The International Journal of Engineering
And Science (IJES)
||Volume|| 1 ||Issue|| 2 ||Pages|| 26-32 ||2012||
ISSN: 2319 – 1813 ISBN: 2319 – 1805

Stability of a System of Electrical Power using a Fuzzy Control

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Abstract

This paper presents the study of the stability of a system electrical power using a Mamdani type fuzzy control. A system of test machine bus-infinite is used, where the synchronous generator is connected to an infinite bus through external impedance. Describes the methodology used for fuzzy control. The results of this type of control are presented and compared with results obtained with conventional control type ST1.

Keywords – Conventional Control ST1, Fuzzy Control, Fuzzy Control type Mamdani, Fuzzy Logic, Stability.

Date of Submission: 19, November, 2012 ⟺ Date of Publication: 5,December 2012

1. INTRODUCTION

The concept of stability in a system of electrical power relates the ability of a system of power to remain in sync and the tendency of a system to return and stay in a point of operation in the steady state after a fault has occurred The electric power systems involve synchronous generators located in long power stations and connected to loads that are dynamic or static. The loads have an important influence on the stability and can affect a generator making it unstable. The electric power systems are systems that have the characteristic of being non-linear, time-varying, operating in different points of operation and have changes in their structures, for this reason, it is the need to maintain the output voltage of a synchronous generator avoiding variations of voltage regardless of the variations in load. One of the major teams of control in a synchronous machine is the automatic voltage regulator and currently the operating are normally tuned to a certain point of operation, and sometimes have to be adjusted manually by highly skilled personnel [1]. On the other hand, are now applying techniques of artificial intelligence, called intelligent controls in various fields of science to overcome the limits of the classical methods [2]. The intelligent controls are characterized by their ability to establish a functional relationship between its inputs and outputs with empirical data, without the use of explicit models of controlled systems. Contrary to conventional controls, intelligent controls can learn, remember and make decisions. The intelligent controls can be trained to operate effectively in conditions of uncertainty; can respond to unforeseen situations autonomously, without the intervention of the system attendant.The type of intelligent control used in this work is the fuzzy control that was introduced in the early 70s as an attempt by designing controls for systems that are structurally difficult to model, due to its non-linear nature and other complexities in the obtaining of the model. This type of control is based on the so-called Fuzzy Logic.

2. FUZZY CONTROL

The underlying principle of a controller based on the knowledge of an expert is to capture and put into practice the knowledge and experience available for example, the operators of a process. A specific type of control based on the knowledge is the fuzzy control based on rules, where the actions of control corresponding to the particular conditions of the system are described in terms of fuzzy if-then rules. Fuzzy sets are used to define the meaning of the qualitative values of the inputs and outputs of the controller such as: small error, control action large. Fuzzy logic can capture the continuing nature of the human decision-making processes and as such, it is a definite improvement on the methods based on the binary logic that are widely used in theindustrial controllers [3].Since then the range of application of a fuzzy control has expanded significantly. The linguistic nature of the fuzzy control allows you to express the knowledge of the process with respect to how the process must be controlled or as behaves the process. The aspect of interpolation of the fuzzy control has led to the point of view where the fuzzy systems are seen as diagrams of a fluids function approximation.In most cases a fuzzy controller is used for the control of direct feedback. However, it can also be used in the monitoring level, for example, as a device in a self-tuning control of conventional type PID; proportional integral differential control. Also, diffuse control because not only is used to directly express a process of a priori knowledge, i.e. a fuzzy control can be derived from a fuzzy model obtained through the identification of the system. The most frequently used in this field are the following [3].The control type Mamdani, either with the consequential diffuse or semi fault. This type of control is generally used as a direct result of the closed-loop controller and control the Takagi-Sugeno, generally used as a supervisory control.The main difference between these controls lies in the consequence of the rules. For the control of type Mamdani this consequence is a diffuse whole and for the Takagi-Sugeno is a linear function of the inputs.2.1. Structure of a fuzzy control [4].

The basic structure of a control system with fuzzy logic is shown in Fig. 1.

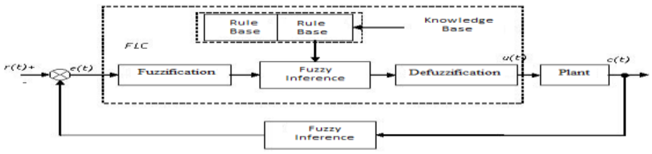


Figure 1. Control System with fuzzy logic.

2.1.1 Fuzzification.

During the first stage within the structure of a fuzzy control performs the process of generation of fuzzy values, i.e. it is the diffuse to assign labels to the universe of discussion for each of our actual entries.Decisions need to be made with respect to: the number of entries, the size of the universe of discussion and the number and shape of fuzzy sets.

2.1.2 Knowledge Base.

It is the second step in the processing of fuzzy logic. Fuzzy logic uses linguistic rules to determine that control action must execute in response to a set of input values.The rule base consists of a fuzzy set of linguistic rules of the form. If "conditions" then "actions".This style of fuzzy conditional statement is often called 'Mamdani type rule'. The rule base is constructed with a priori knowledge of one or all of the following sources: the physical laws that govern the dynamics of a plant, the data from the existing drivers, the imprecise heuristic knowledge obtained from an expert.

2.1.3 Fuzzy inference.

The evaluation of rules, also referred to as fuzzy inference is applied to the diffuse inputs and are transformed in the process of generation of fuzzy values, with which it is evaluated each rule.Fuzzy Inference is therefore, the process of assigning values of membership in the entry window, through the rule base, to the output window.

2.1.4 Defuzzification.

The last step in the processing logic diffuse, is the process of the combination of all the fuzzy outputs, resulting in a real output, which is applied to the output system.One of the techniques commonly used in the generation of actual values is the call center of gravity or the centroid method, in this method, each function of membership is truncated above the value indicated by its diffuse output.

2.2 Control type Mamdani.

A control type Mamdani from the base of rules represents a static mapping between the antecedent and the consequential variables, external dynamic filters should be used to obtain the desired dynamic behavior of the control.The structure of a control of type Mamdani consists of the following stages. Fuzzification, Fuzzy Inference, Defuzzification. The fuzzy systems of type Mamdani are very close in the nature of the manual control, the handler is defined by specifying that the output should be a number of different combinations of input signals. Each combination of input signals is represented as a rule "if-then".

3. FUZZY CONTROL APPLIED TO THE STABILITY OF AN ELECTRICAL SYSTEM OF POWER.

The fuzzy control that was applied in this study is the Mamdani type which consists of 5 functions of membership and a table of rules of 5x5. The purpose of this control is to regulate the voltage, that is to say, is to maintain a suitable profile of voltage in the electrical system of power, the electric power system used [5] is represented in Fig. 2.

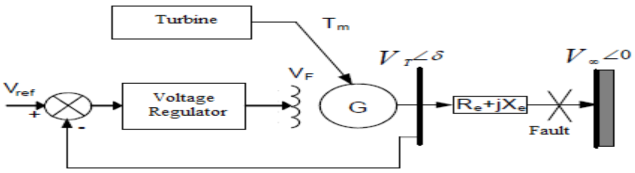


Figure 2. Machine bus-infinito system.

The Fig. 3 shows the structure of the voltage regulator proposed.

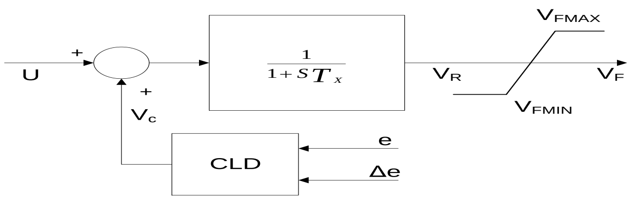


Figure 3. Structure of the fuzzy control type Mamdani.

The real signs of entry for the proposed control are the acceleration of the power, defined as Δe and the deviation of the speed, defined as e.

3.1. Data For The Study.

The system of study is shown in the appendix, is a test system machine bus infinity see Fig. 4, and applies a three-phase fault in the bus infinity with duration of 3 cycles.The failure to the submitted the system is a short circuit. The time when failure occurs is at t=1 second, the bus voltage is up to 0 in per unit.

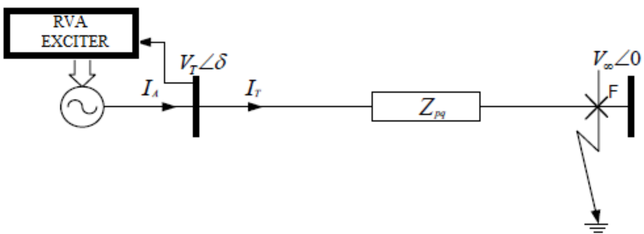


Figure 4. Study system.

The initial points of operation that are used for the tests are shown in table 1.

Table 1. Data of the low system prove

$V_b = 1.0\, p.u.$	$V_T = 1.0\, p.u.$	$\delta_r = 95.4017°$
$P = 0.7500\, p.u.$	$Q = 0.2726\, p.u.$	$\theta = 52.3939°$

3.2 Assessment Data.

Table 2 shows the 25 rules syntonized for a point of operation of a power of 0.75 used in this work and the tuning is performed manually; to trial and error, on the basis of a centralized rule, with the a priori knowledge of the characteristics of the system.

Table 2. Table of 25 rules.

$\Delta e \backslash e$	LN	NM	ZE	PM	LP
LN	LB	LB	LB	LM	ZE
NM	LB	LM	LM	ZE	HM
ZE	LB	LM	ZE	HM	HB
PM	LM	ZE	HM	HM	HB
LP	ZE	HM	HB	HB	HB

The labels used for the e and Δe are shown in table 3 and the membership functions that correspond to these labels are shown in Fig. 5.

Table 3. Labels.

Reglas		Acciones:	
LN	large negative	LB	Low big
NM	negative medium	LM	low medium
ZE	Zero	ZE	Zero
PM	positive medium	HM	high medium
LP	large positive	HB	high big

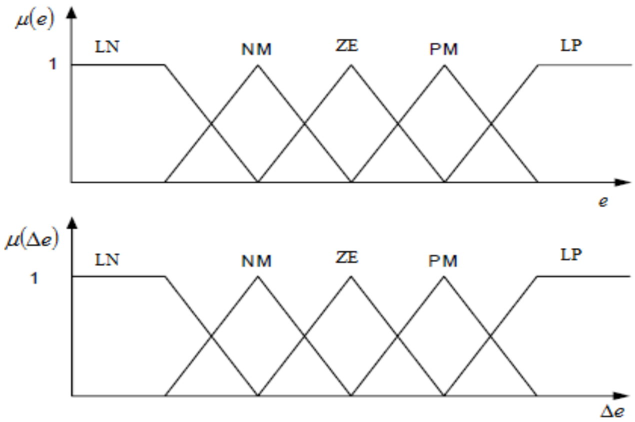


Figure 5. Membership functions.

For the proposed control of the type Mamdani, test data are shown in table 4.

Table 4. Data for the type Mamdani control.

	LN	NM	ZE	PM	LP
Membership e	-0.70	-0.35	0.0	0.35	0.70
Membership Δe	-0.70	-0.35	0.0	0.35	0.70
Singletons	-20.60	-10.30	0.0	10.30	20.60

RESULTS OF THE SIMULATION

For effects of the simulation the proposed control was compared with a conventional control of the IEEE of the type ST1 [6]. The simulations of both controls were carried out under the same conditions of operation, to an active power of P=0.75 p. u. by limiting the excitation voltage U, obtaining the following results, Fig. 6; load angle, Fig. 7; active power, Fig. 8; reactive power, Fig. 9; voltage in terminals, Fig 10; voltage field and Fig. 11; excitation voltage.

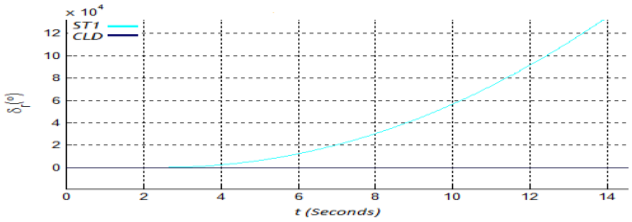


Figure 6. Angle of load.

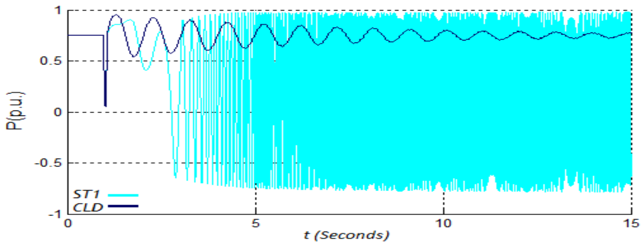


Figure 7. Active Power.

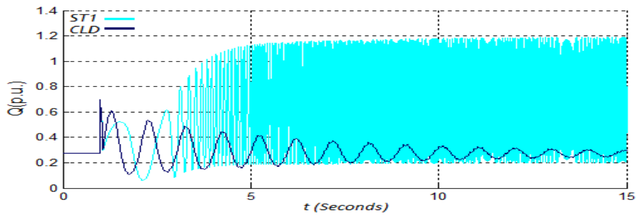


Figure 8. Reactive Power.

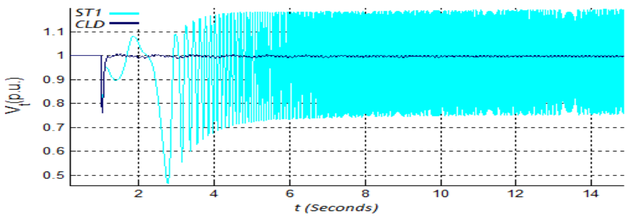


Figure 9. Voltage in terminals.

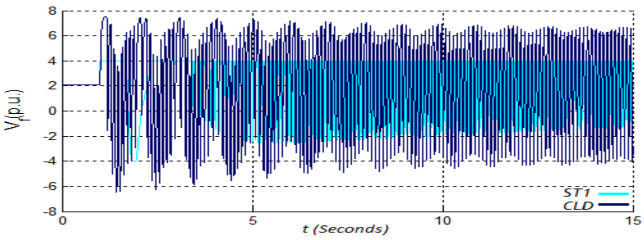
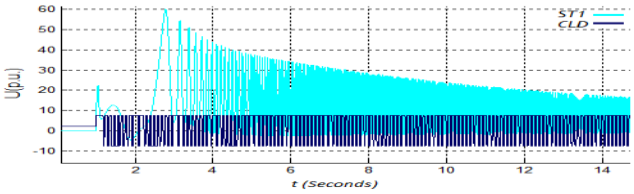


Figure 10. Field Voltage.



Figure

11. Excitation Voltage

4. CONCLUSION

The fuzzy control of the type Mamdani proposed in this work presents a better performance and a greater robustness compared with conventional control of the ST1 type. Of the results of the simulation we can conclude that the active potency and the potency reactivates with the FLC they present a less number of oscillations once applied failure, with a tendency to achieve better stability as passes the test time compared with conventional control ST1.In the case of the voltage in terminals with the FLC is achieved a steady state in a very short time of test in comparison of the ST1 and in the case of field voltage has an oscillatory behaviour for both controls, but with the difference that the FLC performs at a lower amplitude.The behavior of the excitation voltage is according to the conditions laid down in our study, i.e. the excitation voltage is limited in an operating range of ± 6 volts.

APPENDIX

The model of the synchronous machine [5] used in this work are.

$$p\delta_r = \omega_0 s$$

$$Mps = -K_d s + Tm - Te$$

$$T'_{d0} pe'_q = V_f - (X_d - X'_d) i_d - e'_q$$

$$T''_{d0} pe''_q = e'_q - (X'_d - X''_d) i_d - e''_q$$

$$T''_{q0} pe''_d = (X_q - X''_q) i_q - e''_d$$

$$e''_d = V_d + r_a i_d - X''_q i_q$$

$$e''_q = V_q + r_a i_q + X''_d i_d$$

$$Te = e''_d i_d + e''_q i_q - (X''_d - X''_q) i_d i_q$$

The model of the net [5], without loss of generality, the transmission line is described by an equivalent impedance of Thevenin. Therefore, the terminal voltage and their components in direct axis and axis in quadrature, they are the following ones.

$$V_d = V_\infty Sen\delta_r + r_e i_d - X_e i_q$$

$$V_q = V_\infty Cos\delta_r + r_e i_q + X_e i_d \qquad V_T^2 = V_d^2 + V_q^2$$

Table 5. Data of the Low System Prove

Parameters of the System Machine-Bus Infinite			
ω_0	377.0	Xe	0.15
M	5.5294	re	0.01
Kd	3.0	KA	400.0
T'do	5.66	TA	0.02
T''do	0.041	KF	0.008
T''qo	0.065	TF	1.0
Xd	1.904	TX	0.025
X'd	0.312	P	0.824
X''d	0.266	Xq	1.881
X''q	0.260	Ra	0.0

The data of the system machine bus infinite is shown in the table 5. For the regulator of voltage ST1, these they are taken of the reference [5], likewise the data of the transmission line corresponds to a generator of 645 MVA in for unit [5].

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