



FUZZY LOGIC CONTROL OF CRANE SYSTEM

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ABSTRACT:

Fuzzy logic defines rules that determine the behavior of the system using word descriptions instead of mathematical equations, fuzzy logic control algorithms can be used to solve problems that are difficult to address with traditional control techniques. In this research a fuzzy control strategy is proposed to control the stability of an crane work. It is beneficial that the fuzzy logic concentrates on the significance rather than the accuracy and the mechanism is applied without get in complex mathematics, therefore the only important thing here is the stability. The results of the four case studies indicate that the proposed control strategy is feasible with more simplicity and acceptance.

KEYWORDS:

Fuzzy logic, fuzzy controller, crane control modeling and simulation, stability.

الخلاصة:

فقط المنطق الضبابي يمكن وصفه بالحساب بالكلمات بدلا من الأرقام، كما انه السيطرة الضبابية يمكن وصفها بالسيطرة بالجمال بدلا من المعادلات. في هذا البحث تم اقتراح استراتيجية السيطرة الضبابية للسيطرة على استقرارية عمل رافعة (بمعنى اخر مشكلة البندول). تم الاستفادة من خاصية تركيز المنطق الضبابي على الأهمية بدلا من الدقة كما تم تطبيق الآلية دون الخوض في رياضيات معقدة. لذلك فقط الشيء المهم هو الأستقرارية. لقد بينت نتائج اربع دراسات حالة بانه نظام السيطرة المقترح قابل للتطبيق بسهولة جدا ومقبول.

INTRODUCTION:

The development of an active suspension system for high performance cranes that aims to reduce the vibrations in the base of the crane's frame. The oscillations are caused mainly by disturbances that come from the contact between the rollers parts of the suspensions with the alignment guides fixed to the building structure during the crane movement. These guides, although modern processes of manufacture and installation, present inherently small misaligns that are caused, normally, by disturbances in the installation processes. The movements caused for these misalignments, mainly for the high speed cranes of high building (skyscrapers), can compromise the requirements of security and comfort. Consequently, high technology companies are spending resources in the development of modern systems, as active control, to improve the performance of the crane's suspensions without increasing its size and weight, as occurs with the traditional passive systems [S. Miguel, 2008]. This situation can be proven by the elevated number of patents since the middle of the

last decade. In this work it is aimed to reduce the vibration of the crane using fuzzy logic algorithm in order to make an accurate masses translation. Zadeh introduced fuzzy logic in 1965, to represent and manipulate data and information that possess nonstatistical uncertainty. Since this date, fuzzy logic has been applied to many fields such as industry, medicine, economics and so on. The reason for this rapid growth in the use of fuzzy logic worldwide is that fuzzy logic provides an appropriate mechanism to describe the static and/or dynamic behavior of complex physical systems that are difficult to yield their conventional mathematical models. We can consider a fuzzy set as a fuzzy model of human concept.

Fuzzy control mimics human reasoning, where it concentrates on the significance rather than accuracy. Basically, while differential equations are the language of conventional control, heuristics and rules about how to control the plant are the language of the fuzzy control [R. Burns, 2001].

Control systems with fuzzy controllers are often successfully applied in practice. Their great advantage is the possibility to introduce the knowledge of human experts about proper and correct control of a plant in the controller. Fuzzy controllers were applied to industrial control, quality control, elevator control and scheduling, train control, traffic control, loading crane control, reactor control, automobile transmissions and climate control, automobile body panting control, automobile engine control, paper manufacturing, steel manufacturing, power distribution control, and other applications. **Fig.1.**, presents the general scheme of the fuzzy control system [A. Piegat, 2006].

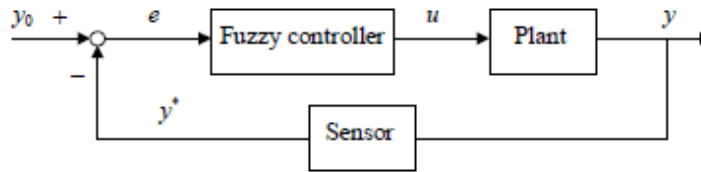


Fig. 1. General scheme of the fuzzy control system.

Jan Jantzen [J. Jantzen, 2005], presents the fuzzy self-organizing controller (SOC). The original controller configuration is shown and compared to modern model reference adaptive systems. A simulation study in simulink demonstrates that the SOC is able to establish a plant having a long dead time. [I. Nedeljkovic, 2005] shows that the fuzzy logic is relatively young theory. Major advantage of this theory is that it allows the natural description, in linguistic term, of problems that should be solved rather than in terms of relationships between precise numerical values. This advantage dealing with the complicated system in a simple way, is the main reason why fuzzy logic theory is widely applied in technique. In this paper, it is considered fuzzy modeling as an approach to form a system model using a description language based on fuzzy logic with fuzzy predicates. This paper presents a general approach to modeling of dynamic system of the mentioned crane based on the fuzzy logic. A table –lookup scheme is presented to generate fuzzy rules from numerical data. This method determines a mapping from input space to output space based on the combined fuzzy rule base using defuzzifying procedure.

I. CRANE MODELING AND ANALYSIS

The schematic of the crane system is shown in Fig. 2., where it consists of two masses one (m_1) moves translational in the x-direction by a force applied to it in the same direction, and the second (m_2) will therefore move translational and rotational motion as shown. Hence the system is two degree of freedom and the mathematical modeling can be derived as following:

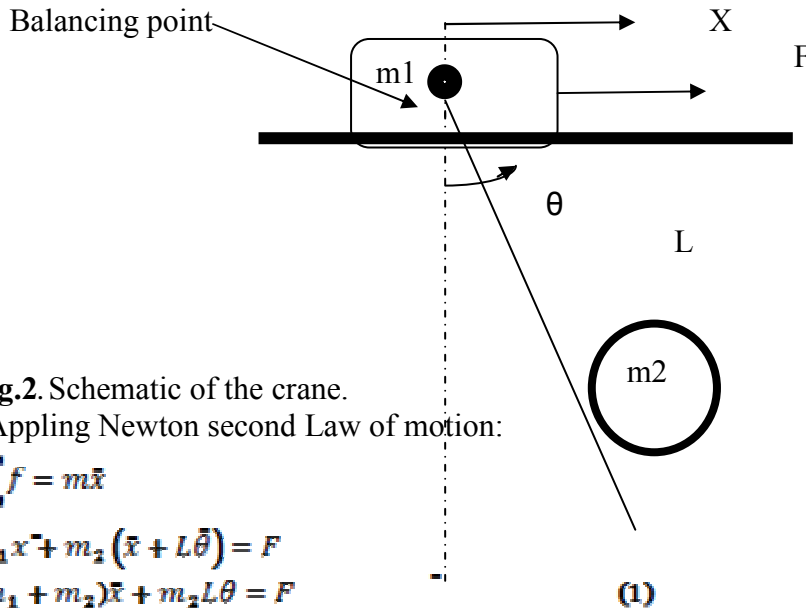


Fig.2. Schematic of the crane.

Applying Newton second Law of motion:

$$\sum f = m\ddot{x}$$

$$m_1\ddot{x} + m_2(\ddot{x} + L\ddot{\theta}) = F$$

$$(m_1 + m_2)\ddot{x} + m_2L\ddot{\theta} = F \quad (1)$$

$$\sum T = J\ddot{\theta}$$

$$J\ddot{\theta} + m_2x\ddot{L} = -m_2gL\theta$$

$$m_2L^2\ddot{\theta} + m_2L\ddot{x} + m_2Lg\theta = 0$$

$$L\ddot{\theta} + \ddot{x} + g\theta = 0 \quad (2)$$

Eq. (1) and (4) are the mathematical model of the crane system and the solution to these two equations is as required here by conversion to the state-space system in order to find the response of the displacements x and θ and velocities $\dot{x}$ and $\dot{\theta}$, where the state-space equations are shown following:

Let $x_1 = x$

$x_2 = \dot{x}$

$x_3 = \theta$

$x_4 = \dot{\theta}$

Then:

$$\dot{x}_1 = x_2 \quad (a)$$

$$\dot{x}_2 = \frac{m_2}{m_1}gx_3 + \frac{1}{m_1}F \quad (b)$$

$$\dot{x}_3 = x_4 \quad (c)$$

$$\dot{x}_4 = -\frac{(m_1 + m_2)}{m_1L}gx_3 - \frac{F}{m_1L} \quad (d)$$

Now after taking a specific crane system of the components: $m_1=500\text{kg}$; $m_2=20\text{kg}$; $g=9.81\text{m/s}^2$; $L=5\text{m}$; $F=100\text{N}$ the solution of the above state-space equations gives the responses shown in Fig.2.

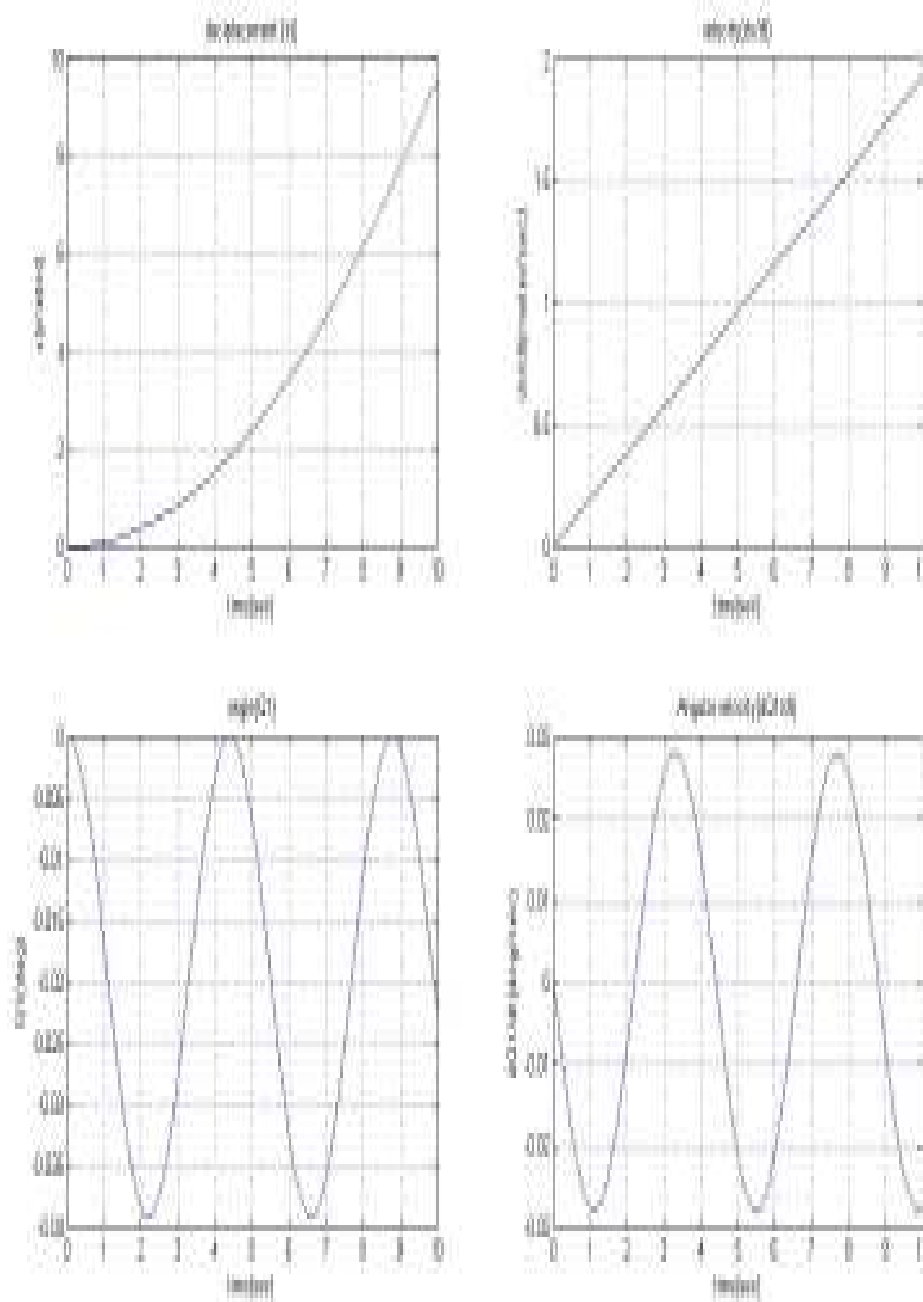


Fig. 3. Responses of the states of the crane system.

As shown from **Fig.3.**, for the given identified system the displacements and velocities responses are agreed in some degree that is the translational displacement nonlinearity is so small and the angular displacement vibrated in a very small range as well as angular velocity. So it is desired here in this research to design a control strategy that will conserve these responses as possible.

II. FUZZY CONTROL

Fuzzy control means the open and closed-loop control of technical processes, including the processing of measured values, which is based on the use of fuzzy rules and their processing with the help of Fuzzy Logic. The basic configuration of the fuzzy logic comprises four important components, which are: Fuzzification Interface, Knowledge Base, Decision making Logic, Defuzzification Interface [S. Khator, 2004]. Fig.4. gives the configuration of the fuzzy logic.

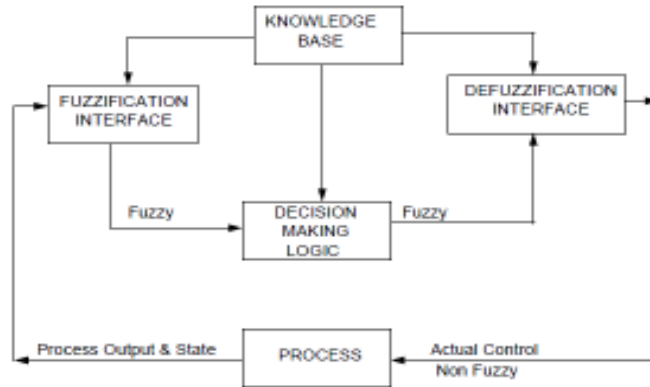


Fig.4. Basic configuration of fuzzy logic.

A. The fuzzification interface involves the following functions:

measures the values of the input variables.

performs the scale mapping that transfers the range of input variables into corresponding universes of discourse.

Perform the function of fuzzification that converts input data into suitable linguistic values which may be viewed as labels of the fuzzy sets.

B. The knowledge base comprises knowledge of the application domain and the attendant control goals. It consists of a database and a linguistic (fuzzy) rule base.

the data base provides necessary definitions, which are used to define linguistic control rules and fuzzy data manipulation in fuzzy logic.

the rule base characterizes the control goals and control policy of the domain experts by means of set of linguistic control rules.

C. The decision-making logic is the core of the fuzzy logic. It has the capability of simulating human decision-making based on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic.

D. The defuzzification interface performs the following functions:

A scale mapping, which converts the range of the values of output variables into corresponding universes of discourse.

defuzzification, which yields a nonfuzzy control action from an inferred control action.

V. CONTROL STRATEGY

The proposed control strategy in this study is by applying the Fuzzy logic control algorithm (i.e. design of Fuzzy logic controller). This controller mimics the way acknowledgeable human operator would control something. That is it supplies a set of control rules appropriate to the situation which may overlap each other [2]. Now back to **Fig.1.**, it is desired to balancing the crane rod by moving the balance point left or right. This movement can achieve by applying a desired amount of force in the proper direction. This force may be generated from applying a desired amount of current to the

electrical motor that is used to derive the mass (m_1) in the elevator as will be seen later. It is clearly now that the inputs to the fuzzy controller are Angle and Delta-Angle. Angle is the pendulum's vertical orientation in degrees and Delta-Angle is the pendulum's angular speed in degree per second. A sensor attached to the pendulum's pivot point could measure the inputs. A potentiometer or optical encoder disk could serve as a sensor to measure and calculate both inputs. The output is the motor current required to move the balance point right or left. Gravitational force causes torque that causes the rod to be unstable. Hence the system should manipulate motor torque to counteract the torque caused by gravity. Motor torque is directly proportional to the motor's armature current with a constant field flux. Hence the system uses a current amplifier instead of voltage amplifier to manipulate the motor.

VI. MEMBERSHIP FUNCTIONS

Membership function (or fuzzy set) provides a numerical definition of each of the Fuzzy logic states. A membership function defines the range of analog values that define a fuzzy logic state. It also defines the degree of membership of each analog value with the range. With the crane's pendulum, the two inputs and one output each have seven membership functions defining a range of levels. Their labels are:

NL Negative-Large
NM Negative-Medium
NS Negative-Small
ZE Zero
PS Positive-Small
PM Positive-Medium
PL Positive-Large

Illustration membership functions in graphical form are shown in **Fig.3**.

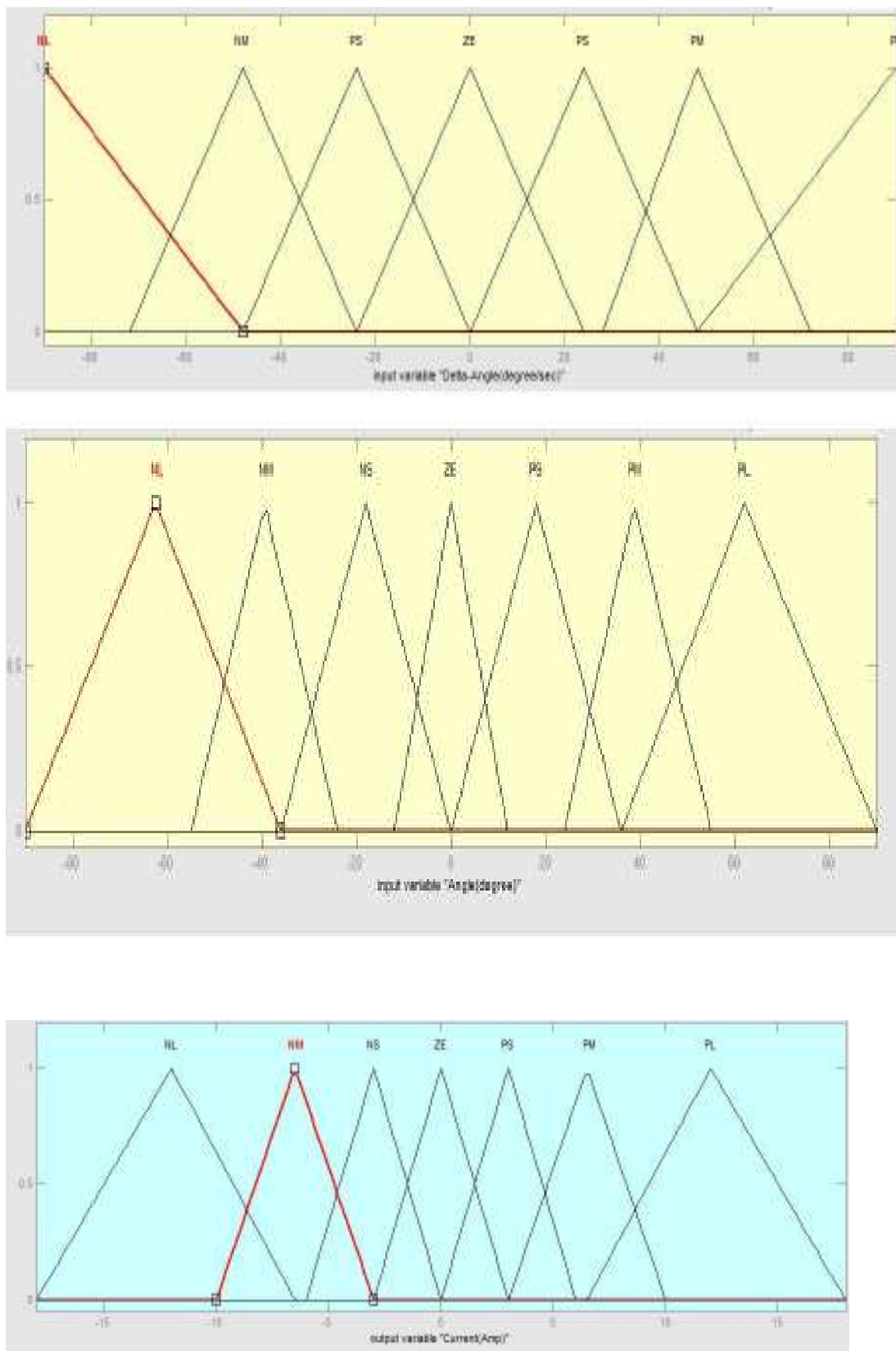


Fig.3. Membership functions of the proposed fuzzy controller

For the pendulum system the Fuzzy output can be calculated through building the matrix rule shown in **Table 1**. Noting that the building of the matrix is a common sense dependency [R. Burns ,2001].

Table 1. Fuzzy matrix rule.

Angle Delta-Angle	NL	NM	NS	ZE	PS	PM	PL
NL	PL	PL	PL	PM	PM	PS	ZE
NM	PL	PL	PM	PM	PS	ZE	ZE
NS	PM	PM	PS	PS	ZE	NS	NM
ZE	PM	PS	PS	ZE	NS	NM	NM
PS	PM	PS	ZE	NS	NM	NM	NL
PM	PS	ZE	NS	NM	NM	NL	NL
PL	ZE	NS	NM	NM	NL	NL	NL

VII. RESULT AND DISCUSSION

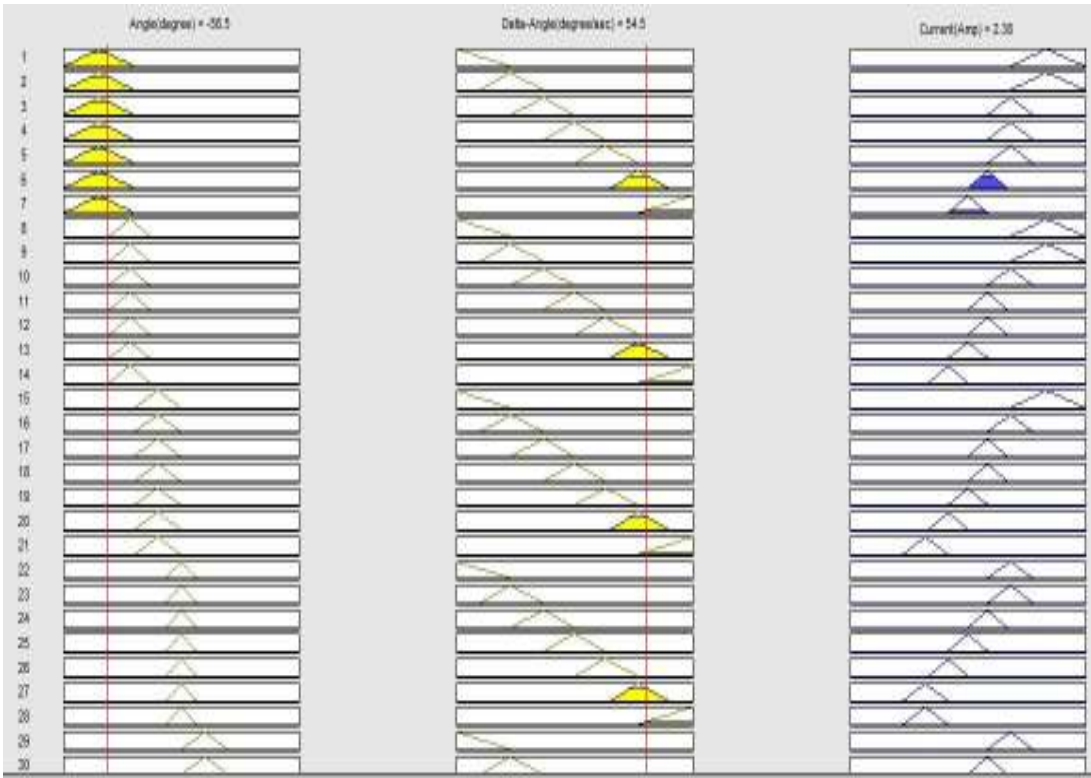
The results of the proposed fuzzy control system can be more comprehensive from taking different case studies (i.e. taking different inputs values and measuring the generated outputs) as shown in **Fig. 6**.

From **Fig. 6.**, (a) the inputs (Angle=-56.5 degree, Delta-Angle=54.5degree/sec) so the output current is a small positive value =2.38 Amp.as required to give small force in the right direction to keep the system stable.

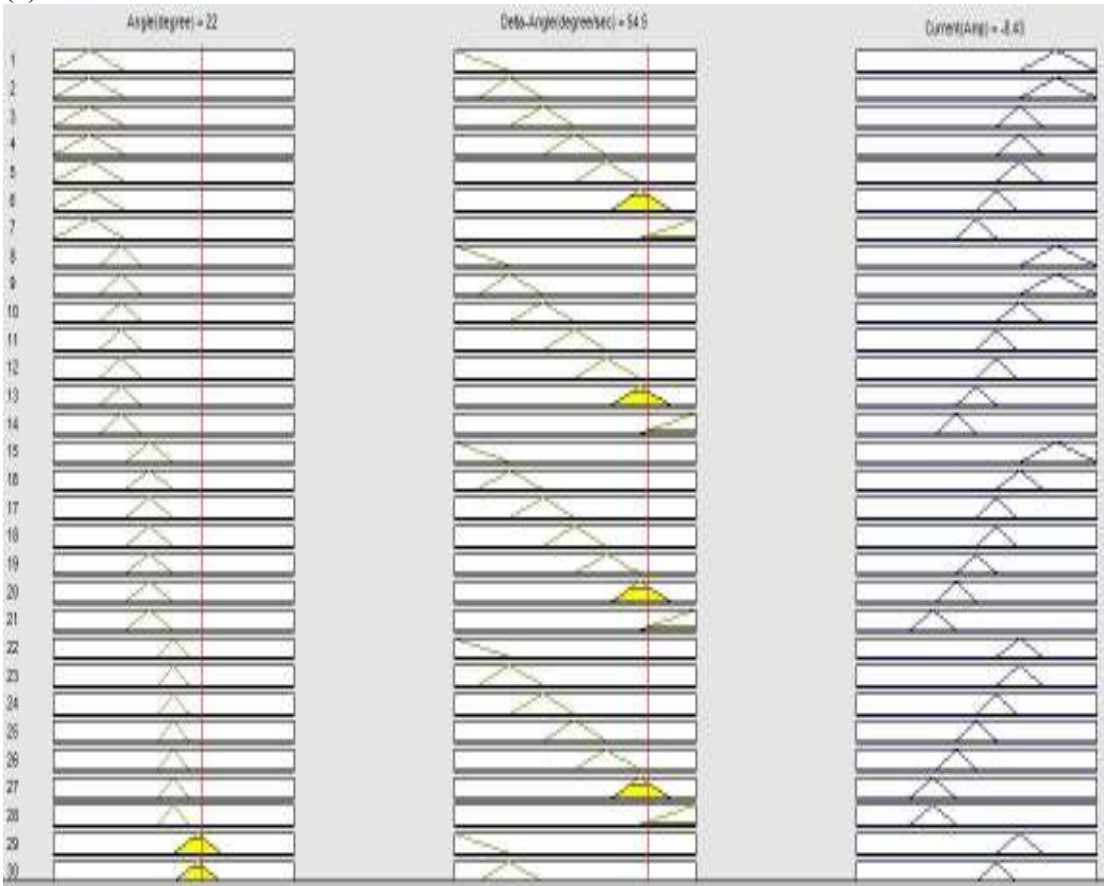
From **Fig.6.**,(b) the inputs Angle is positive =22 degree and Delta-Angle increases in the positive direction also where that need large current in the reverse direction to generate negative force required and that is right where the generated output current = - 8.43 Amp., as shown from the figure.

If the Angle is positive as shown in **Fig. 6.**,(c) =22 degree and the Delta-Angle decreasing = -55.2 degree/sec, then the output current needed is small to generate the desired force that will keep the system stable (current=3.95 Amp).

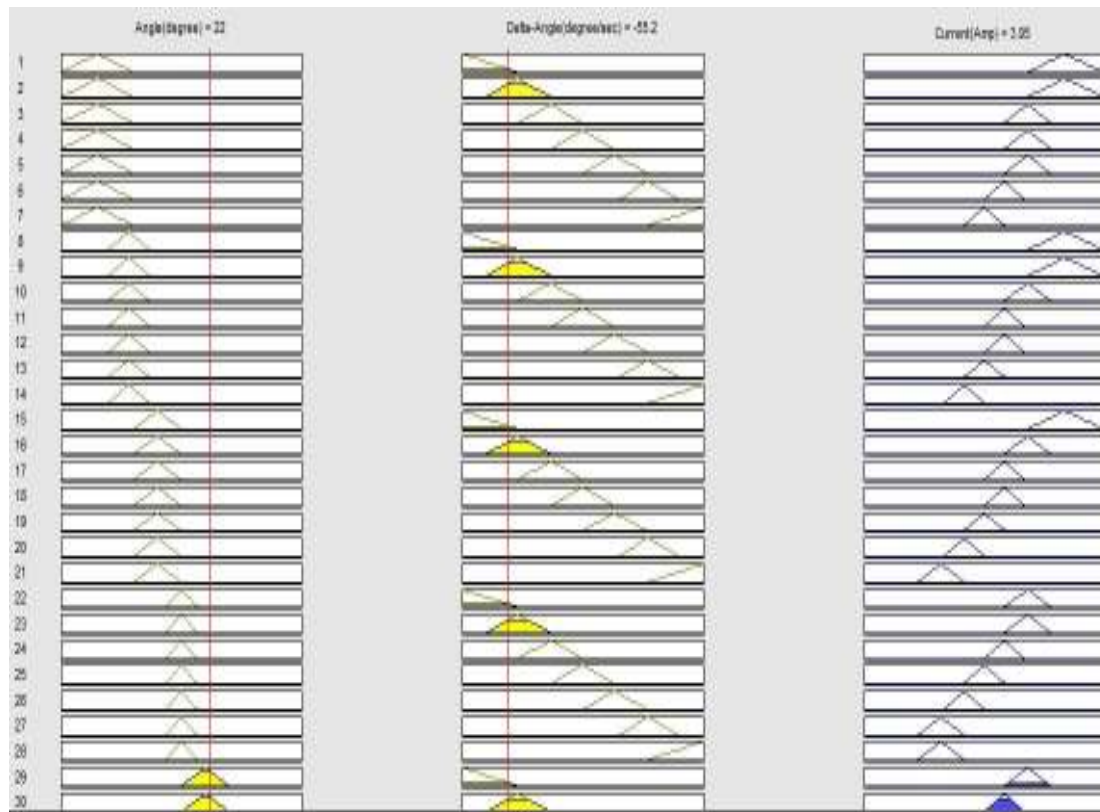
Another case when the Angle is negative and Delta-Angle decreased as shown in **Fig. 6.**,(d) (Angle=-11.2 degree and Delta-Angle=-55.2) the output current required here is positive large to generate large amount of force required where the current = 8.69 Amp as shown.



(a)



(b)



(c)



(d)

Fig. 6. Results of different case studies.

IV. Conclusions

From the mentioned results it is clearly understood that the proposed fuzzy controller is feasible and applicable where the accuracy is not very important in the

fuzzy and rather the stability is the important thing but if it is desired to thinking on the accuracy, it is not a significant problem where the accuracy of the response can increased by increasing the number of the membership functions. Where one can reach the system requirements without get in the complexity of the mathematical modeling especially when the system nonlinearity is the pioneer problem.

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