Buletinul Ştiinţific al Universităţii "Politehnica" din Timişoara

Seria ELECTRONICĂ şi TELECOMUNICAŢII
TRANSACTIONS on ELECTRONICS and COMMUNICATIONS

Tom 53(67), Fascicola 1, 2008

Fuzzy Logic Controllers for Resonant Inverters

Marin V. Tomşe[1], Viorel Popescu[2], Dan Simu[3]

Abstract - Fuzzy logic command is a valuable option instead of traditional methods for resonant inverters command. This method assumes simple mathematical operations and requires only understanding of system behavior and identifying the rules after which this system work. This paper presents a comparison between four variants of fuzzy logic controller designated to command the resonant inverters on induction heating applications. The comparison is achieved based on computer simulations using MATLAB/SIMULINK software.

Keywords: resonant inverter, fuzzy logic controller

I. INTRODUCTION

The resonant inverters are frequently used in practice as a supplies for induction heating, where they operates under different disturbances, the main being the oscillations and distortions of the power supplies voltage and parameters of inductive load changing.

Traditional frequency-domain analog methods are predominantly used in controller design and are based essentially on an equivalent linear small-signal model, which have rather restricted validity, especially for systems with strong nonlinearity.

There are two possible ways of escape from the conventional framework of linear control. First of them is to develop more accurate nonlinear models on which high-performance controller design can be based. The discouraging fact in this way is that complex mathematical derivations are often involved which, with few exceptions, lead to very complicated control algorithms that are not suitable for practical implementation. The second way consists of to use heuristic reasoning based on human experience a studied system. Such experience is usually collected in the form of linguistic statements and rules. In this case the modeling is not necessary and the controller design is reduced to conversion of a set of linguistic rules into an automatic control algorithm. In this case, fuzzy logic offers the method for performing this conversion.

II. ANALYZE OF FUZZY LOGIC CONTROLLERS USED IN INDUCTION HEATING

A. *Description of the analyzed controllers*

The schematic diagram of a closed loop fuzzy logic controller of resonant inverter with phase shift is presented in Fig. 1.

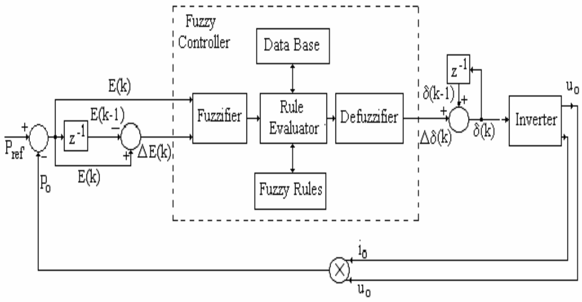


Fig. 1. Basic diagram for a fuzzy controller of resonant inverter with phase shift

The input variables of fuzzy logic controllers are the error E(k) and the change of error ΔE(k) and the output variable is the variation of command angle Δδ(k). From Δδ(k) we obtain the command angle δ(k), which is the control parameter of the inverter. The fuzzy inference method used is *max - min* and the defuzzification is obtained trough the center of gravity method, both most frequently used in engineering domain [1]. In the paper, four variants of fuzzy controllers presented below are analyzed.

Controller1. The membership functions for E(k), ΔE(k) and Δδ(k) are shown in Fig. 2. The fuzzy rules for controller 1 are presented in Tab. 1.

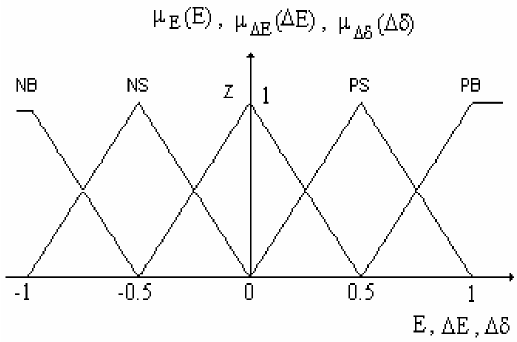


Fig. 2. The membership functions for controller 1

[1]Facultatea de Inginerie Electrică şi Tehnologia Informaţiei, Str. Universităţii Nr.1, 410087, Oradea, mtomse@uoradea.ro
[2]Facultatea de Electronică şi Telecomunicaţii, Departamentul Electronică Aplicată, Bd. V. Pârvan Nr. 2, 300223 Timişoara
[3]S.C. Timteh SRL, dan.simu@timteh.ro

Tab.1. Fuzzy rules for controller 1

ΔE \ E	NB	NS	Z	PS	PB
NB	NB	NB	NB	NS	PS
NS	NB	NS	NS	PS	PS
Z	NB	NS	Z	PS	PB
PS	NS	NS	PS	PS	PB
PB	NS	PS	PB	PB	PB

For writing of fuzzy rules we used the following control criteria, valid for all studied controllers:

- if output power is far from the reference value then the variation of command angle must be big in order to bring the output power quickly to a reference value;
- if the output power of inverter closes slowly to a reference value, then the variation of command angle must be little;
- if the output power of inverter closes rapidly to a reference value, then the command angle must remain the same in order to escape the oscillations at output of inverter;
- if the reference value is reached but the output power intends to change, then the command angle must be changed little bit, so that to prevent the deviation of output power from reference value;
- if the reference value is reached and the output power not intend to change, then the command angle must be maintained constant;
- if the error of output power is positive, then the change of command angle must be negative;
- if the error of output power is negative, then the change of command angle must be positive.

Controller 2. The membership function for E(k) is the same as at controller 1 (Fig. 2). For ΔE(k) and Δδ(k) the membership function are shown in Fig. 3. The fuzzy rules for controller 2 are presented in Tab. 2.

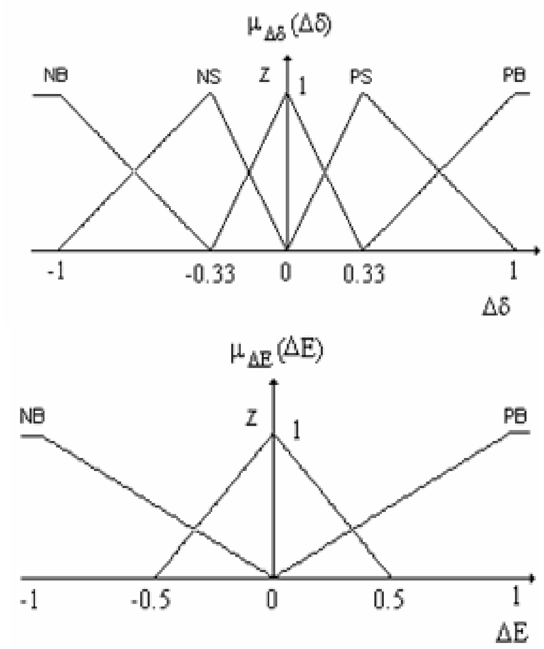


Fig. 3. Membership functions for variables ΔE(k) and Δδ(k) for controller 2

Tab. 2. Fuzzy rules for controller 2

ΔE \ E	NB	NS	Z	PS	PB
NB	NB	NB	NS	PS	PB
Z	NB	NS	Z	PS	PB
PB	NB	NS	PS	PB	PB

Controller 3. The membership function for E(k) and ΔE(k) are the same as at controller 1. For Δδ(k) the membership function are shown in Fig. 4. The fuzzy rules for controller 3 are presented in Tab. 3.

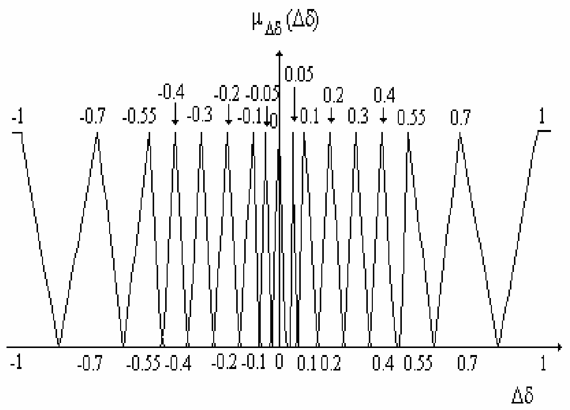


Fig. 4. Membership functions for variables ΔE(k)and Δδ(k) for controller 3

Tab. 3. Fuzzy rules for controller 3

ΔE \ E	NB	NS	Z	PS	PB
NB	-1	-0,55	-0,1	0	0,2
NS	-0,7	-0,3	-0,05	0,05	0,3
Z	-0,4	-0,1	0	0,1	0,4
PS	-0,3	-0,05	0,05	0,3	0,7
PB	-0,2	0	0,1	0,55	1

Controller 4. The membership function for E(k), ΔE(k) and Δδ(k) are shown in Fig. 5.The fuzzy rules for controller 4 are presented in Tab. 4. For all controllers, the membership functions are given for normalized values of variables.

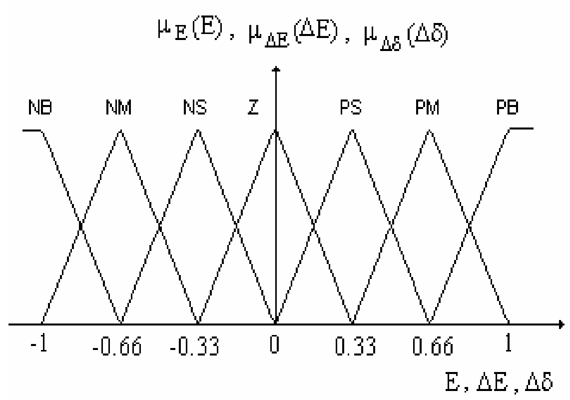


Fig. 5. Membership functions for variables, E(k) ΔE(k) and Δδ(k) for controller 4

Tab. 4. Fuzzy rules for controller 4

ΔE \ E	NB	NS	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

B. *Numerical simulations*

Using the basic diagram from Fig. 1, we achieve the model of a series resonant inverter with phase shift, driven by one of the four analyzed controllers, presented in Fig. 6. The software support is MATLAB / SIMULINK.

It is noticed that the variables E(k), ΔE(k) and Δδ(k) are multiplied by coefficients k_E, $k_{\Delta E}$ and k_δ. This is necessary for an easier optimization of inverter functioning.

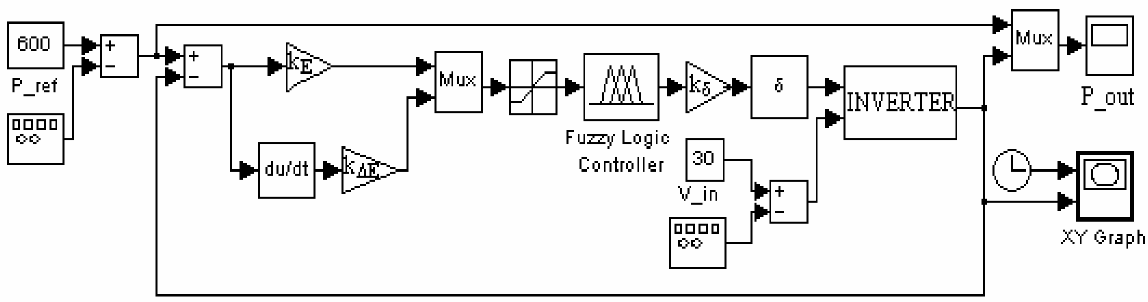


Fig. 6. The model of series resonant inverter driven by fuzzy controller

The main parameters of a prototype for a low power series resonant inverter are: V_d = 30 V, L =19.4 μH, C = 880 nF and R = 0,6 Ω and the SIMULINK model is given in Fig. 7.

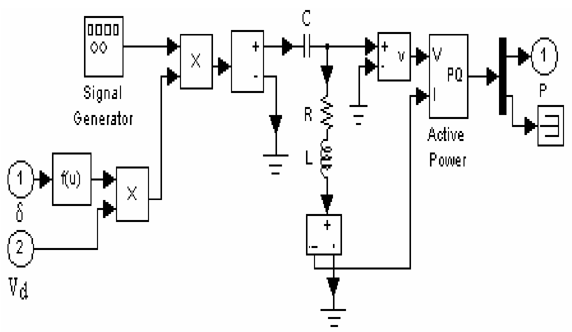


Fig. 7. The SIMULINK model of series resonant inverter

III. COMPARISON BETWEEN VARIANTS OF FUZZY CONTROLLERS

Studying the four variants of fuzzy logic controllers, we search a set of coefficients that ensure the better response of inverter, without any oscillations. The combinations of coefficients and inverter performances for all studied variants of fuzzy controllers are presented in Tab. 5 and influence of coefficients variations is shown in Tab. 6.

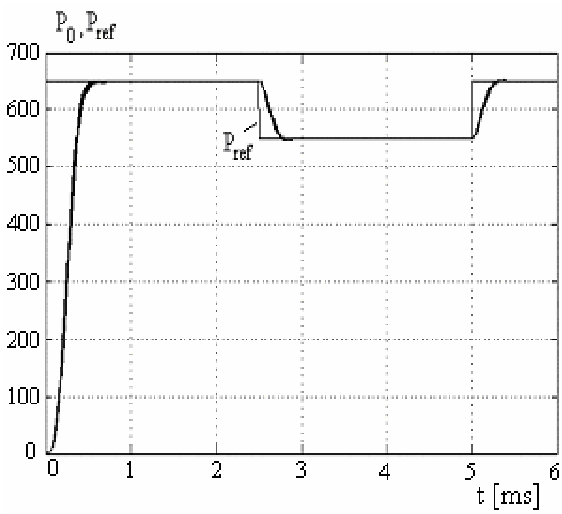
Tab. 5. Optimal values of coefficients from numerical simulations.

Parameters	k_E	$k_{\Delta E}$	k_δ	Overshoot	Rise Time
Units	$\times10^{-3}$	$\times10^{-8}$	$\times10^{-3}$	[%]	[ms]
Controller 1	2,2	0,1	5	0	0,65
Controller 2	2	1	5	0,5	0,85
Controller 3	7,5	10	4	0,5	1,1
Controller 4	3	0,1	5,5	0	0,5

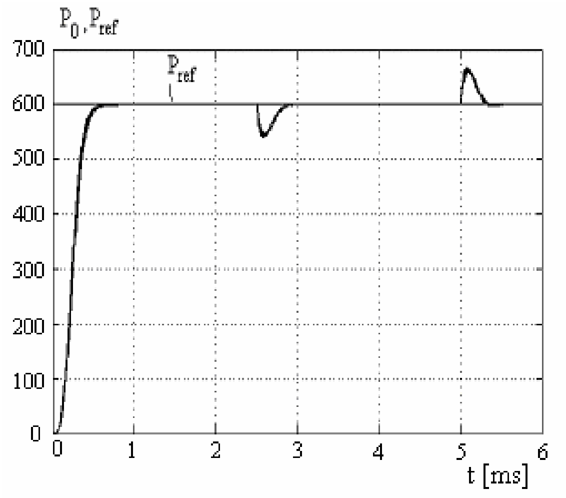
Tab. 6. The dependence between inverter performances and coefficients variations

		Overshoot	Rise Time
k_E	↗	↗	↘
	↘	↘	↗
$k_{\Delta E}$	↗	↘	↗
	↘	↗	↘
k_δ	↗	↘	↗
	↘	↗	↘

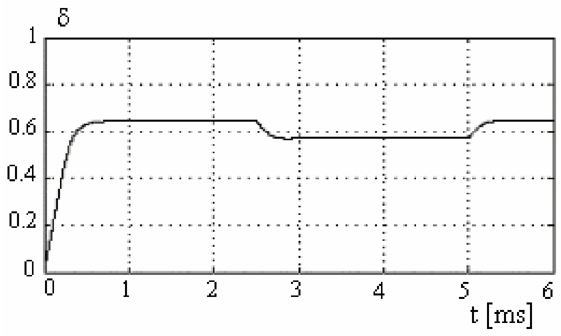
We studied the responses of the four fuzzy controllers at unit step type variation of reference power respectively of supply voltage. All controllers give correct responses at these types of disturbances, but the best performances are obtained with controller 4, in accordance with data from Tab. 5. For fuzzy logic controller 4, Fig. 8 presents the response at these variations.



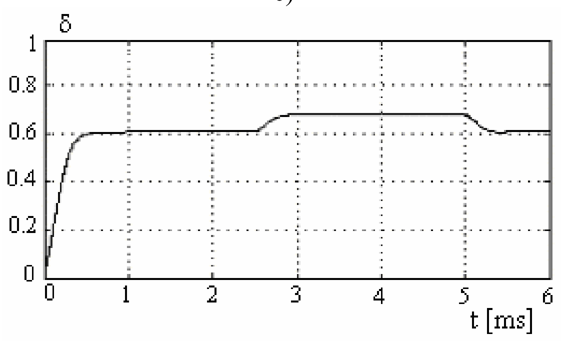
a)



b)



c)



d)

Fig. 8. Response of controller 4: a) at variation of reference power; b) at decreasing of supply voltage; c) and d) variation of command angle corresponding at variations from a) respectively b)

V. CONCLUSIONS

The paper presents a study of fuzzy logic controllers of series resonant inverters tacking into account the possibilities of choosing the membership functions of controller variables, of fuzzification rules and of multiplication coefficients. Based on numerical simulations we obtained important dates for fuzzy controller design.

REFERENCES

[1] Preitl, Ş., Precup, R.E., *Introduction in fuzzy command of processes* (in Romanian), Ed. Tehnică, Bucureşti, 1997.
[2] So, W.C., Tse, C.K., Lee, Y.S., "Development of a Fuzzy Logic Controller for DC/DC Converters: Design, Computer Simulation and Experimental Evaluation", *IEEE Transactions on Power Electronics*, vol. 11, no.1, January 1996.
[3] Dzliev, S. V., Chashin, V. N., Bondarenko, D. N., Poltavtsev, A. V., "Fuzzy Control of Transistor Converter for Induction Heating", *Proceedings of the International Seminar on Heating by Internal Sources HIS 01*, Padua, Sept. 2001, pp. 79-83.