods. D.C. Motor Fuzzy Fault Cause Classifier (DCMFFCC) was designed originally as FLC. The details are presented below.

2. D.C. Motor Fuzzy Fault Cause Classifier

Fuzzy classification is a technique which considers elements and individuals depending on fuzzy basis and λ-cut values. By using this technique, elements can be classified depending on the relation among them(8). The Figure 1 below shows that developed fuzzy classifier was applied to an electric motor(9). DCMFFCC has two parts as it is shown(figure2). The first part shows all functions of the typical FLC(10). λ-cut has been produced from this part(11). So mentioned cut value is given to the place which will classify the final part. By this way, the working conditions of the motor are determined. This kind of original theoric structure will be concretised on example motor given below.

2.1. Fuzzy Logic Controller

Working and parametric values of Sample D.C. Motor are shown below (12).

$W = 97$ rad/s ; $V = 230$ V ; $I = 27$ A ; $M_Y = 50$ Nt ;
$V_f = 60$ V ; $R_f = 12\Omega$; $L_f = 30$H ; $K_f = 0.366$;
$R_a = 2\Omega$; $L_a = 10$mH ; $J = 0.0125$ kgm^2 ; $B = 0$;

Motor working values(W,I,V,M_Y) are nominal working values. There are four fuzzy sets for single input depends on speed(W). Membership functions belong to fuzzy sets in question are shown below.

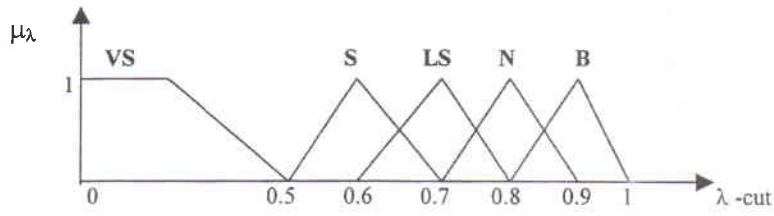

Figure 4. λ -cut Membership Functions

For the classifier, decision making table which belongs to FLC is formed as shown below.

Table 1. DCMFFCC Decision Making Table

If W = Z Then λ -cut = S
If W = L Then λ -cut = LS
If W = N Then λ -cut = N
If W = B Then λ -cut = B

2.2. Fuzzy Fault – Cause Classifier

According to experiences for the classifier, fuzzy elements(15) are chosen. Classes to form include the needed element according to cause of faults. Mentioned 15 elements consist of speed, current, voltage and special circuit conditions with coils. In other words, if we look at these elements, we can comment about the behaviour of the motor. However Current and voltage are not inputs of FLC, they refer to speed as fuzzy sets(Z,L,N,B). This situation is shown below clearly.

Table 2. The Fuzzy Values of peed,Current,Voltage and Special Conditions

	Z	L	N	B
Speed	1	2	3	4
Current	5	6	7	8
Voltage	9	10	11	12
Other Conditions = X_1 , X_2 , X_3				

X_1 = *The situations of pressing or contactness in* brushes and bearings

X_2 = The short-circuit situation of shunt or series Winding

X_3 = The short-circuit situation on armature coils or between slices of collector.

For Table 2, it is necessary to form fuzzy relations among fifteen elements. The table included this relation is shown below (Table 3)(13).

When table 3 is examined diagonally, we can see the form of symmetrical condition. After all preperation phase, it can be passed to apply DCMFFCC system to the motor.

Sample motor reaches its nominal working values(w,i) at about 3.75s(12). Developed the fuzzy classifier system is designed to analyse conditions in motor after 3.75s.

The effects of DCMFFCC was searched with helping Win Matlab 4.0. Generally load and voltage values are considered to watch the behaviour of different problems of the motor. Concerned load and voltage for different values by increasing or decreasing, fault and their causes are watched by means of classifications.

Table 3. Fuzzy Relations Among Speed, Current, Voltage and Special Conditions

w,1,v	1	2	3	4	5	6	7	8	9	10	11	12	X_1	X_2	X_3
1	1	0	0	0	0.54	0.36	0.2	0.53	0.7	0.1	0.73	0.55	0.65	0.58	0.57
2	0	1	0	0	0.1	0.67	0.2	0.83	0.1	0.81	0.58	0.68	0.53	0.69	0.75
3	0	0	1	0	0.79	0.79	0.89	0.69	0	0.2		0.78	0	0.79	0
4	0	0	0	1	0	0.9	0.77	0.67	0.58	0.3	0.55	0.98	0.1	0.9	0.65
5	0.54	0.1	0.79	0	1	0	0	0	0.58	0.28	0.56	0.81	0	0	0
6	0.36	0.67	0.79	0.9	0	1	0	0	0.56	0.69	0.57	0.96	0.25	0.95	0
7	0.2	0.2	0.89	0.77	0	0	1	0	0	0.68		0.74	0	0.72	0
8	0.53	0.83	0.69	0.67	0	0	0	1	0.56	0.76	0.58	0.67	0.54	0.64	0.75
9	0.7	0.1	0	0.58	0.58	0.56	0	0.56	1	0	0.66	0	0.66	0.57	0
10	0.1	0.81	0.2	0.3	0.28	0.69	0.68	0.76	0	1	0	0	0.56	0.82	0.75
11	0.73	0.58		0.55	0.56	0.57		0.58	0.66	0	1	0	0.66	0	0.35
12	0.55	0.68	0.78	0.98	0.81	0.96	0.74	0.67	0	0	0	1	0	0.95	0.65
X_1	0.65	0.53	0	0.1	0	0.25	0	0.54	0.66	0.56	0.66	0	1	0	0
X_2	0.58	0.69	0.79	0.9	0	0.95	0.72	0.64	0.57	0.82	0	0.95	0	1	0
X_3	0.57	0.75	0	0.65	0	0	0	0.75	0.5	0.75	0.35	0.65	0	0	1

3. Conclusion

After mentioned principles of DCMFFCC are applied to the motor, then four different meaningful classifications are observed for four different λ -cut value. In other words, for each λ -cut, a different classification was formed. These are shown below.

λ -cut > = 0.6 ; λ -cut > = 0.7 ; λ -cut > = 0.8 ;
λ -cut > = 0.9

According to the fuzzy relations in Table 3, we can get four different fuzzy classes. Depending on each λ -cut value, there is only one meaningful class. The list is below.

Table 4. Classes for Different λ -cut Values

λ -cut	Classes
> = 0.6 [0.6 – 0.7)	1, 9 , 11 , X_1
> = 0.7 [0.7 – 8)	2, 8 , 10 , X_3
> = 0.8 [0.8 – 9)	3, 7
> = 0.9 [0.9 – 1]	4, 6 , 12 , X_2

When the data is examined, four classes (A,B,C,D) which cover possible faults and their causes will be seen depending on fuzzy relations among speed, current and voltage. These are like below.

A{1, 9, 11, X_1} ; B{2, 8, 10, X_3} ;
C{3, 7} ; D{4, 6, 12, X_2}

According to the fuzzy design, concerned classes form under circumstances below :

A Class, is formed when motor speed is **Zero** ;
B Class, is formed when motor speed is **Low** ;
C Class, is formed when motor speed is **Nominal** ;
D Class, is formed when motor speed is **Big** ;

The developed fuzzy classifier classifies totally four conditions and three of them are faults and also there is a normal working condition. On the other hand, in fact, four classes which are observed are faced often in the motor. The most popular of these causes are below.(14).

a - Motor does not work
b – Motor does not reach its normal speed or always work in low speed
c – Motor works normally
d – Motor speed is too high

When results are examined, there is a relation between classes and causes like
(a-A, b-B, c-C, d-D). In other words it can be seen clearly that causes of (a,b,c,d) are in the realized fuzzy classifier system(A,B,C,D).

Finally, the developed Fuzzy Fault-Cause Classifier (DCMFFCC) for d.c. motors in the study can be classified the most common three faults and one normal working condition with possible causes. However If the fuzzy relations matrix is designed bigger, it is possible that more complicated conditions can be classified too.

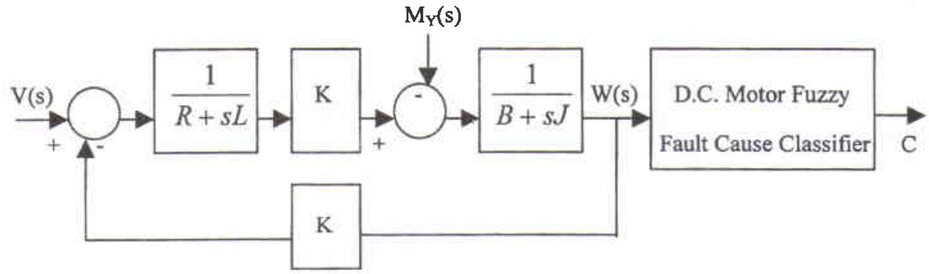

Figure 1. Fuzzy D.C. Motor Status Classifier

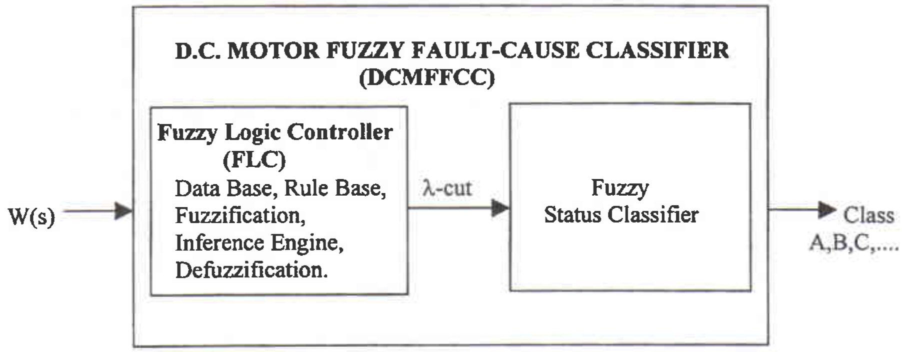

Figure 2. D.C. Motor Fuzzy Fault – Cause Classifier

Zero = **Z** = {1/0,0.8/10,0.5/20,0.2/30,0/40}
Low = **L** = {0/0,0.2/10,0.4/20,0.7/30,1/35,0.79/40, 0.75/50,0.7/60,0.5/70,0.2/80,0/90}

N = Normal = {0/40,0.35/50,0.5/60,0.8/70,0.85/80, 0.9/90,1/95,1/100,0.7/105,0/110}
Big = **B** = {0/95,0.1/100,0.25/105,0.35/110,0.5/120, 0.7/130,0.85/140,0.95/150,1/160}

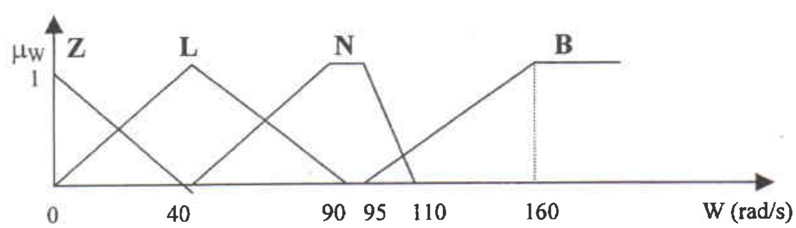

Figure 3. Speed Membership Functions

Membership functions whose λ-cut are fixed as below. They are formed out of FLC.

VS = Very Small ; **S** = Small ; **LS** = Little Small ; N = Normall ; **B** = Big

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