FUZZY BASED PERMANENT MAGNET CONTACTOR DESIGN, OPTIMIZATION AND CONTROL

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Abstract - ***This paper presents the propose method of a permanent-magnet (PM) actuator and an intelligent control module for the coupled PM contactor. The original propose parameters of the PM actuator are obtained using magnetic circuit method. The model for the PM actuator is solved by Fuzzy logic. A enthusiastic control technique based on voltage feedback is predictable to recognize the intelligent dynamic adjustment of the manufacture process for the PM contactor. The electromagnetic force calculation model, the dynamic making model of the iron core and contact, the buffering model for the iron core, and the contact bounce model are all built using MATLAB.The simulation method and the effectiveness of the feedback control technique to decrease the closing velocities of both the movable contact and the moving iron core that, in turn, will reduce the first and the second contact bounces extensively to lengthen the life span of the device.***

Key Words: dynamic optimization design, intelligent control, intelligent control module, permanent magnet (PM) contactor ,fuzzy logic.

1. INTRODUCTION

In resent years, contactors have been broadly used in many industrial applications for manufacture and flouting the load current with the use of their contacts. No matter what ac or dc electromagnetic contactors are used. A great amount electric energy will be dissipated by these contactors. As the energy problem impacts the people life is rising, attempting to find a new type of contactor with exceptional energy saving performance is dedicated to more and more attention. For a conventional ac electromagnetic (EM) contactor, both the armature and the fixed iron core generally need to be hold by electromagnetic force during holding process.

Therefore, several significant disadvantages, such that consumes lots of energy to hold the armature, produces noise at lower voltage and their coils are easy to be burnt due to continual working state. To overcome above mentioned disadvantages of the conventional ac EM contactor, the recently developed actuator is increasingly applied in the development of the permanent magnet (PM) contactor.

As a result of several exceptional benefits with the PM contactor, such as energy saving, no noise pollution, and no voltage-sags dropouts, the progress related to new type of permanent magnet has attracted many researchers 'attention [1- 4]. Most of the past researching work is focused on the conventional EM contactor, such that making use of the finite element method to analysis the response of the magnetic coupling field [5-8], reduces the average bounce-duration after contacts closing [9-16], and so forth. However, little information is available on the development of new PM contactor. Intelligent control strategies can often be implemented to improve both the performance and reliability of electromagnetic contactors. Most efforts on PM contactors are, in different to common electromagnetic contactors, focusing on the intelligent control devices with closing phase angle selection [17],intelligent control approach of displacement profile [18], and intelligent control strategy of flux weakening [19]. All these approaches are considered to develop the dynamic characteristic to prolong the electric lifetime of the contactors.

This paper reports the finding on the development of a fast dynamic simulation fuzzy logic and associated intelligent control methods to match the dynamic attraction force and anti forces so as to decrease the first and the second contact bounces during the making process.

This paper describes a propose algorithm to find the structural parameters of the contactors using the magnetic circuit method. The parameters are optimized using Fuzzy logic. The dynamic behavior and contact bounces of the contactor exploiting the proposed intelligent control strategy are simulated using MATLAB by combining the electromagnetic force calculation model, the making motion model of the iron core and contact, the buffering model for the iron core, and the contact bounce model. A PM actuator proto type designed and manufactured to verify the design algorithm which incorporates the proposed control strategy.

1.1 DESIGN OF PERMANENT MAGNET CONTACTOR:

a. contactor:

A **contactor** is an electrically controlled switch used for switching an electrical power circuit, related to a relay except with higher current ratings. A contactor is controlled by which has a much lower power level than the switched circuit. Contactor come on many forms with varying capacities and features. Unlike a circuit breaker, a contactor is not planned to interrupt a short circuit current. Contactors range from those having a breaking current of a number of amperes to thousands of amperes and 24 V DC to many kilovolts. The physical size of contactors ranges from a device small enough to pick up with one hand, to large devices approximately a meter (yard) on a side.Contactors are used to control electric motors, lighting, heating, capacitor banks,thermalevaporat ors, and other electrical loads.

b. design of permanent magnet contactor:

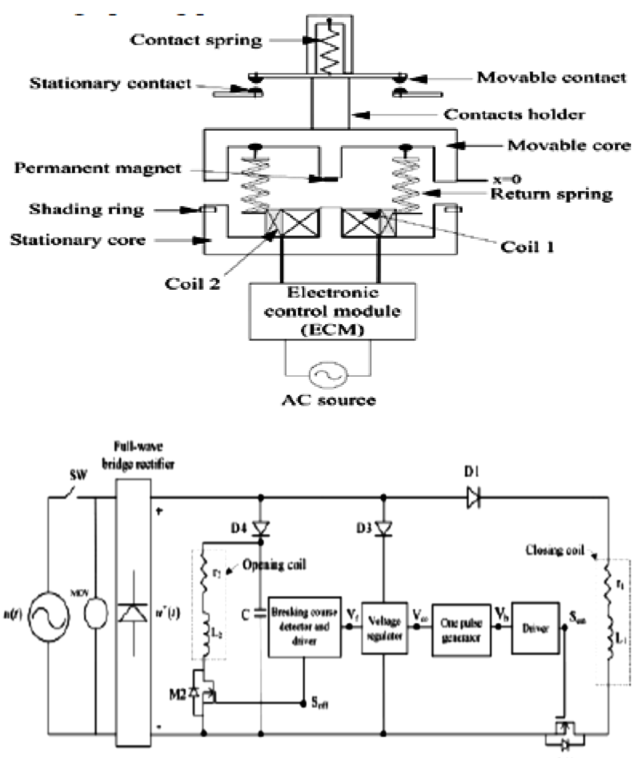

Fig.1. Two sketches related to PM contactor ,(a)mechanical structure (b) schematic block diagram of ECU

As can be shown in Fig. 1(a),the mechanism of thr proposed ac PM contactor includes three subsystems: such as electric system, magnetic energy-conversion system, and mechanical system. The magnetic energy-conversion system of the ac PM contactor consists of a permanent magnet, and it is set on the fixed E-type core, of course, it can also be arranged on armature as well [3].

This permanent magnet is prepared of Nd-Fe-B material; hence, its volume is small. additionally, to decrease the energy losses, all cores existed in the magnetic circuit are made of the ferromagnetic material. Fig. 1(a) depicts a new colenoid actuator that is built in the proposed ac PM contactor is controlled by an electronic control unit (ECU). The ECU is composed of simple digital and analog hardware contactor two sets of exciting coils, that is, closing coil $N1$ and opening coil $N2$. The closing coil is only driven by external ac voltage source, while the opening coil is driven by a breaking capacitor voltage. Fig. 1(b) shows the schematic block diagram of ECU. observably, the manufacture course and flouting course of this new ac PM contactor is controlled by an independent control circuit. In the following, According to the reference [3], in fact, no matter how the permanent magnet is approved on the armature or the fixed part of the magnetic circuit, the effect of the permanent-magnet force upon armature is near to equal. The total resultant force, which acts on armature, includes the gravitational force, friction force, and magnetic force. Since the normal line of system platform is commonly parallel with to the geometrical central line of contactor mechanism, as shown in Fig. 1(a), the gravitational force almost does not affect on the total resultant force; therefore, the final resultant force can be simply expressed as shown be

$$F=F_{mag}-F_f \qquad (1)$$

where $Fmag$ is thr magnetic force which consists of electromagnetic force and permanent-magnet force. F_f means the spring anti-force. In the closing process, Fmag is the addition of the electromagnetic force and permanent-magnet force and larger than the spring anti-force. In the holding process, Fmag is only corresponding to the permanent-magnet force, but the resultant magnetic force is still capable of overcoming the spring anti-force due to the great reduction of reluctance in the magnetic circuit. In the opening process, the electromagnetic force first counteracts the permanent-magnet force and the remaining magnetic force Fmag is then integrated with the spring antiforce , the armature is severed from the fixed part of the magnetic circuit as quickly as possible. As seen in Fig. 4, the equation governing the motion of

armature is often directly formulated from Newton's law of motion.
where *m* is the mass of armature and *x* is armature displacement.

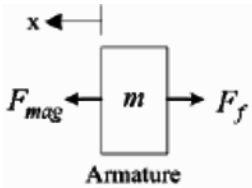

Fig. 2. Armature is viewed as a typical force-mass system.

1.2 FUZZY LOGIC :

Fuzzy set comprises from a membership function which could be defined by parameters. The value between 0 and 1 reveals a degree of membership to the fuzzy set. The method of convert the crisp input to a fuzzy value is called "fuzzification".The optput of fuzzifier module is interfaced with the rules. The basic process of Fuzzy Logic Controller (FLC) is constructed from fuzzy control rules utilizing the values of fuzzy sets in general for the error and the change of error and control action. The results are mutual to give a crisp output controlling the output variable and this process is called as "DEFUZZIFICATION".

The proposed fuzzy based Permement magent Contactor Design, Optimization and control method consists of fuzzy Vref and duty ratio thar produces optimum control by using Vref and Dutyratio. Fuzzy logic control rules are defined in Table 1 that produces output from fuzzy logic Vref and Dutyratio.

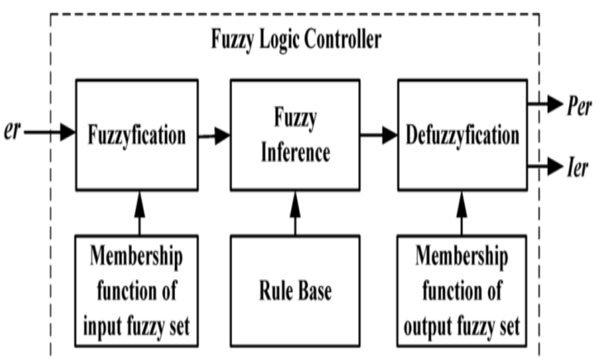

Fig. 3. Fuzzy basic model

Table-1: Rule Editor

1.If(Vref is BN) then (Dutyratio is BN)(1)
2.If(Vref is SN) then (Dutyratio is SN)(1)
3.If(Vref is Z) then (Dutyratio is Z)(1)
4.If(Vref is SP) then (Dutyratio is SP)(1)
5.If(Vref is BP) then (dutyratio is BP)(1)

(a). FIS Editor

The Fuzzy interface system editor has giving Vref is the Input and Dutyratio is the Output and the flatform type is mamdani .Linguistic terms for error are defined in Table 2.

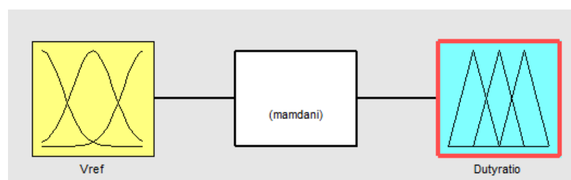

Fig. 4. Fis editor

Table-2: Linguistic variables

Linguistic Variable	Symbol
Big Negative	BN
Small Negative	SN
Zero	Z
Small Positive	SP
Big Positive	BP

2.GENETIC ALGORITHM:

The roulette wheel selection method is invoked first to prioritize the fitness of every individual within a population in the order from strong to weak.

In this paper the parameters of genetic algorithm number of variables used is 3,
Maximum number of Iterations used is 10,The population size is 10,The percentage of the crossover is 0.7, Number of parents(offsprings) is 2,Mutation percentage 0.2 the number of mutations variables are 3.

The probability of each individual's fitness in the total fitness of the species group is

$$P(x_i) = \frac{f(x_i)}{\sum_{j=1}^{N} f(x_j)}, \quad i, j = 1,2,\ldots,N \qquad (2)$$

where $f(x_i)$ is the fitness of individual i and N is the population size The probability interval of each individual can be calculated, and the lower limit of
the probability interval for an individual to be selected is the sum of the probability values of all the individuals prior to the individual being measured,
The genetic algorithm flowchart is shown in Fig. 5

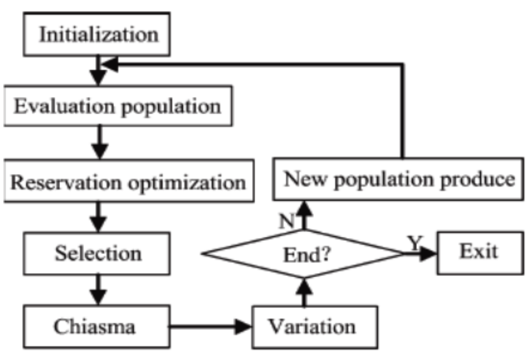

Fig.5. Flowchart of genetic algorithm

3. DYNAMIC MATHEMATICAL MODEL

The PM contactor is a fixed system comprising mechanical and electrical circuits as well as magnets. The voltage equivalence equation in the switching on process is written

$$d\psi/_{dt} = u - Ir \qquad (4)$$

where u is the coil voltage, i is the coil current, and ψ is the coil flux linkage. The elctromagentic force during the switching on process can be written as

$$F_{mag} = \frac{\psi^2}{2\mu_0 S N^2} \qquad (5)$$

where S is the area of the contact surface between the movable core and the static core. The movement of the movable core during the closing method is governed by D'Alembert's mechanical movement equation. The motion process of the movable core includes the movement behavior before the movalble core touches the static core as well as the buffered motion process motion process after the movable core touches the static core. The previous motion process includes two movements before and after the moving contact touches the static contact. Before the moving contact touches the static contact, the mechanical movement equation of the movable core can be written as

$$F_{mag} - F_s - (m_a + m_m + m_{sc})g - f_a = (m_a + m_m + m_{sc})\frac{d^2x}{dt^2} \qquad (6)$$

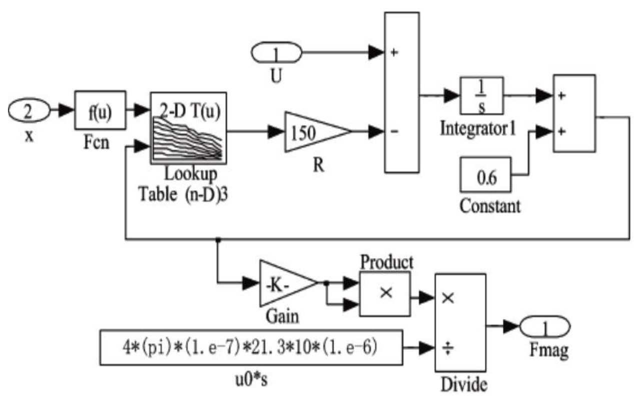

Fig. 6. Electomagentic force calculation submodel

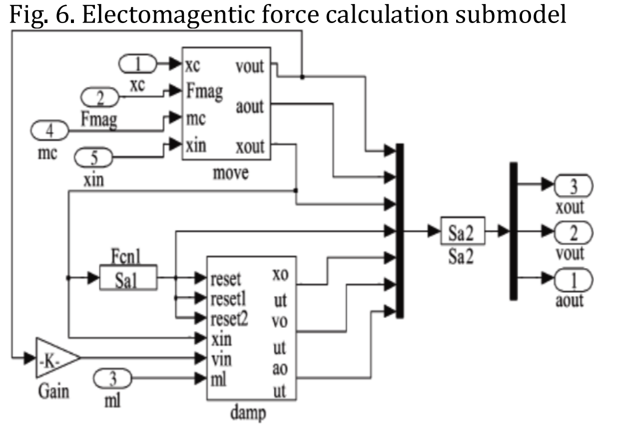

Fig. 7. Motion model of the movable core.

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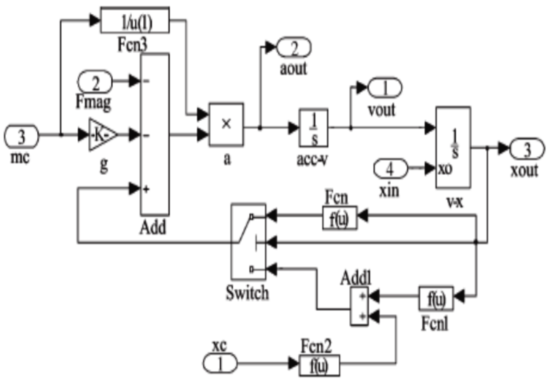

Fig. 8. Closing submodel of the movable core.

where *Fs* is the antiforce of the spring. The spring system includes four antiforce springs and three contact springs ,with an opening range of 8 mms and an overall travel of 3.3 mm. Therefore, the spring antiforce and the contact spring can be written as

$$F_s = 4k_s x_1 + 4F_0, \quad 0 \le x_1 \le 11.3 \qquad (7)$$

$$F_{sc} = 3k_{sc} x_2 + 3F_{sc0}, \quad 0 \le x_2 \le 3.3 \qquad (8)$$

where *x*1 and *x*2 are the displacement of the antiforce spring and the displacement of the contact spring respectively, and F_0 and Fsc_0 are the initial prestress of the antiforce spring and the initial prestress of the contact spring, respectively. After the moving contact touches the static contact, the mechanical motion equation of the movable core can be written as

$$F_{mag} - (F_s + F_{sc}) - (m_a + m_m)g - f_a = (m_a + m_m)\frac{d^2x}{dt^2} \qquad (9)$$

In the bufferd movement after the movalble core touches the static core , the mechanical equation of the damped vibration of the movable can be written as

$$(m_a + m_m + m_s)\frac{d^2x}{dt^2} = F_{rub} + (F_s + F_{sc}) \qquad (10)$$

where *F*rub is the force of the plastic caushion acting on the static core

$$F_{rub} = C_r\frac{dx}{dt} + k_r x \qquad (11)$$

The motion of the moving contact in the PM contator consist of two stages, which include the motion process before the moving contact touches the static contact and the bouncing process after the moving contact touches the static contact. The previous process meets (4), and the latter procedure satisfies the following equation:

$$m_{sc}\frac{d^2x_{sc}}{dt^2} = m_{sc}g + F_{sc} \qquad (12)$$

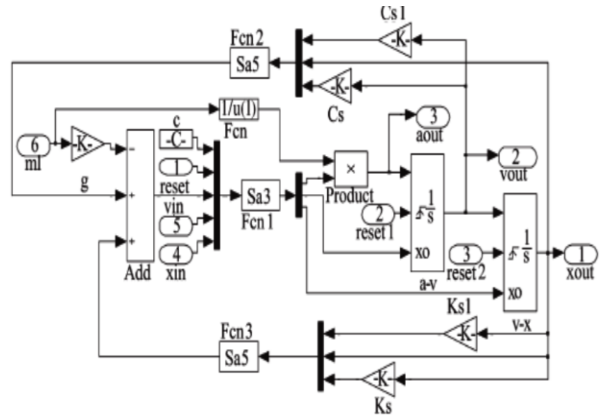

Fig. 9. Buffering submodel of the movablr iron core.

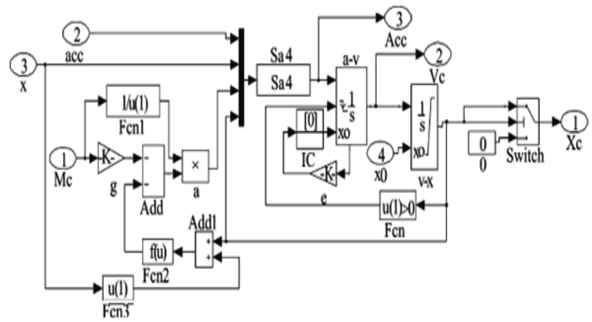

Fig. 10. Contact bounce model

4. Simulation Model:

1)Electromagnetic Force Calculation Meodel :

By using finite-element analysis, the nonlinear organization among the displacement *x*, the flux linkage ψ, and the current *i* can be calculated. The value of the electromagnetic force as a function of time can be obtained through linear table lookup interpolation. According to (4) and (5), the electromagnetic computing submodel in MATLAB can be built as shown in Fig. 4. When the current is forthcoming zero, the PM flux linkage is constant.

2)Motion Model Of The Movable Core:

The motion process of the movable core includes the closing action before the movable core touches the static core and the buffered procedure after the movable touches the static core.Consequently ,this Motion model include the movable core closing submodel and the movable core buffering submodel. Figs. 7–9 show the movable core movement model, the movable core closing submodel, and the movable core buffering submodel, respectively, according to (6)–(11) in MATLAB. The *S* function is used to change the mechanical parameter of the movable core movement.

3)Contact Bounce Model :

motion method of the moving contact includes the movement dynamics before the moving contact touches the static contact and the bouncing action after the moving contact touches the static contact; the previous process satisfies (6), which can be calculated using the movable core closing submodel, and the latter process can be used to build the contact bounce model, as shown in Fig. 8, according to(10).

4) System Simulation Model:

Fig. 11 shows the simulation model of the PM contactor in the complete switching on process, which includes the electromagnetic force computing model, the movable core movement nodel, and the contact bounce mode. The electromagnetic force computing model calculates the output electromagnetic force for specified input voltage and displacement, and the force is subsequently input into the movable core motion model. The displacement, speed, and accelerated speed in the motion process of the movable core can then the calculated subsequently. The contact bounce model calculates the displacement,, soeed, and acceleration of the moving contact in the bounce process after the moving contact touches the static contact.

5. SIMULATION RESULTS ANALYSIS

The voltage *U* is set to 190 V, and the maximum displacement of the movable core is 11.3 mm. Figs. 12 and 13 show the simulated results , respectively. It can be seen that there is observable bouncing after the moving contact runs into the static contact due to the effect of the plastic mitigate pad after the movable core collides with the static core.

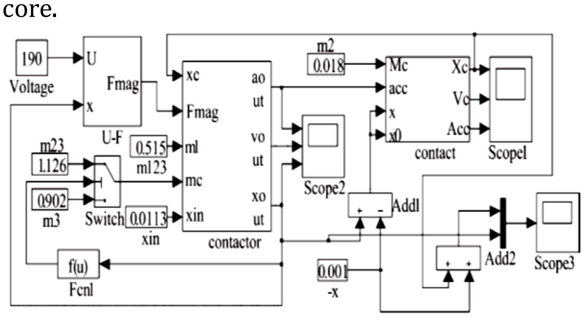

Fig.11 . system simulation model.

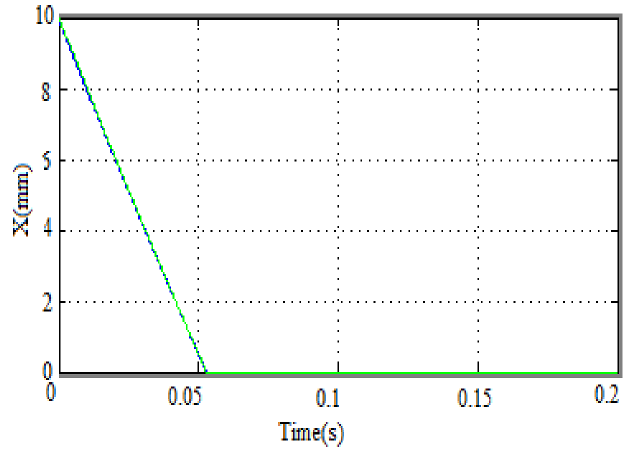

Fig. 12. Simulation results of the fuzzy moving contact displacement

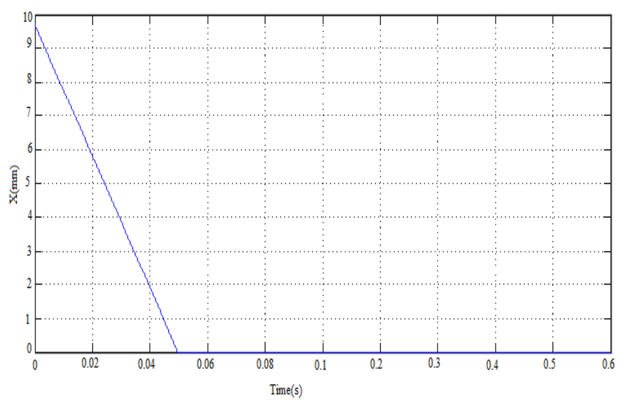

Fig. 13. Simulation results of the genetic algorithm moving contact displacement

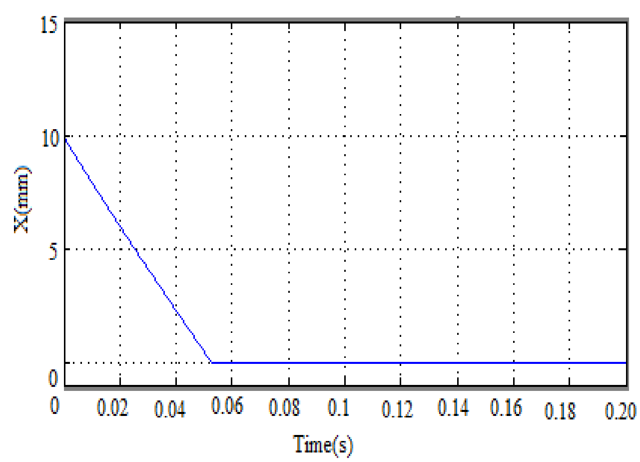

Fig. 14. Simulation results of the fuzzy movable iron displacement

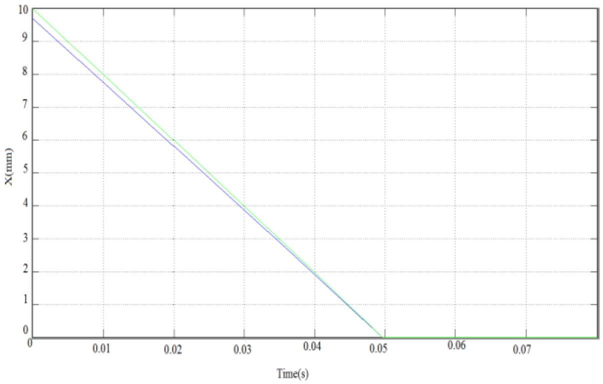

Fig. 15. Simulation results of the genetic algorithm movable iron core displacement

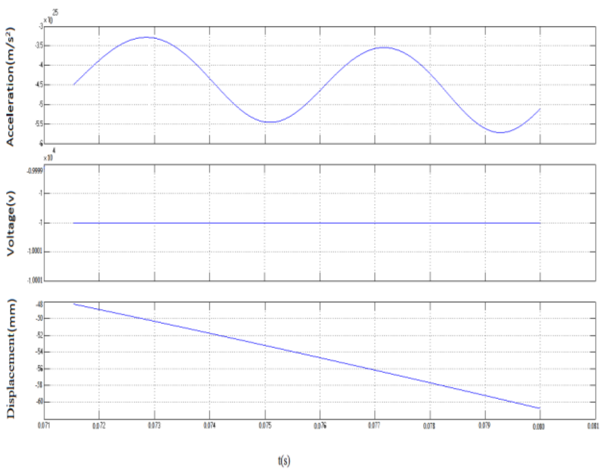

Fig. 16. Simulation results of the contactor

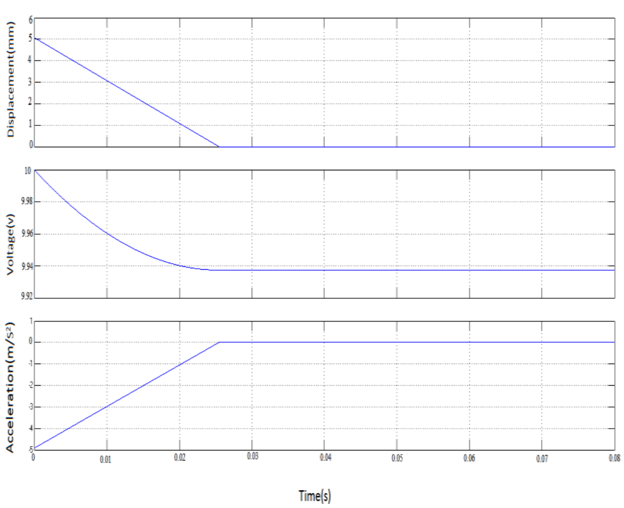

Fig. 17. Simulation results of the contact

Comparision Fuzzy logic creates rules that use estimated or subjective values. It describes a particular experience or process linguistically and then represents that logic in a small number of flexible rules.

Genetic algorithm are analytical methods that use the model of existing organisms adapting to their environment. probable solutions are evaluated, the "best" choices are made, then more probable solutions are created by combining the factors involved in those first "best" choices, and choosing again. The method continues until an optimum solution is reached. These genetic algorithm are useful for finding the optimal solution for a specific problem by examining a very large number of another solutions for that problem.

6. CONCLUSION:

In this paper, the propose of a fuzzy logic based permanent magnet contactor design,optimization and intelligent control. The results are analysed, designed and the system performance was studied widely.A unique voltage feedback intelligent control technique has been developed using the MATLAB software to allow one to construct the following: 1) the computing model of voltage, displacement, and electromagnetic force; 2) the switching-on movement model of the movable core; 3) the buffering damped oscillation model of the movable core; and 4) the contact bounce model. The motion displacement of the movable core and the moving contact in the whole switching on process can be instinctively visualized in the simulation. it can be seen that, after the insertion of the voltage feedback intelligent control technique, the first and second contact bounces are reduced significantly.as compared to genetic algorithm fuzzy is be better to get results. In this reason fuzzy used instead of geneticalgorithm

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